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Biological and Social Outcomes of Antler Point Restriction Harvest Regulations for White-Tailed Deer

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ABSTRACT Selective harvest criteria, such as antler point restrictions (APRs), have been used to regulate harvest of male ungulates; however, comprehensive evaluation of the biological and social responses to this management strategy is lacking. In 2002, Pennsylvania adopted new APRs for white-tailed deer (*Odocoileus virginianus*) that required, depending on wildlife management unit, ≥3 or ≥4 points on 1 antler for legal harvest. Historically, harvest rates of subadult (1.5 yr old) and adult (≥2.5 yr old) antlered males averaged 0.80. Antler point restrictions were designed to protect ≥50% of subadult males from harvest. Most adult males remained legal for harvest. We estimated harvest rates, survival rates, and cause-specific mortality of radio-collared male deer (453 subadults, 103 adults) in 2 wildlife management units (Armstrong and Centre counties) to evaluate biological efficacy of APRs to increase recruitment of adult males during 2002–2005. We administered statewide deer hunter surveys before and after each hunting season over the same 3 years to evaluate hunter attitudes toward APRs. We conducted 2 types of surveys: a simple random sample of all license buyers for each survey and a longitudinal panel of hunters who completed all 6 surveys. At the same time APRs were implemented, the Pennsylvania Game Commission (PGC) increased antlerless harvests to reduce deer density to meet deer management goals.

Survival rates varied by month and age but not between study areas or among years after implementation of APRs. Monthly survival rates for subadults ranged from 0.64 to 0.97 during hunting seasons and 0.95 to 0.99 during the non-hunting period. Annual survival of subadults was 0.46 (95% CI = 0.41–0.52). Adult monthly survival rates ranged from 0.36 to 0.95 during hunting seasons and we had no mortalities during the non-hunting period. Annual survival of adults was 0.28 (95% CI = 0.22–0.35). Antler point restrictions successfully reduced harvest rate for subadults to 0.31 (95% CI = 0.23–0.38), and approximately 92% of these deer survived to the following hunting season. Vehicle collisions were the greatest source of mortality outside the hunting season for subadults and adults. Also, we observed decreased harvest rates for adults (0.59, 95% CI = 0.40–0.72), although nearly all were legal for harvest. Of radio-collared subadults, 6–11% were harvested with sub-legal antlers, indicating hunters generally complied with APRs. Overall, antlered harvest declined statewide and in our study areas, in part because of APRs but also because of increased antlerless harvests that reduced the statewide population from 1.49 million deer in 2000 to 1.14 million deer in 2005. However, between 2000 and 2005, harvest of adult males increased by 976 (112%) in Armstrong County, decreased by 29 (−3%) in Centre County, and increased by 14,285 (29%) statewide because more males survived to the 3- and 4-year-old age classes.

Proportion of hunters from the random sample surveys who supported statewide APRs varied among years between 0.61 (95% CI = 0.59–0.64) and 0.70 (95% CI = 0.66–0.73). The proportion of hunters from the longitudinal panel who supported APRs did not increase as hunters gained experience under the new regulations; 0.23 were more supportive, 0.29 were less supportive, and 0.48 were unchanged in their level of agreement after 3 years. Although >50% of hunters supported APRs throughout the study, support for the PGC's deer management program declined; 41% of the longitudinal panel of hunters rated the deer management program lower after 3 years and 21% rated it higher.

We considered APRs biologically successful because of decreased subadult harvest rates and increased harvest of adult males with larger antlers. Likewise, because the majority of hunters supported APRs throughout the study, we considered APRs socially successful. However, we predicted APRs would become increasingly popular after hunters experienced biological results of APRs, but there was little change in support. We believe hunters formed an initial

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impression of the effects of APRs, and additional experience and information failed to change their opinion. Furthermore, the concurrent reduction in overall deer densities to accommodate more males in the population and to meet agency deer population goals likely further reduced support for APRs. We found APRs as implemented in Pennsylvania to be enforceable, adhered to by hunters, and successful in recruiting more antlered males to older age classes. To facilitate social acceptance of these regulation changes, we found that obtaining support before the changes were implemented may have been important because most hunters did not change their opinions about APRs after 3 years of experience with the new regulations. © 2017 The Wildlife Society.

KEY WORDS age structure, antler point restrictions, harvest rate, hunter satisfaction, *Odocoileus virginianus*, Pennsylvania, survival, white-tailed deer.

Résultats Biologiques et Sociales des Restrictions Basées Sur le Nombre de Cors Présents Sur les Ramures du Cerf de Virginie

RÉSUMÉ Certains critères sélectifs de prélèvement, tels que les restrictions basées sur le nombre de cors présents sur les ramures, ont été introduits afin de réguler le prélèvement des ongulés mâles. Toutefois, ni l'impact biologique de cette stratégie de gestion, ni sa réception par les communautés de chasseurs n'ont fait l'objet d'une évaluation exhaustive.

En 2002, la Pennsylvanie introduisit des restrictions basées sur le nombre de cors présents sur les ramures du cerf de Virginie (*Odocoileus virginianus*). Selon la zone de gestion cynégétique concernée, seul le prélèvement des individus dotés de $\geq$3 ou $\geq$4 cors sur l'une de leurs ramures devenait dès lors autorisé, alors que les taux de prélèvement des subadultes (1 an et demi) et des adultes ($\geq$2,5 ans) à ramures avoisinaient traditionnellement 0,80. Ces mesures furent introduites afin de protéger $\geq$50% des mâles subadultes de tout prélèvement, mais la plupart des mâles adultes pouvaient être prélevés en toute légalité.

Dans deux zones de gestion de la faune sauvage (les comtés d'Armstrong et de Centre), nous avons procédé à l'estimation des taux de prélèvement et des taux de survie des cerfs adultes porteurs d'un collier radio-émetteur, ainsi qu'à une étude typologique de leur mortalité. L'objectif de cette estimation était d'évaluer dans quelle mesure les restrictions basées sur le nombre de cors étaient biologiquement efficaces, et si elles permirent d'accroître la population des mâles adultes sur la période 2002–2005.

Au cours de cette période de trois ans, nous avons mené, avant et après chaque période de chasse, des enquêtes auprès des chasseurs de toute la Pennsylvanie afin de sonder la manière dont ils percevaient les restrictions basées sur le nombre de cors présents sur les ramures. Nous avons conduit deux types d'enquêtes: un sondage mené auprès d'un échantillon de licenciés sélectionnés au hasard, et une étude longitudinale au cours de laquelle un panel de chasseurs devait répondre à une série de six questionnaires. Au moment même où ces mesures de restrictions furent introduites, la Commission de la chasse de Pennsylvanie (Pennsylvania Game Commission, ou PGC) décida d'augmenter les prélèvements de cerfs sans ramures afin de réduire la densité des populations, et atteindre ses objectifs de gestion en la matière.

Suite à l'introduction des restrictions, il est apparu que les taux de survie fluctuaient selon les mois et l'âge des individus, mais qu'ils étaient constants d'une région à l'autre et d'une année sur l'autre. Le taux de survie mensuel des subadultes variait ainsi de 0,64 à 0,97 en période de chasse, et de 0,95 à 0,99 pendant le reste de l'année. Le taux de survie annuel de ces individus était de 0,46 (IC 95% = 0,41–0,52).

Le taux de survie mensuel des adultes variait quant à lui de 0,36 à 0,95 en période de chasse, le taux de mortalité étant nul le reste de l'année. Le taux de survie annuel de ces individus était de 0,28 (IC 95% = 0,22–0,35). Les restrictions basées sur le nombre de cors présents sur les ramures parvinrent à faire chuter le taux de prélèvement des subadultes à 0,31 (IC 95% = 0,23–0,38) et environ 92 % de ces individus survécurent jusqu'à la période de chasse suivante.

La mortalité non cynégétique des subadultes comme des adultes était majoritairement attribuable à des collisions avec des véhicules ($\leq$7%). Nous avons également observé un taux réduit de prélèvement sur les adultes (0,59, IC 95% = 0,40–0,72), bien que, pour la quasi-totalité d'entre eux, le prélèvement était autorisé. Parmi ceux équipés d'un collier radio-émetteur, de 6 à 11% furent prélevés alors que leurs ramures n'avaient pas encore atteint la taille autorisée, ce qui semble indiquer que les chasseurs respectèrent globalement les restrictions en la matière.

Dans l'ensemble, les prélèvements d'individus à ramures reculèrent dans tout l'État et dans les zones étudiées en raison, d'une part, des restrictions basées sur le nombre de cors, et d'autre part, de l'augmentation des prélèvements effectués sur les individus sans ramures. À l'échelle de la Pennsylvanie, la population de cerfs passa de 1,49 million d'individus en 2000 à 1,14 million en 2005. Pourtant, entre 2000 et 2005, le prélèvement de mâles adultes connut

une progression de 112% (976 individus) dans le comté de Armstrong, un recul de −3% (29 individus) dans le comté de Centre, et une augmentation globale de 29% (14 285 individus) à l'échelle de l'État. Ces chiffres s'expliquent par le fait qu'un nombre accru de mâles survécurent pour atteindre la tranche d'âge des 3–4 ans.

Parmi les chasseurs sélectionnés au hasard pour participer au sondage, le taux d'adhésion aux mesures de restrictions basées sur le nombre de cors variait de 0,61 (IC 95% = 0,59–0,64) à 0,70 (IC 95% = 0,66–0,73). Parmi les participants au panel interrogé dans le cadre de l'étude longitudinale, le taux d'adhésion n'augmenta guère alors que les chasseurs expérimentaient la nouvelle réglementation sur le terrain: au terme de la période de trois ans, 23% se prononcèrent plus favorables aux mesures, 29% se dirent moins favorables, et 48% d'entre eux déclarèrent qu'ils n'avaient pas changé d'avis sur la question. Alors qu'au cours de l'étude, les chasseurs étaient plus de 50% à se dire favorables aux restrictions basées sur le nombre de cors, leur soutien au programme de gestion des populations de cerfs mis en place par la PGC affichait un recul. Les participants au panel de l'étude longitudinale étaient ainsi 41% à lui donner une note plus faible après trois ans, et ils étaient 21% à lui donner une meilleure note.

Au regard de la baisse des taux de prélèvement sur les subadultes, et de la hausse des prélèvements sur les adultes à ramures, nous avons conclu au succès biologique des mesures de restrictions basées sur le nombre de cors présents sur les ramures. Dans la mesure où, durant l'étude, une majorité de chasseurs s'y étaient déclarés favorables, nous en avons conclu que le succès de ces mesures auprès du public était tout aussi avéré. Nous avions toutefois misé sur le fait que les chasseurs seraient plus nombreux à soutenir ces restrictions une fois constaté leur impact biologique, mais les opinions ont peu varié.

Il semblerait que, dès le départ, les chasseurs se soient fait une opinion sur l'impact possible de ces restrictions, et que ni l'expérience, ni les données produites ne soient parvenues à leur faire changer d'avis. Il est également probable que la décision prise par la PGC de réduire la densité des populations et d'accroître le nombre de mâles afin d'atteindre ses propres objectifs de gestion a constitué un frein à l'adhésion des chasseurs aux mesures de restrictions basées sur le nombre de cors.

Nous avons conclu que les restrictions introduites en Pennsylvanie sont des mesures applicables, que les chasseurs y sont favorables, et qu'elles permettent à un plus grand nombre de mâles à ramures de parvenir à l'âge adulte. Afin de faciliter l'acceptation de ces évolutions réglementaires par les communautés de chasseurs, il nous semble important d'obtenir leur soutien en aval, car la majorité des chasseurs qui ont expérimentés ces restrictions pendant ces trois années ont refusé de revoir leurs positions.

Resultados Biológicos y Sociales de las Regulaciones de Restricción de Puntos de Cuerno en la Cosecha de Venado de Cola Blanca

RESUMEN Criterios de explotación selectiva, tales como restricciones en el número de puntos presentes en el cuerno (APR), han sido usadas para regular la explotación de ungulados machos; sin embargo, hace falta una evaluación exhaustiva de las respuestas biológicas y sociales de ésta estrategia de manejo. En el año 2002, Pennsylvania adoptó nuevas APRs para venados de cola blanca (*Odocoileus virginianus*) que requiere, dependiendo de la unidad de manejo de la fauna silvestre, $\geq$3 ó $\geq$4 puntos en un cuerno para que la cosecha sea legal. Históricamente, las tazas de cosecha de machos sub-adultos (1.5 años de edad) y adultos ($\geq$2.5 años de edad) con cuernos ha promediado 0.80. Las APRs fueron diseñadas para proteger de la cosecha $\geq$50% de los machos sub-adultos. La mayoría de los machos permanecían legales para la cosecha. Hemos estimado tazas de cosecha, tazas de sobrevivencia, y mortalidad por causas específicas de venados machos con radio-collares (453 sub-adultos, 103 adultos) en dos unidades de manejo de fauna silvestre (condados Armstrong y Centre) para evaluar la eficacia biológica de APRs en aumentar el reclutamiento de adultos machos durante los años 2002–2005. Hemos distribuido a nivel estatal encuestas a cazadores de venados antes y después de cada estación de caza en los mismos 3 años para evaluar las actitudes de los cazadores hacia las APRs. Realizamos dos tipos de encuestas: para cada encuesta realizamos una muestra aleatoria simple de todos los compradores de licencias y además realizamos un panel longitudinal de cazadores que completaron todas las 6 encuestas. Al mismo tiempo que se implementaban las APRs, la Comisión de Caza de Pennsylvania (Pennsylvania Game Commission; PGC) aumentó la caza de venado sin cuernos para reducir la densidad de venados y así cumplir con sus objetivos de manejo de venado.

Tazas de sobrevivencia variaron por mes y edad pero no entre áreas de estudio o entre años después de la implementación de las APRs. Tazas de sobrevivencia mensuales de sub-adultos osciló entre 0.64 y 0.97 durante las estaciones de caza y entre 0.95 y 0.99 durante el periodo de no-caza. La sobrevivencia anual de sub-adultos fue 0.46 (95% CI = 0.41–0.52). Las tazas de sobrevivencia mensual de adultos osciló entre 0.36 y 0.95 durante la estación de caza y no hubo mortalidad durante el periodo de no-caza. La sobrevivencia anual de adultos fue de 0.28

(95% CI = 0.22–0.35). Restricciones en el número de puntos presentes en el cuerno disminuyeron exitosamente la taza de cosecha de sub-adultos a 0.31 (95% CI = 0.23–0.38), y aproximadamente 92% de estos venados sobrevivieron la siguiente estación de caza. Coalición con vehículos causó la mayoría (≤7%) de la mortalidad no relacionada a la caza en sub-adultos y adultos. También observamos una disminución de las tazas de cosecha de adultos (0.59, 95% CI = 0.40–0.72), aunque casi todos eran legales para la caza. De los sub-adultos con radio-collares, 6-11% fueron cosechados con cuernos sub-legales, indicando que los cazadores en general cumplieron con las APRs. En general, la cosecha/caza de venados con cuernos disminuyó a nivel estatal y en nuestras áreas de estudio, en parte por las APRs pero también debido a un incremento en la caza de venados sin cuernos que redujeron la población estatal de 1.49 millones de venados en el año 2000 a 1.14 millones de venados en el año 2015. Sin embargo, entre los años 2000 y 2005, la cosecha de machos adultos aumentó 976 animales (112%) en el condado Armstrong, disminuyó 29 animales (−3%) en el condado Centre y aumentó 14,285 animales (29%) a nivel estatal porque más machos sobrevivieron a las clases etarias de 3 y 4 años.

Las proporciones de cazadores de las muestras aleatoria que apoyaron las APRs a nivel estatal variaron entre 0.61 (95% CI = 0.59–0.64) y 0.70 (95% CI = 0.66–0.73). La proporción de cazadores del panel longitudinal que apoyaron las APRs no aumentó en la medida que los cazadores ganaron experiencia bajo las nuevas regulaciones; 0.23 brindaron más apoyo, 0.29 brindaron menos apoyo y 0.48 no cambiaron su nivel de apoyo luego de 3 años. Aunque >50% de los cazadores apoyaron las APRs a lo largo del estudio, apoyo al programa de manejo de venado de la PGC disminuyó; después de 3 años 41% de los cazadores del panel longitudinal clasificaron el programa de manejo de venado más bajo que al principio y 21% de los cazadores lo clasificaron más alto.

Consideramos que las APRs son biológicamente exitosas porque disminuyeron las tazas de cosecha de sub-adultos e incrementaron la caza de adultos machos con cuernos más grandes. De la misma forma, debido a que la mayoría de los cazadores apoyaron APRS a lo largo del estudio, consideramos APRs socialmente exitosas. Sin embargo, predijimos que APRs se volverían más populares después que los cazadores observaran los resultados biológicos de su uso, pero hubo muy poco cambio en el apoyo. Creemos que los cazadores formaron una impresión inicial de los efectos de las APRs, y que la experiencia e información adicional falló en cambiar dicha opinión. Más aún, la disminución concurrente en la densidad general de venados para acomodar más machos en la población y cumplir con objetivos de población de venados de la agencia disminuyeron el apoyo a las APRs aún más. Hemos encontrado que las APRs implementadas como en Pennsylvania son ejecutables, los a cazadores se adhieren, y son exitosas en reclutar más machos con cuernos en clases etarias más altas. Para facilitar la aceptación de estos cambios en regulaciones, hemos encontrado que el obtener apoyo antes de que los cambios sean implementados podría haber sido importante porque la mayoría de los cazadores no cambió su opinión sobre las APRs después de 3 años de experiencia con las nuevas regulaciones.

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INTRODUCTION

Recovery of white-tailed deer (*Odocoileus virginianus*) populations in North America began in the late 1800s as the result of translocations to restore populations, legislation that provided authority to natural resource agencies to protect the species and regulate harvest, and resources to enforce laws and regulations. Harvest regulations maximized hunting opportunity and minimized harvest mortality of female deer with the intent to maximize population growth rates. Consequently, many wildlife

agencies enacted laws that allowed only harvest of antlered deer or strictly regulated the harvest of antlerless deer. Such a harvest management strategy commonly resulted in >75% of deer harvests composed of antlered males. In addition, there were such high harvest rates on males that in some instances >80% of the antlered harvest was composed of 1.5-year-olds (Adams and Hamilton 2011).

A harvest management strategy that emphasized harvest of antlered deer and minimized harvest of antlerless deer successfully restored deer populations but later became an impediment to maintaining populations within biological carrying capacity (Leopold et al. 1947, Adams and Hamilton 2011). In Pennsylvania, it was not until 1957 that an antlerless deer season was held annually, which was almost 30 years after the first antlerless season (Luttringer 1931, Kosack 1995). Although wildlife biologists understand the importance of balancing wildlife populations with habitat conditions, this idea often is not accepted by hunters. One of the reasons for the lack of acceptance for lower deer densities is because hunters do not recognize the effects of deer browsing on habitat conditions (Leopold et al. 1947, Diefenbach et al. 1997).

Problems with deer exceeding biological capacity have been a concern for decades in Pennsylvania (Clepper 1931, Leopold et al. 1947, Latham 1950, Hough 1965, Tilghman 1989, deCalesta 1994, Horsley et al. 2003). However, attempts to reduce deer densities in Pennsylvania have met with limited success (Frye 2006). Deer densities periodically were reduced through increased antlerless harvests (Kosack 1995), but by the close of the 20th century deer densities still exceeded deer management goals in Pennsylvania (Diefenbach et al. 1997). Pennsylvania Game Commission (PGC) biologists were led to investigate how changes to deer harvest regulations could maintain hunter satisfaction and also meet the agency objective to keep deer densities in balance with habitat conditions. The PGC considered implementing harvest regulations that increased the number and proportion of older-aged antlered deer as a way to offset the perceived negative consequences of overall reduced deer densities.

Regulations that reduce harvest rates of antlered deer, especially harvest rates of younger age classes, include criteria such as number of antler points, inside spread (max. distance between antler main beams), outside spread (max. spread of antlers), antler beam diameter, and main antler beam length. In addition, these criteria can be combined, such as in Mississippi where a combination of minimum inside spread or main beam length defined an antlered deer legal for harvest (https://www.mdwfp.com/law-enforcement/hunting-rules-regs.aspx, accessed 4 May 2016). Similarly, Texas enacted regulations where antlered deer legal for harvest had a minimum inside spread of 33 cm (13 inches) or had at least 1 unbranched antler, which restricted harvest to only large-antlered deer or deer with ≥1 unbranched antler (http://tpwd.texas.gov/regulations/outdoor-annual/regs/animals/white-tailed-deer, accessed 4 May 2016).

In theory, antler point restrictions (APRs) that restrict the harvest of antlered deer should allow more males to survive into older age classes; however, monitoring of APRs has been lacking (Carpenter and Gill 1987). For example, although APRs have increased male to female ratios in moose (*Alces alces*; Schwartz et al. 1992, Young and Boertje 2008) and elk (*Cervus elaphus*; Boyd and Lipscomb 1976, Bender and Miller 1999), no accompanying research was conducted to document how much male survival increased in these populations. Bullock et al. (1995) and Demarais et al. (2005) reported on an antler-based regulation for white-tailed deer that resulted in fewer 1.5-year-old and more ≥2.5-year-old males in the harvest, but they did not monitor harvest rates or survival rates, and changes in the harvest simply may have reflected changes in harvest regulations rather than changes in the sex-age structure of the population. Bowman et al. (2007) monitored survival and cause-specific mortality of antlered white-tailed deer under voluntary Quality Deer Management (QDM) guidelines intended to protect all 1.5-year-old males in relatively small areas rather than statewide regulations.

Complex APRs usually are applied on private lands where hunter cooperation is easier to obtain and peer pressure is more likely to ensure compliance (Adams and Hamilton 2011). Application on a broad management scale (i.e., statewide) with regulated enforcement requires simple regulations. Simple regulations can be easily followed in hunting situations and readily understood by hunters so that unintended violations are minimized and intentional violations can be prosecuted. Beginning in 2001, the PGC made numerous regulation changes to reduce deer populations and to increase the male age structure. To reduce deer populations, antlerless hunting opportunities increased via longer firearm seasons and more antlerless licenses. To increase the male age structure, the PGC implemented APRs to protect the majority (≥50%) of subadult (1.5-yr-old) antlered males from harvest. Antler point restrictions can be applied easily by hunters in the field, which would minimize unintentional violation of the regulation, and readily enforced by law enforcement personnel because antler points can be objectively defined.

Carpenter and Gill (1987) identified 3 elements that should accompany the implementation of APRs: 1) education of hunters on the possible consequences of the harvest strategy; 2) experimentation to determine whether antler restrictions achieve biological objectives; and 3) assessment of hunter support. Following these recommendations, the PGC launched a statewide educational campaign to inform hunters about the anticipated outcomes of regulation changes (Frye 2006). Concurrently, we studied the effects of new APRs in Pennsylvania from both biological and social perspectives.

We judged management success of APRs by 2 components: acceptance by hunters and increased age of antlered population (Table 1). To assess whether APRs increased age of the antlered population, we monitored survival and harvest rates of >1-year-old male deer. If substantial proportions of protected antlered deer were shot during hunting season but left in the field (i.e., defined as "shoot and sort" by Carpenter and Gill [1987]), then APRs might not achieve management goals. Furthermore, APRs could fail to produce more adult males if greater post-hunting mortality of 1.5-year-olds offset reduced hunting mortality. We used 3 criteria to evaluate the biological effects of APRs: 1) harvest rates of 1.5-year-old males had to decline; 2) males that survived the hunting season had to be available for harvest the following year (i.e., reduced harvest rates were not offset by

Table 1. Four possible management outcomes when antler point restriction harvest regulations are implemented with the intent to increase the number and proportion of older-aged male white-tailed deer in the population and harvest.

	Regulations increase number and proportion of older-aged male deer	Regulations do not increase number and proportion of older-aged male deer
Hunters support regulations and perceive management success	Management success (outcome I)	Deer management failure Hunter management success (outcome II)
Hunters do not support regulations or perceive management failure	Deer management success Hunter management failure (outcome III)	Management failure (outcome IV)

increased illegal or natural mortality); and 3) number of adults harvested needed to increase after implementation of APR regulations. We surveyed hunters before implementation of APRs and during the first 3 years after implementation to evaluate support for APRs and hunters' perception of the effects of APRs. We evaluated how hunter support changed after experiencing APRs and explored whether hunters believed APRs were successful because their experience informed their opinion or because their initial beliefs persisted despite the biological effects of APRs. Combining both elements facilitated a comprehensive evaluation of Pennsylvania's APRs because successful wildlife management must achieve 2 goals concurrently: 1) accomplishment of biological objectives and 2) acceptance by stakeholders; neither one, by itself, constitutes success (Table 1).

STUDY AREA

To estimate survival parameters of antlered white-tailed deer in Pennsylvania, we captured deer within 2 study areas in the state: Armstrong County in western Pennsylvania, and Centre County in central Pennsylvania. Additional descriptions of the study areas can be found in Long (2005) and Long et al. (2010). We chose an approximately 1,200-km^2 area of eastern Armstrong County on the east side of the Allegheny River in the Appalachian Plateau region of Pennsylvania as the western study area (Fig. 1). Annually, there was a mean of 37.2 days with snow depth $\geq$2.5 cm and 4.6 days with snow depth $\geq$25 cm. Forested land (49% of the study area) was dominated by northern red oak (*Quercus rubra*) and white oak (*Q. alba*) along with other species such as maple (*Acer* spp.), birch (*Betula* spp.), American beech (*Fagus grandifolia*), and hickory (*Carya* spp.). However, forests were fragmented by agricultural fields, which composed most of the remainder of the landscape. Corn and soybeans were the most common crops, and much of the forested landscape existed as isolated woodlots. The Armstrong County study area was almost exclusively private land. Elevations ranged from 240 m to 450 m, but topography was irregular (i.e., the region lacked directionally oriented topography) and there were no large ridges in the area. Armstrong County was within the PGC Wildlife Management Unit (WMU) 2D, and beginning in 2002, antlered deer legal for harvest were required to have at least 1 antler with $\geq$4 points.

The Centre County study area (765 km^2) was part of 2 physiographic provinces: the Appalachian Plateau in western Centre County and the Ridge and Valley province in central and eastern Centre County (Fig. 2). Public land within the study area included Moshannon State Forest (60 km^2) and adjacent State Game Lands 33 (60 km^2) in the Appalachian Plateau region of western Centre County, and State Game Lands 176 (25 km^2) in the Ridge and Valley province of south-central Centre County. A third component of the Centre County study area consisted of 620 km^2 of parallel ridges and valleys. Annually, there was a mean of 49.3 days with snow depth $\geq$2.5 cm and 4.0 days with snow depth $\geq$25 cm. Unlike Armstrong County, Centre County had long, parallel ridges aligned northeast–southwest across the region. Ridges were interspersed by long, narrow valleys, typically 2–4 km wide. Elevations ranged from 350 m to 650 m. Forests (57% of the study area) were less fragmented than in Armstrong County because agriculture, primarily row crops (mostly corn and soybeans) and dairy farming, was restricted to valleys. Forests along ridges were contiguous. Dominant tree species were similar to those of Armstrong County, including oaks, red maple (*A. rubrum*), and hickory. Ownership was primarily private, but deer hunting occurred on most properties as well as the large tracts of public land along the southeastern and northwestern borders of the county. The Centre County study area was within WMU 4D in central Pennsylvania. Beginning in 2002, antlered deer legal for harvest were required to have at least 1 antler with $\geq$3 points.

METHODS

Regulation Changes

The PGC historically established regulations for hunting white-tailed deer in which there were separate firearms seasons for antlered and antlerless deer. To be legal for harvest during 1953–2001, an antlered deer had to possess $\geq$1 antler $\geq$7.6 cm (3.0 inches) in length or 1 antler with $\geq$2 points (Kosack 1995). Further, no quotas were placed on hunter numbers statewide or within management units for antlered deer. In contrast, since the early 20th century, the number of hunters licensed to harvest antlerless deer has been limited via antlerless license allocations within each management unit.

Beginning in 2001, the PGC increased the allocation of antlerless licenses and increased the opportunity to harvest antlerless deer to reduce deer densities. The firearms deer season for antlered and antlerless deer became concurrent, which lengthened the antlerless firearms season from 3 to 12 days. The PGC also enacted other regulation changes with the intent of increasing hunter success rates and reducing deer densities. In 2000, the PGC introduced a 2-week concurrent antlered and antlerless firearms season for youth and senior hunters and a 3-day flintlock season for antlerless deer in October. In 2001, the October flintlock season for antlerless deer was expanded to 7 days for all hunters and youth and senior hunters could use modern firearms the last 3 days. Beginning in 2003, any muzzleloading firearm could be used in the October antlerless

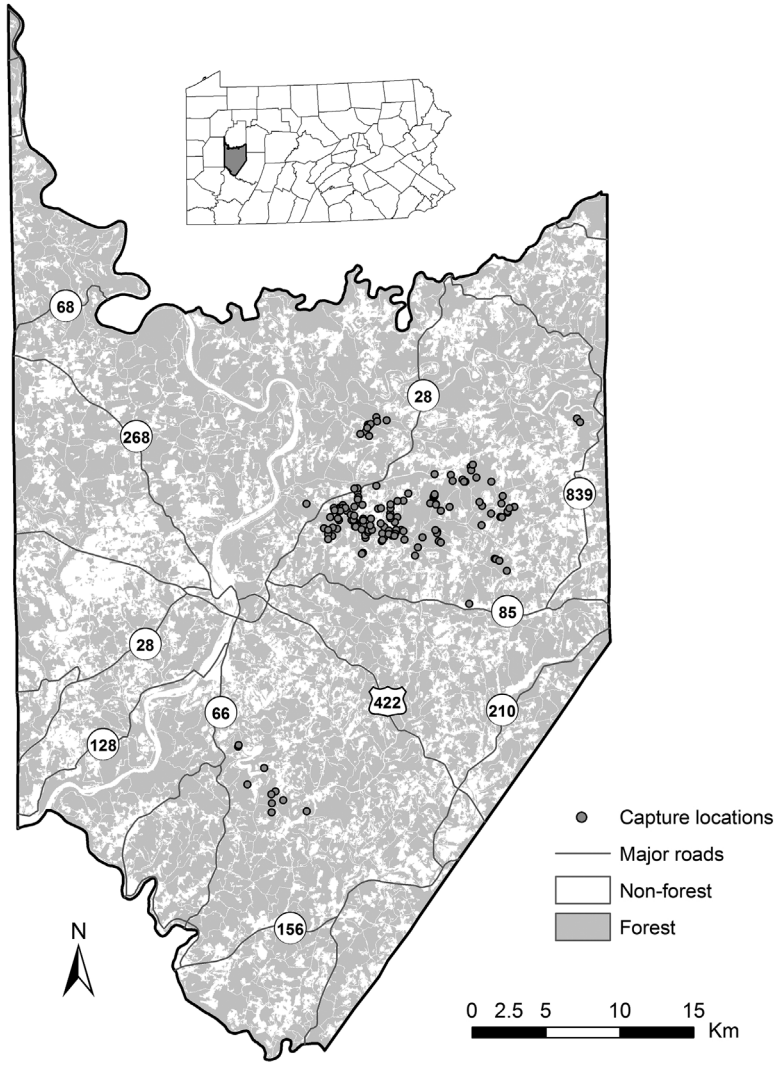

Figure 1. Map of Armstrong County showing location in Pennsylvania, USA and major roads and forested lands (shaded areas). We present capture locations for 325 male white-tailed deer trapped and radio-marked during 2001–2004.

season. Also in 2003, the PGC initiated the deer management assistance program, which was a volunteer program that provided public and private landowners with additional antlerless licenses that could be distributed to hunters to increase antlerless harvests of deer on their property. Hunting deer on Sunday was illegal by law (34 Pa. Consolidated Statutes).

In 2002, the PGC changed the definition of an antlered deer legal for harvest to increase the proportion of older males in the population. The new APRs were intended to protect >50% of subadult males from harvest but allow all hunters the opportunity to harvest an antlered deer and be readily applied by hunters in the field to maximize hunter compliance. To determine the antler criteria that would meet the above objectives, we collected antler measurements (points on each antler) and ages (subadult vs. adult) of harvested deer during the 2000 and 2001 hunting seasons from each deer management unit (Fig. 3, Appendix). The new APRs defined an antlered deer for harvest as having a minimum of 4 points on 1 side in 10 western management units (counties) and a minimum of 3 points on 1 side in the remainder of management units (Fig. 3, Appendix). However, in 6 urbanized counties surrounding Pittsburgh and Philadelphia, the definition of a legal antlered deer was not changed (1 antler $\geq$7.6 cm [3 inches] long). A point was defined as any point $\geq$2.5 cm (1 inch) long and a brow tine of any length. The new APR definitions made 52.3% of subadult males ($n = 43{,}283$) illegal to harvest in the 3-point area (26–74% among counties) and 60.0% in the 4-point area ($n = 12{,}399$; 44–68% among counties; Appendix). For counties with the 3-point APR, 15% of adult males were protected, and in counties with the 4-point APR, 21% of adult males were protected (Appendix). However, junior hunters (12–16 yr old), hunters issued a disabled hunter permit, and residents currently serving active military duty were permitted to harvest any antlered deer with an antler $\geq$7.6 cm (3 inches) long or with $\geq$2 points.

In addition to the regulation changes, the PGC also established policies for handling violation of the APRs. Mistakenly killed antlered deer (i.e., antlered deer not meeting the definition of an antlered deer legal for harvest and voluntarily reported by the hunter) were penalized with an administrative fee (25 USD) and loss of the deer but were given a replacement antlered deer tag for

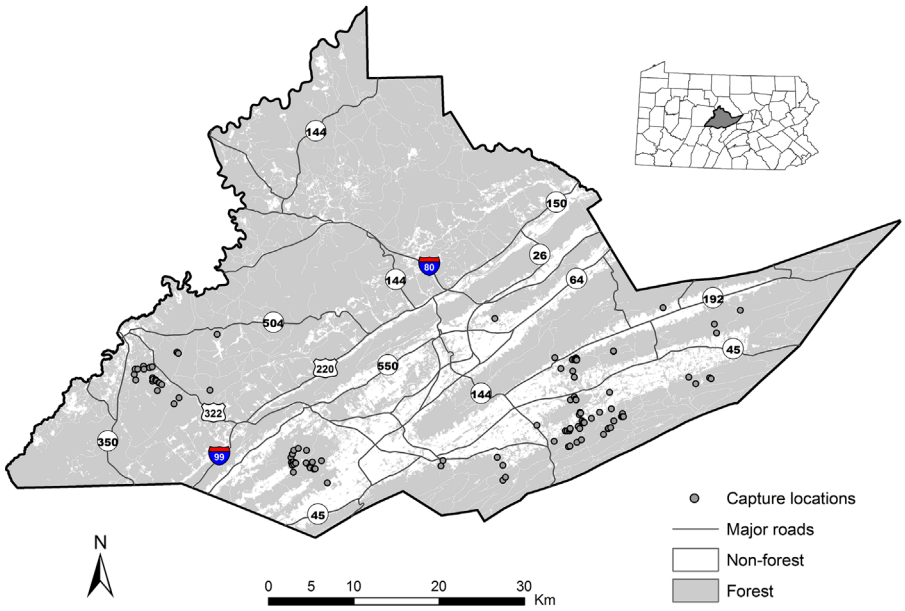

Figure 2. Map of Centre County showing location in Pennsylvania, USA and major roads and forested lands (shaded areas). We present capture locations for 231 male white-tailed deer trapped and radio-marked during 2001–2004.

the season. Sub-legal deer (i.e., antlered deer not meeting the definition of an antlered deer legal for harvest and not voluntarily reported by hunters) were treated as illegal deer and carried increased penalties as determined by Pennsylvania statute (34 Pa. Consolidated Statutes).

In 2003, the PGC defined 22 WMUs based on geographical rather than 67 political (i.e., county) boundaries. Wildlife management units in western Pennsylvania remained under the 4-point APR rule and essentially encompassed the same area as the original 10 counties, whereas WMUs in the rest of the state

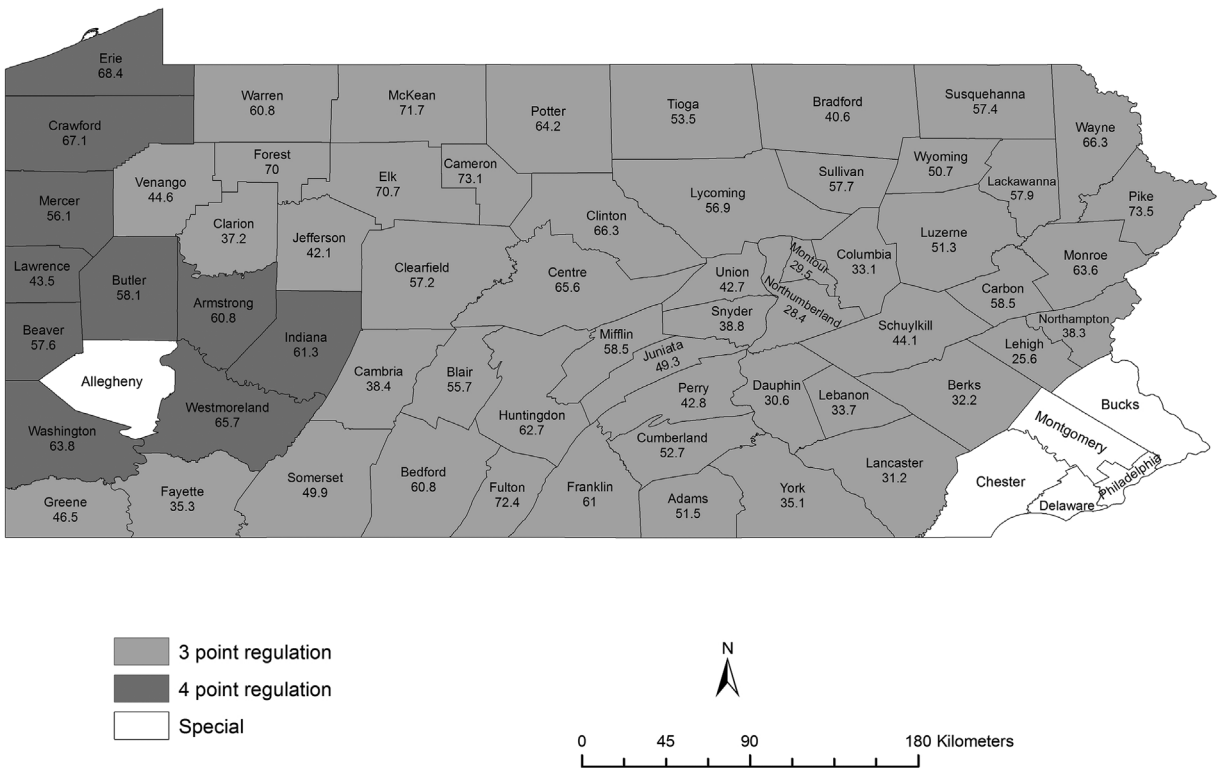

Figure 3. Percent of subadult (1.5-yr-old) male deer that would not be legal to harvest when antler point restrictions (APRs) required 3 or 4 points on at least 1 antler, Pennsylvania, 2000–2001. Special counties represent highly developed areas with special firearm regulations (e.g., no rifle firearms) and were not included in the first year of APRs.

remained under the 3-point APR rule. Also, APR exceptions for urban areas were removed. Additionally, the legal definition of an antler point changed in 2003; all antler tines were required to be ≥2.5 cm (1 inch) in length.

We used several methods to educate hunters about regulation changes and intended outcomes of APRs prior to implementation and during the early stages of the regulation changes following Carpenter and Gill's (1987) recommendation. One of us (G. L. Alt) conducted a statewide educational campaign consisting of >200 seminars with the goal of conducting a seminar within 20 miles of every Pennsylvania hunter each year during 2000–2002. The day of each seminar, whenever possible, the PGC arranged editorial board meetings at local newspapers where G. L. Alt could be interviewed by newspaper staff. Most seminars were preceded by a press conference providing local television, radio, and newspaper reporters with an opportunity to interview G. L. Alt and learn what changes in policy were under consideration and their purpose. Many of the seminars were sponsored by local legislators, members of the PGC Board of Commissioners, or conservation organizations. Seminars began with the introduction of G. L. Alt, as supervisor of the deer management section of the PGC, who then presented a 1-hour slide presentation of the natural history and management of white-tailed deer. The seminar concluded with a detailed description of what policy changes were proposed and their justification. A question and answer session would follow the presentation until all questions were answered, often lasting >3 hours. The PGC staffed a display booth at each seminar dispensing brochures and press releases, and answering questions. In 2002, the PGC distributed 35,000 free videos that explained the rationale behind proposed management changes (i.e., APRs and increased antlerless harvest) and intended outcomes (i.e., increased proportion of older males in the population and overall population reduction).

Study Design

We designed this study to evaluate the biological effects on the deer population and the effect on hunter behaviors and attitudes. Although 2 different APR regulations were adopted to reflect geographic differences in antler development, they both were expected to reduce harvest of subadults from approximately 80% to 25–50% (Fig. 3). To evaluate the biological effects of APRs in both zones, we captured and radio-marked male white-tailed deer in a study area in each zone (Armstrong County in the 4-point zone and Centre County in the 3-point zone). Captures began in winter 2001–2002 before implementation of APRs for autumn hunting seasons in 2002 and continued for the next 2 winters.

We estimated harvest rates and age structure of the antlered population before and after APRs were implemented using harvest and telemetry data. We used telemetry to monitor deer during 2002–2005 to estimate cause-specific mortality and monthly survival and harvest rates under APR regulations. To estimate harvest rates and age structure before APRs were implemented, we assumed harvest rates were equal among age classes and the population was stationary, such that the proportion of subadults in the antlered harvest was an estimate of the harvest rate (Burgoyne 1981). During 1981–2001, the average statewide harvest rate was 0.81 (range = 0.77–0.84, $n = 315{,}175$). Given the large proportion of subadults in the antlered harvest, even if harvest rates of adults were substantially lower (e.g., 0.6), the harvest rate of subadults was within 0.03 of the estimated harvest rate. We used our estimated annual survival rates from telemetry data to estimate the age structure of the male population after APRs were implemented by assuming survival rates were constant and calculating the number of animals surviving to each age class (Caughley 1977).

Following a statewide outreach program to educate hunters about anticipated changes of the new APRs, we surveyed hunters before and after the hunting seasons to evaluate expectations and experiences relative to APRs. We surveyed hunters for 3 years (2002–2005) to assess hunter attitudes and opinions regarding APRs, using both a random sample of hunters and a longitudinal sample.

Biological Changes

Capture, marking, and monitoring.—We radio-instrumented male deer during December through April of each capture season. Subadults were 7–10 months of age at capture and were 1.5 years old during the subsequent hunting season. All antlered males that survived the hunting seasons as subadults were classified as adults in subsequent seasons.

We contracted a helicopter crew who used net guns to capture deer in the Armstrong County study area 10–12 December 2001 (Hawkins and Powers Aviation, Inc., Greybull, WY, USA). We captured all other deer from mid-January to mid-April of 2002, 2003, and 2004 using modified Clover traps (Clover 1954, Beringer et al. 1996, Haulton et al. 2001), drop nets (Ramsey 1968, Conner et al. 1987) modified for remote-release, rocket nets (Beringer et al. 1996, Haulton et al. 2001), and dart guns (Pneu-dart, Inc., Williamsport, PA, USA).

We did not use immobilizing drugs for males caught with the helicopter net gun or in Clover traps because handling times were short (<15 min for pursuit and handling for helicopter capture and <5 min for Clover traps). We blindfolded males caught in rocket nets and drop nets and immobilized them with intramuscular injections of xylazine hydrochloride (100 mg/ml) at approximately 0.56 mg/kg (Rosenberry et al. 1999). To simplify drug application, we administered subadults with 0.2 ml and adult males 0.4 ml of xylazine hydrochloride (Long 2005). We reversed the effects of xylazine hydrochloride with intramuscular injections of yohimbine hydrochloride (3 ml for subadults and 5 ml for adults at 5 mg/ml) or tolazoline hydrochloride (1.5 ml for subadults and 3 ml for adults at 100 mg/ml). The capture protocol was approved by the Pennsylvania State University Institutional Animal Care and Use Committee (#01R135).

We marked all captured male deer with 2 uniquely numbered plastic ear tags (Original Tags™, Temple Tag Co., Temple, TX, USA), imprinted with toll-free contact information for the PGC. Also, we fitted subadult males with 19-g very-high-frequency (VHF) ear-tag transmitters (Advanced Telemetry Systems, Isanti, MN, USA), or 1 of 2 types of radiocollars: 245-g expandable VHF neck collars (Advanced Telemetry Systems) or 700-g expandable, automatic-release global positioning system (GPS) neck collars (Telonics, Mesa, AZ, USA). To minimize censoring of deer fitted

with ear-tag transmitters because a transmitter was cast, we fitted deer with 2 ear-tag transmitters beginning in 2003. We fitted adult males with 1,100-g GPS collars (Advanced Telemetry Systems) without an expandable collar. Also, we included 12 male deer with functional radiocollars from an earlier study (Vreeland et al. 2004) conducted in Centre County. In May–July of 2000 and 2001, male fawns were caught at 1–2 weeks of age, and fitted with uniquely numbered ear tags of the same manufacturer used in our study and a 97-g expandable VHF neck collar (Advanced Telemetry Systems; Diefenbach et al. 2003, Vreeland et al. 2004). All radio transmitters contained a mortality sensor, which doubled the pulse rate of the transmitter signal after 4 hours of remaining motionless. To increase battery life, ear tag transmitters were active only during 0800–2000 hours. During winter (Jan–Apr) and summer (Jul–Aug), ear tags only transmitted 3 days per week. We monitored survival of radio-marked deer via ground and aerial telemetry $\geq$1 time per week in 2002, 2003, and 2004. In 2005, we monitored radio-marked deer for survival at least once per month through the 2005–2006 deer hunting season.

Survival and harvest rates.—We estimated survival and harvest rates using known-fate models in Program MARK v. 4.2 (White and Burnham 1999). To estimate harvest rates, we estimated survival after censoring all males dying from causes other than hunting and estimated harvest rate as the complement of the survival rate. Deer not located during any given monitoring period were temporarily censored from analyses. We defined monthly monitoring periods as the 24th day of the month to the 23rd day of the subsequent month. These starting and ending dates best encompassed the early autumn archery (first 3 weeks beginning the Saturday closest to 1 Oct), late autumn archery and early muzzleloader (second 3 weeks), firearm (2 weeks beginning the Monday after the Thanksgiving holiday), and winter archery and flintlock firearm (3 weeks beginning 26 Dec) deer hunting seasons.

We developed 11 candidate models to estimate survival based on 4 grouping variables (month of year, year, age [subadults vs. adults], and study site) using Akaike's Information Criterion adjusted for sample size (AIC_c) to select the most parsimonious model of survival (Burnham and Anderson 2002). We used the best model to report survival rates, standard errors, and 95% confidence intervals.

We investigated all mortalities to determine cause of death. If we could not immediately determine cause of death, we submitted the carcass for necropsy to the Pennsylvania State University Animal Diagnostic Laboratory. Carpenter and Gill (1987) identified documentation of mortalities related to APRs within and outside the hunting season as essential to evaluating the effect of APRs. Therefore, we separated mortalities into hunting season (24 Sep–23 Jan; including archery, firearms and muzzleloader seasons) and non-hunting season (24 Jan–23 Sep) periods to estimate the loss of antlered deer in relation to APRs. We defined 4 categories of human-caused mortality that occurred during the hunting season: legal kills, sub-legal kills, mistaken kills, and illegal kills. We ascertained when deer were killed legally when hunters reported their harvest or we located the hunter via the radio-collar signal. We defined sub-legal kills as antlered deer with antlers below minimum requirements but confirmed dead from gunshot or arrow wounds during a deer hunting season (i.e, "shoot and sort" as defined by Carpenter and Gill 1987). We defined mistaken kills as sub-legal kills self-reported by hunters to the PGC. Illegal kills were independent of antler size and occurred during an illegal time period (after hunting hours or a time period when no deer hunting season was open) or during a deer hunting season but with a sporting arm not legal for that season. We classified mortalities outside hunting season as road-killed, starvation, killed for crop damage, disease, illegal, predation, and unknown. Males could be legally killed for crop damage, but we classified any other male deer found shot outside the hunting season as an illegal kill.

Deer abundance, harvest, and hunter effort.—We estimated the antlered deer harvest statewide and for the county that encompassed each study area. We estimated harvest using sex-age-kill data collected during the firearms deer season. Personnel from the PGC visited deer processing businesses and recorded sex, age, hunter license number, and date of kill, which was then cross-checked with hunter self-reported harvests to estimate the harvest by adjusting self-reported harvests by the hunter reporting rate (Rosenberry et al. 2004). We estimated the number of adult and subadult antlered deer in the harvest from the ratio of subadult:adult antlered deer from sex-age-kill data and combined the standard error from reporting rates and age ratios using a Taylor series approximation (the delta method).

We used estimates of the number of deer hunters and hunter-days from the annual Game Take Survey conducted by the PGC, which surveys approximately 2% of license buyers, to obtain information on species hunted, harvest, and hunter effort. We estimated the abundance of deer using the Pennsylvania sex-age-kill (PASAK) model (Norton et al. 2013).

Hunter Surveys

We monitored hunter opinions concerning the effects of APRs via pre-season and post-season mail surveys for the 2002–2004 deer hunting seasons. We conducted 2 types of surveys to monitor changes in support for APRs as deer population sex and age structures changed because of APRs. The first type was a simple random sample of hunting license buyers (hereafter, random sample survey) selected for each pre-season and post-season survey and the second type was a longitudinal panel survey of the same random sample of deer hunters for the duration of the study (hereafter, panel survey). Sample sizes for each survey type were sufficient for a return of >600 surveys and a minimum confidence interval of $\pm$4% (Krueger 2001). However, the initial survey was larger ($n = 2{,}906$) to develop the panel sample to analyze longitudinal responses from individuals. Questionnaires for panel surveys and random sample surveys were identical. Procedures for all surveys followed Dillman (2000) and were approved by The Pennsylvania State University Office for Research Protections (Institutional Review Board #14835).

We conducted an initial pre-season survey in October and November 2002, which was immediately before the firearms hunting season. We accepted surveys postmarked before or on the opening day of firearms season for the pre-hunting season survey. Respondents to the first pre-season survey were mailed the first post-season survey and asked if they would participate as part of a panel of hunters to be monitored repeatedly across time

to evaluate changes in attitudes and opinions (LaPage 1994, Fulton and Manfredo 2004).

We mailed the first post-season survey in April 2003 to ensure the most current list of hunters was available for sampling. In the subsequent years of 2004 and 2005, we conducted the post-season survey during January–February using the previous year's license buyers so the survey could be mailed immediately after the hunting season. Mazurkiewicz et al. (1996) found no difference in opinion-preference survey data after a 4-month period, so although there was a considerable time lag in the April 2003 survey, we considered the responses to be reliable.

The objective of random sample surveys was to measure hunter opinions about APRs and their perceptions of the effects of APRs on the deer population over the course of the study. We evaluated 9 topics from the deer hunter survey: 1) hunter support for APRs, 2) perception of subadult male deer survival, 3) satisfaction with the antlered deer harvest, 4) perception about changes in breeding activity, 5) satisfaction with observed sex ratios, 6) satisfaction with observed antler size, 7) satisfaction with the number of antlered deer seen, 8) influence of APRs on their deer hunting experience, and 9) acceptance of potential problems associated with APRs (e.g., lack of hunter compliance with regulations).

Survey questions measured attitudes using a 5-point Likert scale with the categories of strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree. For summary statistics, we excluded survey questions without responses because the lack of a response to a question cannot be interpreted. Therefore, sample sizes for specific questions were less than or equal to the number of returned surveys. We combined responses of agree and strongly together, and combined responses of disagree or strongly disagree together. We concluded that changes in the proportion of respondents of a given response differed among surveys (i.e., over time) or among categories (e.g., agree vs. disagree) if 95% confidence intervals ($\pm 1.96 \times$ SE) did not overlap. Similarly, we concluded a majority of respondents agreed or disagreed with a statement if the 95% confidence interval did not overlap 0.50.

We used confirmatory factor analysis (FACTOR procedure, SAS version 9.1, SAS Institute, Cary, NC, USA) and varimax rotation with the random sample survey data to test hypotheses about factors that influenced hunter support for APRs. We hypothesized hunter responses were related to 3 major issues (subadult survival, sex ratios, and antlered harvest), each measured by multiple variables in the survey. We selected 10 questions from the survey to factor analyze and we estimated the number of underlying factors using a scree plot (Cattell 1966) to identify visually the number of components important to the analysis. We used Cronbach's alpha coefficient of internal consistency (Cronbach 1951) to assess similarity in responses to all multi-item factors we created.

Panel surveys can provide stronger inferences than cross-sectional surveys (i.e., our random sample surveys) about variables influencing change within individuals (Markus 1979, Wright et al. 2001); however, loss of participants over time (death, loss of interest, movement) is a limitation of panel studies (Fulton and Manfredo 2004). Only respondents who continued to return completed surveys were sent subsequent surveys. If there were differences between respondents who dropped out and respondents who finished the panel surveys, then results of the panel surveys would be of limited value. Therefore, we mailed an abbreviated survey in September 2005 to panel members who dropped out of the panel survey and posed questions regarding their support of APRs. We chose 4 questions *a priori* from the September 2005 survey to compare the response of dropouts to panel member finalists (respondents who completed all 6 surveys). Three questions assessed attitudes regarding support for APRs and 1 question assessed support for a regulation to increase the antlered to antlerless ratio. We used Chi-square analyses to test for differences between dropouts and finalists ($\alpha = 0.05$). If we found differences between the dropouts and finalists of the panel group, we analyzed only the panel data from the first and last surveys, which included data from the September 2005 follow-up survey to panel dropouts.

We calculated the change in response to specific survey questions from the same hunter over time as the difference in Likert scores (1–5). Score differences could range from -4 to 4, where a score of 0 indicated no change, a negative score indicated declining agreement or support, and a positive score indicated greater agreement or support. We grouped score differences into less support (difference <0), no change (difference $= 0$), and greater support (difference >0).

RESULTS

Biological Changes

We monitored 556 males during December 2001–January 2006. The total number of adults captured each year increased from 13 in 2002 to 70 in 2004 as APRs increased the adult male population and proportion of adult males in the population (Table 2).

Survival and harvest rates.—The best model (AIC_c weight $= 0.70$) varied survival by age and month of year but did not include a study area or year effect (Table 3). Monthly survival rates ranged from 0.64 to 0.99 for subadults and 0.36 to 1.00 for adults (Table 4). The cumulative harvest rate of subadult males (0.31) was lower than adults (0.59; Table 5) and harvest mortality was the single greatest source of mortality for both age

Table 2. Number of male white-tailed deer captured and fitted with radiotransmitters in Armstrong and Centre counties, Pennsylvania, 2001–2004. Subadults were 7–10 months old at capture and adults were ≥1.5 years old at capture.

Study area	Year	Subadults	Adults	Total
Armstrong	2002	81	10	91
	2003	103	13	116
	2004	76	42	118
	All years	260	65	325
Centre	2002[a]	47	3	50
	2003	74	7	81
	2004	72	28	100
	All years	193	38	231
All study areas and years		453	103	556

[a] Includes 11 subadults and 1 adult monitored in this study but captured as neonates in previous years (Vreeland et al. 2004).

Table 3. Performance of 11 candidate models estimating survival rate of subadult and adult male white-tailed deer in central and western Pennsylvania, 2002–2005. We tested models based on monthly monitoring periods from the 24th day of each month to the 23rd day of the following month in each year and each site.

Model	Model description	No. parameters	ΔAIC_c[a]	w[b]
Age × month	Survival varied by age (subadult vs. adult) and month.	24	0.00	0.70
Age × month × site	Survival varied by site, age, and month.	48	1.73	0.30
Age × month (1–10,11,12) × site	Survival varied by age, site, and month when months 1–10 had equal survival rates and months 11 and 12 differed.	12	19.80	0.00
Age × month (1–10,11,12)	Survival varied by age and month when months 1–10 had equal survival rates and months 11 and 12 differed.	6	24.25	0.00
Age × month (1–10,11,12) × yr	Survival varied by age, year, and month when months 1–10 had equal survival rate but months 11 and 12 differed.	21	43.09	0.00
Age × month × yr	Survival varied among age, months, and years.	84	75.63	0.00
Age × month (1–11,12) × site	Survival varied between age, site, and month when months 1–11 had equal survival rates but month 12 was different.	8	89.85	0.00
Age × month (1–11,12)	Survival varied between age and month when months 1–11 had equal survival rate but month 12 was different.	4	90.57	0.00
Age × month (1–11,12) × yr	Survival varied between age, year, and month when months 1-11 had equal survival rates but month 12 was different.	14	101.88	0.00
Age × month × yr × site (subadults)	Survival varied by site (subadults only), age, month, and year.	155	142.80	0.00
Null	Survival probability constant by site, age, year, and month.	1	745.41	0.00

[a] Difference from model with lowest Akaike's Information Criterion adjusted for sample size (AIC_c) value.
[b] AIC_c weight.

classes (Table 6). Greater than 80% of subadult harvest mortality and >90% of adult harvest mortality occurred during the 12-day firearm season (Table 5). Consequently, APRs accomplished the objective of reducing harvest rates of subadults to 0.25–0.50.

The probability of surviving a year was 0.46 (SE = 0.03; 95% CI = 0.41–0.52) for subadults and 0.28 (SE = 0.03; 95% CI = 0.22–0.35) for adults. If a deer survived the hunting seasons, the probability of surviving and being available for harvest at the beginning of the hunting seasons the following year was 0.92 (SE = 0.02) because monthly survival rates were >0.95 during this period (Table 4).

Cause-specific mortality.—We were not able to determine whether radio-collared deer were legal to harvest because we did not know their antler size before the hunting season, so we based analyses on the entire marked sample of males. Legal harvest was the greatest source of mortality for subadults and adults, accounting for 20% of subadults and 63% of radio-collared adults (Table 6). Thirty-three of 274 (12%) subadults were illegally harvested during the hunting seasons (Table 6), with 21 of these 33 classified as sub-legal kills. Of the adults, 9 of 140 (6%) were classified as illegal harvests. During the period outside of the hunting season, road-kills were the source of greatest mortality for both subadults (5%) and adults (4%; Table 7). Of 16 adult deer that died between the conclusion of one hunting season and prior to the following hunting season, 2 were illegally shot (Table 7).

Deer abundance, harvest, and hunter effort.—The number of adult antlered deer harvested statewide increased after the initiation of APRs. In 2000 and 2001 prior to APRs, adult males in the harvest averaged 42,099 (Table 8). In the initial year of APRs, we estimated 49,832 adult males in the statewide harvest, and adult males in the harvest averaged 57,692 during 2003–2005 (Table 8). In Armstrong County, the average adult male harvest increased from 486 during 2000–2001 to 1,097 during 2003–2005 (Table 9). Similarly in Centre County, the average adult male harvest increased from 1,062 during 2000–2001 to 1,270 during 2003–2005.

Table 4. Monthly survival estimates ($\hat{S}$), standard errors (SE($\hat{S}$)), and 95% confidence intervals (CI) for subadult and adult male white-tailed deer in Armstrong and Centre counties, Pennsylvania, 2002–2005. Subadults at 7–10 months of age and were antlered during the following deer hunting season. Adults were males that survived their first hunting season with antlers.

	Subadult				Adult			
Time period	n[a]	$\hat{S}$	SE ($\hat{S}$)	95% CI	n[a]	$\hat{S}$	SE ($\hat{S}$)	95% CI
24 Dec–23 Jan	50	0.98	0.02	0.94–1.00	117	0.99	0.01	0.95–1.00
24 Jan–23 Feb	199	0.95	0.01	0.92–0.98	141	0.98	0.01	0.95–0.99
24 Feb–23 Mar	373	0.96	0.01	0.93–0.97	166	0.97	0.01	0.94–0.99
24 Mar–23 Apr	421	0.97	0.01	0.95–0.98	167	1.00	<0.01	1.00–1.00
24 Apr–23 May	401	0.98	0.01	0.96–0.99	163	0.99	0.01	0.96–1.00
24 May–23 Jun	377	0.99	<0.01	0.98–1.00	160	1.00	<0.01	1.00–1.00
24 Jun–23 Jul	355	0.99	<0.01	0.98–1.00	155	1.00	<0.01	0.97–1.00
24 Jul–23 Aug	343	0.99	0.01	0.97–1.00	149	0.99	0.01	0.96–1.00
24 Aug–23 Sep	324	0.99	0.01	0.97–1.00	142	0.99	0.01	0.96–1.00
24 Sep–23 Oct	310	0.97	0.01	0.95–0.98	134	0.95	0.02	0.90–0.97
24 Oct–23 Nov	290	0.91	0.02	0.87–0.94	115	0.89	0.03	0.83–0.93
24 Nov–23 Dec	253	0.64	0.03	0.58–0.69	95	0.36	0.04	0.29–0.45

[a] Number of individuals at risk.

Table 5. Seasonal and cumulative harvest rate ($\hat{H}$) estimates and measures of precision for subadult (1.5 yr old) and adult (≥2.5 yr old) male white-tailed deer in Pennsylvania, 2002–2005.

		Season $\hat{H}$			Cumulative $\hat{H}$		
Age group	**Hunting season**	$\hat{H}$	**SE ($\hat{H}$)**	**95% CI**	$\hat{H}$	**SE ($\hat{H}$)**	**95% CI**
Subadults	Archery early[a]	0.02	0.01	0.01–0.05	0.02	0.01	0.01–0.04
	Archery late[b]	0.04	0.01	0.02–0.07	0.06	0.01	0.03–0.09
	Firearms[c]	0.26	0.03	0.21–0.32	0.31	0.03	0.25–0.36
	Archery-flintlock[d]	0.01	0.01	0.00–0.03	0.31	0.04	0.23–0.38
Adults	Archery early	0.04	0.01	0.02–0.08	0.04	0.01	0.01–0.07
	Archery late	0.08	0.02	0.04–0.13	0.11	0.02	0.06–0.16
	Firearms	0.54	0.04	0.46–0.63	0.59	0.04	0.50–0.67
	Archery-flintlock	0.00			0.59	0.08	0.40–0.72

[a] Early autumn (first 3 weeks) archery season.
[b] Late autumn (final 3 weeks) archery and muzzleloader season.
[c] Twelve-day firearm season that opened Monday following the last Thursday in November.
[d] Winter archery and flintlock firearm seasons opened 26 December.

The deer population declined from 1.49 million in 2000 to 1.14 million in 2005 (12.4 to 9.5 deer/km^2; Table 10). The number of deer hunters declined from >900,000 in 2000 to <740,000 in 2005, approximately 45,000 fewer hunters per year. Similarly, hunter effort declined from almost 3.5 million hunter-days to 3.2 million hunter-days (Table 10).

Hunter Education and Surveys

Collectively >100,000 people, mostly hunters, attended the seminars presented by G. L. Alt. Audience size averaged approximately 550 and ranged from about 200 to >1,400 per seminar. At the conclusion of each program, by a show of hands a majority would indicate support for the proposed policy changes. Respondents to the first survey in 2002 ($n = 1{,}953$) indicated 10.9%, which represented approximately 86,000 deer hunters, attended a seminar, and 40.3% (approx. 318,000 hunters) observed G. L. Alt at a public presentation or on a television program, or watched the PGC video.

We received responses from 666–1,819 hunters for the 6 random sample surveys, and 728–1,819 responses from hunters for the panel surveys. Response rates for the random sample surveys were 64–69% (Table 11), and achieved a 95% confidence interval of ±4% or less. Response rates for the panel surveys ranged from 64–94%, and increased as hunters not wanting to participate resigned from the panel (Table 11).

We observed consistent differences between study areas, in which a greater proportion of hunters who principally hunted the 3-point APR area supported APRs than those who principally hunted the 4-point APR area. When asked to indicate their level of agreement with the statements 1) "I support a statewide antler restriction," 2) "I support an antler restriction in the wildlife management units I principally hunt for deer," and 3) "Antler restrictions are a good change in Pennsylvania's deer management program," most surveys had statistically different responses according to the APR criterion (Fig. 4). In the 3-point area, the proportion of hunters who agreed and strongly agreed with these

Table 6. Fate of subadult (1.5-yr-old) and adult (≥2.5-yr-old) males during the Pennsylvania hunting season under antler point restrictions, 2002–2005. Thirty-one subadults and 34 adults were censored and excluded from the analysis. One adult mortality caused by a collar malfunction in the Centre County study area was excluded.

	Subadult						Adult					
	Armstrong County		Centre County		Both counties		Armstrong County		Centre County		Both counties	
Fate	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
Legal harvest	37	23	19	17	56	20	52	63	36	63	88	63
Illegal harvest												
Sub-legal kills[a]	18	11	3	3	21	8	3	4	4	7	7	5
Illegal kills[b]	5	3	0	0	5	2	0	0	0	0	0	0
Mistaken kills[c]	2	1	5	4	7	3	1	1	1	2	2	1
Unknown legality[d]	12	7	12	11	24	9	5	6	1	2	6	4
Non-harvest												
Road-killed	4	2	6	5	10	4	4	5	1	2	5	4
Natural injury	2	1	0	0	2	<1	0	0	0	0	0	0
Disease	2	1	0	0	2	<1	0	0	0	0	0	0
Unknown mortality	0	0	2	2	2	<1	0	0	1	2	1	<1
Survived	79	49	66	58	145	53	18	22	13	23	31	22
Total	161	100	113	100	274	100	83	100	57	100	140	100

[a] Sub-legal males were antlered deer not legal for harvest but confirmed dead from gunshot or arrow wounds during a deer season.
[b] Illegal kills were males killed in an illegal time period during the deer season, or during a deer season but with an illegal weapon.
[c] Mistaken kills were sub-legal, killed during a deer season, and self-reported by hunters to law enforcement.
[d] Unknown legality were males confirmed dead during the hunting season, but the number of points could not be ascertained.

Table 7. Cause-specific mortality of subadult (1.5-yr-old) and adult (>1.5-yr-old) male white-tailed deer under antler point restrictions during the period from the conclusion of the hunting season in one year (mid-Jan) to the following hunting season (Saturday closest to 1 Oct), Pennsylvania, 2002–2005. Ninety-two subadults and 67 adults were censored and excluded from the analysis. Four males (3 subadult, 1 adult) were excluded because of capture-related mortality.

	Subadult						Adult					
	Armstrong County		Centre County		Both counties		Armstrong County		Centre County		Both counties	
Source	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Road-killed	15	7	4	3	19	5	5	5	3	4	8	4
Starvation	0	0	15	10	15	4	0	0	1	1	1	<1
Crop damage	4	2	0	0	4	1	1	1	0	0	1	<1
Disease	2	1	0	0	2	1	1	1	1	1	2	1
Illegally shot	2	1	0	0	2	1	2	2	0	0	2	1
Predation	0	0	1	<1	1	<1	0	0	1	1	1	<1
Unknown	4	2	6	4	10	3	1	1	0	0	1	<1
Survived	182	87	123	83	305	85	100	91	75	93	175	92

Table 8. Harvest estimates and standard errors (SE) for antlered white-tailed deer, subadults (1.5 yr old), and adults (≥2.5 yr old), Pennsylvania, 2000–2005.

	Antlered harvest[a]		Subadult harvest		Adult harvest	
Year	Estimate	SE	Estimate	SE	Estimate	SE
2000	241,397	2,433	198,585	2,135	42,579	416
2001	198,832	1,834	157,089	1,597	41,619	393
2002	161,949	1,987	112,019	1,586	49,832	930
2003	140,987	1,788	81,507	1,278	59,340	987
2004	124,107	1,596	59,323	990	56,873	942
2005	120,080	1,760	63,251	1,152	56,864	1,046

[a] Includes deer reported as harvested in which the wildlife management unit was unknown but not corrected for hunter reporting rate (98-208 report cards each year; ≤0.33% of report cards received).

Table 9. For each study area, harvest estimates and standard errors (SE) for antlered white-tailed deer subadults (1.5 yr old) and adults (≥2.5 yr old), Pennsylvania, 2000–2005.

		Total		Subadults		Adults	
County	Year	Harvest	SE	Harvest	SE	Harvest	SE
Armstrong	2000	5,273	462	4,759	429	514	110
	2001	4,764	361	4,305	336	459	88
	2002	3,215	319	2,636	281	579	116
	2003	3,094	322	2,454	270	640	110
	2004	3,208	328	2,046	238	1,162	164
	2005	3,206	310	1,716	199	1,490	181
Centre	2000	5,590	276	4,545	239	1,045	96
	2001	4,621	214	3,541	181	1,080	93
	2002	3,830	230	2,327	167	1,503	129
	2003	2,983	208	1,457	129	1,526	133
	2004	2,197	176	930	102	1,267	123
	2005	1,833	180	817	108	1,016	124

statements ranged from 0.53 to 0.73, whereas in the 4-point area support ranged from 0.44 to 0.61. However, hunters who agreed or strongly agreed with APRs always outnumbered those opposed by more than a 2:1 ratio. By the end of the study, however, we did not detect differences between 3-point and 4-point areas (Fig. 4). Consequently, to evaluate hunter opinions about APRs and the consequences of these regulation changes, we combined responses from hunters in 3- and 4-point areas for all surveys. The proportion of hunters from the random sample surveys who supported statewide APRs varied between 0.61 (95% CI = 0.59–0.64) and 0.70 (95% CI = 0.66–0.73).

Overall satisfaction with PGC deer management program (rating of excellent or good) increased after the first hunting season with APRs in 2002, remained stable through the pre-season in 2004, and declined after the 2004 hunting season (Table 12). Before and after the 2002 hunting season, the proportion of hunters who rated the program as fair or poor declined from 0.53 (SE = 0.01) to 0.37 (SE = 0.02). During post-season 2002 through pre-season 2004, 0.47–0.56 (SE = 0.02) of hunters rated the program as good or excellent. However, after the 2004 hunting season, the proportion of hunters who rated the program as good or excellent declined to 0.29 (SE = 0.02) and the proportion who rated it poor increased to 0.41 (SE = 0.02; Table 12).

The proportion of hunters that believed current APRs would cause a dramatic decrease in the number of males harvested in the area they hunted was greatest in 2002 before the first hunting season with APR regulations (0.60) but declined and varied around 0.50 in subsequent surveys (0.43–0.54; Table 13). The proportion of hunters that believed there would be very few legal

Table 10. Statewide estimates of white-tailed deer population size and density (deer/km^2) prior to the hunting season, number of hunters, and number of days hunters participated in the firearms season, Pennsylvania, 2000–2005.

			No. hunters		Hunter days	
Year	Pre-hunt population	Pre-hunt density	Estimate	95% CI	Estimate	95% CI
2000	1,487,898	12.4	913,646	907,311–919,981	3,478,022	3,420,905–3,535,139
2001	1,372,594	11.5	858,622	850,310–866,934	3,571,833	3,507,181–3,636,485
2002	1,380,479	11.5	793,502	783,913–803,091	3,259,869	3,191,897–3,327,841
2003	1,254,997	10.5	790,595	781,280–799,910	3,264,793	3,195,350–3,334,236
2004[a]	1,174,230	9.8				
2005	1,140,321	9.5	739,532	730,057–749,007	3,188,982	3,118,930–3,259,034

[a] The PGC annual Game Take Survey was not conducted in 2004.

Table 11. Sample sizes and response rates for 11 deer hunter surveys mailed to randomly selected hunters to determine support for white-tailed deer antler point restriction regulations in Pennsylvania, 2002–2005. Random sample surveys were a random selection of hunting license buyers for each survey, whereas the panel survey was composed of respondents to the first random sample survey.

	Random sample survey			Panel survey		
Survey	Mailed	Not deliverable	Response rate (%)	Mailed	Not deliverable	Response rate (%)
Pre-season 2002	2,906	135	65.6			
Post-season 2002	1,070	29	64.0	1,819	10	63.8
Pre-season 2003	1,159	55	65.9	1,154	3	85.9
Post-season 2003	1,138	58	68.9	989	1	87.9
Pre-season 2004	1,166	48	64.1	868	2	89.5
Post-season 2004	1,202	54	65.6	775	1	94.1

males harvested varied but was greatest at the end of the study (0.38–0.66; Table 13).

Most hunters (0.59–0.73) believed APRs would increase subadult survival and result in more older-aged males, although the lowest agreement (0.59) with this statement occurred post-season 2004 (Table 14). About 25% (0.19–0.27) of respondents believed there would be no increase in older-aged males because of pre-season poaching and the highest agreement with this statement occurred in the last survey of the study. The proportion of hunters that believed the shooting of sub-legal males in hunting season would negate any increase in large males due to APRs varied from 0.23 to 0.33, with the greatest agreement occurring at the beginning and end of the study. About 33% (0.29–0.36) of respondents believed hunters would shoot any antlered deer and not retrieve it if it were sub-legal, except before the first hunting season with APRs (0.45; Table 14).

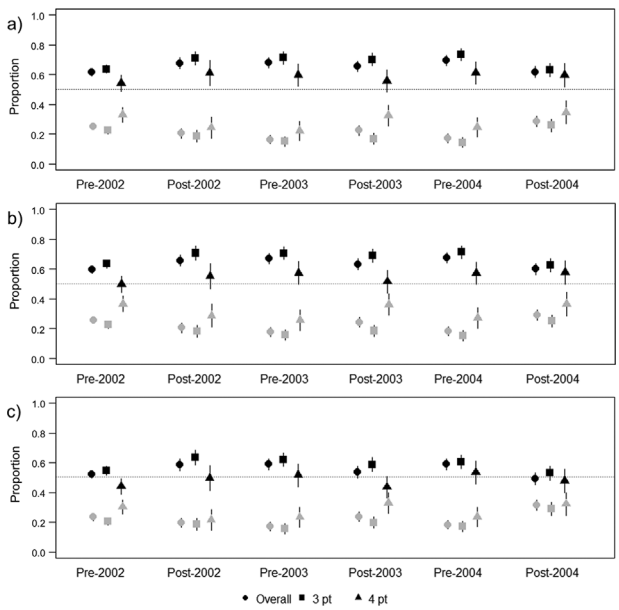

Figure 4. Proportion of Pennsylvania hunters who agreed or strongly agreed (black symbols) and who disagreed or strongly disagreed (gray symbols) with statements that a) they support a statewide antler point restriction regulation for white-tailed deer in Pennsylvania, 2002–2004, b) they support antler point restriction regulation for in the wildlife management unit they principally hunted white-tailed deer in Pennsylvania, 2002–2004, and (c) antler point restrictions for white-tailed deer were a good change in Pennsylvania's deer management program in Pennsylvania, 2002–2004. Squares represent responses of hunters who hunted deer in areas with 3-point (3 pt) antler point restrictions (APRs), triangles represent responses of hunters who hunted deer in areas with 4-point (4 pt) APRs, and circles represent statewide responses. We conducted surveys each year before and after the 12-day firearms deer season. Vertical lines represent the 95% confidence interval and the dotted horizontal line indicates where agreement with statements is 0.50.

Most hunters (0.52–0.73) supported a regulation to increase the ratio of antlered to antlerless deer (Table 15), but this support declined to the lowest level after the 2004 hunting season. The proportion of hunters that believed the area they hunted had an acceptable ratio of antlered to antlerless deer was $\leq$0.27 (0.19–0.27), but they also did not agree that they saw too many antlerless deer (0.13–0.34). Prior to implementing APRs, 34% of hunters agreed they observed too many antlerless deer, but this had dropped to 13% after the 2004 hunting season. The proportion of hunters that agreed the new harvest regulations for antlered deer would result in a male:female ratio closer to 1:1 was stable (0.36–0.41) until after the 2004 hunting season, when it declined to 0.29 (Table 15).

The proportion of hunters that agreed males in their hunting area had adequate antler size was 0.41 prior to APRs being implemented, and then remained stable at 0.29–0.34. However, about 67% agreed current harvest regulations would result in more males with larger antlers (0.64–0.72) until after the 2004 hunting season, when it declined to 0.57 (Table 16).

The proportion of hunters that agreed APRs would reduce their enjoyment of deer hunting varied between 0.22 and 0.37 and was greatest after the 2004 hunting season (Table 17). Of these hunters, 0.62–0.74 agreed deer hunting enjoyment would be less because they could not shoot a any male with antlers $>$7.6 cm (3 inches) long or $\geq$2 points on 1 side (i.e., the regulation prior to APRs). Of hunters that agreed APRs would reduce their enjoyment of deer hunting, 0.44–0.63 indicated the APRs were too complex. However, the most common reason given for APRs reducing deer hunting enjoyment (0.69–0.84 of all hunters) was the concern about shooting an illegal male (Table 17).

Most hunters (0.51–0.66) agreed it would be difficult to identify legal males with the new APRs (Table 18) with agreement highest before the first hunting season with APRs. Prior to APRs, 55% of hunters agreed it would be too easy to accidentally kill a sub-legal male in season, but after the initial season the proportion of hunters agreeing declined to 0.39–0.46 (Table 18). About 7 of 10 hunters (0.67–0.75) agreed current APRs were clear and easy to understand (Table 18). At least half of hunters (0.50–0.63) agreed deer herd quality would increase with the current APR, but that declined to 0.40 after the 2004 hunting season (Table 18). About 67% of hunters (0.62–0.71)

Table 12. Proportion of hunters (± SE) who rated the Pennsylvania Game Commission's deer management program as excellent, good, fair, poor, or don't know, Pennsylvania, 2002–2004.

Survey	Excellent	Good	Fair	Poor	Don't know	*n*
Pre-season 2002	0.06 (0.01)	0.33 (0.01)	0.40 (0.01)	0.13 (0.01)	0.08 (0.01)	1,669
Post-season 2002	0.12 (0.01)	0.45 (0.02)	0.25 (0.02)	0.13 (0.01)	0.06 (0.01)	597
Pre-season 2003	0.12 (0.01)	0.41 (0.02)	0.29 (0.02)	0.09 (0.01)	0.09 (0.01)	665
Post-season 2003	0.09 (0.01)	0.38 (0.02)	0.27 (0.02)	0.20 (0.02)	0.07 (0.01)	661
Pre-season 2004	0.11 (0.01)	0.42 (0.02)	0.27 (0.02)	0.14 (0.01)	0.06 (0.01)	672
Post-season 2004	0.06 (0.01)	0.23 (0.02)	0.25 (0.02)	0.41 (0.02)	0.05 (0.01)	656

agreed APRs would improve their opportunity to harvest a larger male in the future, but agreement declined to 0.53 after the 2004 hunting season (Table 18).

The confirmatory factor analysis (Table 19) indicated that respondents who did not support APRs noted that they saw too few antlerless deer, did not support changes to increase the antlered: antlerless ratio (factor 2—sex ratio), agreed that illegal harvest would be a problem (factor 1—subadult survival), and believed antlered harvest would decline (factor 3—antlered harvest). Three variables loaded on the major factor labeled subadult survival: 1) no increase in quality because of poaching; 2) no increase in quality because hunters will shoot sublegal males; and 3) hunters will shoot sub-legal deer and not retrieve them. Four variables loaded on the second major factor, labeled sex ratio: 1) regulations resulting in older-aged males; 2) support for a regulation to increase the antlered:antlerless ratio; 3) harvest regulations will result in a male: female ratio closer to 1:1; and 4) hunters seeing too many antlerless deer. Three variables loaded on the third factor, labeled antlered harvest, and 2 of these loaded heavily: 1) hunter agreement APRs will cause a dramatic decrease in the number of males harvested where they hunt; and 2) hunter agreement that very few legal males will be harvested where they hunt. The remaining variable, measuring agreement that the deer population had an acceptable ratio of antlered:antlerless deer, had a weak loading on the factor antlered harvest (−0.21) but was retained because it had almost no relationship to either of the remaining 2 factors, with loadings of 0 and −0.02 for subadult survival and sex ratio, respectively (Table 19). The weak factor loading on antlered harvest was the probable cause of the low measure of consistency (Cronbach's alpha = 0.11) and removal of the variable had no effect on the confirmatory factor analysis results but did increase Cronbach's alpha to 0.56, indicating consistency among responses to the multi-item factors we created.

Based on a follow-up survey at the end of the study of panel members who did not complete all 6 surveys, we received responses from 576 hunters. Panel dropouts were less likely to support APRs on all 4 questions asked (Table 20). Therefore, we concluded the panel respondents were not representative of all hunters and we did not perform full longitudinal analyses but simply compared responses to the first and last surveys by including responses of panel dropouts in the last panel survey.

A comparison of responses before APRs took place and after they had been in place 3 years indicated nearly half of hunters were unchanged in their support regarding most aspects of APRs (Table 21). However, the proportion of hunters that became less supportive of APRs after 3 years (0.29–0.30) was greater than the proportion that became more supportive (0.23). The same proportion of hunters became less supportive of a regulation to increase the ratio of antlered to antlerless deer (0.42) as remained unchanged (0.42). With respect to their rating of the PGC's deer management program, more hunters became less supportive (0.41) than remained unchanged (0.38) or more supportive (0.21; Table 21).

DISCUSSION

We concluded that implementation of APRs in Pennsylvania represented a management success because we achieved our

Table 13. Agreement (proportion of respondents and SE) from Pennsylvania deer hunters to survey statements regarding antler point restrictions and hunter perception of antlered deer harvest, 2002–2005. Agreement was the proportion of respondents who selected strongly agree or agree on a 5-point Likert scale.

	Current regulations will cause a dramatic decrease in the number of bucks harvested where I hunt		In the area I hunt, there will be very few legal bucks harvested	
Survey	Agree	SE	Agree	SE
Pre-season 2002	0.60	0.01	0.49	0.01
Post-season 2002	0.46	0.02	0.48	0.02
Pre-season 2003	0.47	0.02	0.38	0.02
Post-season 2003	0.53	0.02	0.59	0.02
Pre-season 2004	0.43	0.02	0.39	0.02
Post-season 2004	0.54	0.02	0.66	0.02

Table 14. Agreement (proportion of respondents and SE) from Pennsylvania deer hunters to survey statements regarding antler point restrictions and hunter perception of subadult survival, 2002–2005. Agreement was the proportion of respondents who selected strongly agree or agree on a 5-point Likert scale.

	More older males[a]		Pre-season poaching[b]		Accidental kills[c]		Shoot and sort[d]	
Survey	Agree	SE	Agree	SE	Agree	SE	Agree	SE
Pre-season 2002	0.70	0.01	0.24	0.01	0.33	0.01	0.45	0.01
Post-season 2002	0.69	0.02	0.21	0.02	0.27	0.02	0.32	0.02
Pre-season 2003	0.73	0.02	0.19	0.02	0.23	0.02	0.34	0.02
Post-season 2003	0.67	0.02	0.22	0.02	0.25	0.02	0.29	0.02
Pre-season 2004	0.70	0.02	0.22	0.02	0.24	0.02	0.36	0.02
Post-season 2004	0.59	0.02	0.27	0.02	0.31	0.02	0.34	0.02

[a] The statement was "Current regulations will result in older aged bucks."
[b] The statement was "Current regulations will result in no older aged bucks because large bucks will be poached before season."
[c] The statement was "Current regulations will result in no increase in large bucks because hunters will still shoot sublegal bucks."
[d] The statement was "Hunters will shoot any antlered deer and leave them in the woods if they are not legal."

Table 15. Agreement (proportion of respondents and SE) from Pennsylvania deer hunters to survey statements regarding antler point restrictions (APRs) and hunter perception of sex ratios, 2002–2005. Agreement was the proportion of respondents who selected strongly agree or agree on a 5-point Likert scale.

	Increase antlered: antlerless ratio[a]		Antlered: antlerless ratio acceptable[b]		Too many antlerless deer[c]		APRs will improve M: F ratio[d]	
Survey	Agree	SE	Agree	SE	Agree	SE	Agree	SE
Pre-season 2002	0.68	0.01	0.27	0.01	0.34	0.01	0.41	0.01
Post-season 2002	0.72	0.02	0.23	0.02	0.29	0.02	0.39	0.02
Pre-season 2003	0.73	0.02	0.23	0.02	0.31	0.02	0.42	0.02
Post-season 2003	0.63	0.02	0.20	0.02	0.24	0.02	0.36	0.02
Pre-season 2004	0.69	0.02	0.22	0.02	0.25	0.02	0.36	0.02
Post-season 2004	0.52	0.02	0.19	0.02	0.13	0.02	0.29	0.02

[a] The statement was "I support a regulation that would increase the ratio of antlered bucks to antlerless deer in the statewide deer population."
[b] The statement was "In the area I hunted most often last year, the deer population has an acceptable ratio of antlered to antlerless deer."
[c] The statement was "In the area I hunted most often last year, I saw too many antlerless deer."
[d] The statement was "The current harvest regulations for bucks will result in a buck to doe ratio closer to 1:1."

biological objectives (i.e., subadult male harvest rates declined resulting in more adult males in the population and more adult males harvested by hunters) and the APR regulations were accepted by >50% of deer hunters (Table 1). We found that the amount of illegal harvest of deer was sufficiently low to allow a greater proportion of subadult males to survive the hunting season, post-hunting season survival was high (>0.90) such that most males were available for harvest as adults the following year, and harvest of adults increased under APRs.

Most hunters formed their opinion about APRs prior to their experience with these regulations, but there was evidence that after the first hunting season with APRs their concerns about mistakenly harvesting an illegal deer declined. However, despite support for APRs, the necessary reduction in overall deer density to meet agency objectives to keep deer in balance with the habitat led to dissatisfaction with the PGC's deer management program. Furthermore, opinions about hunter cooperation with APRs and the effects of APRs on the deer population (change in sex ratio, etc.) became increasingly negative as deer density declined.

Table 16. Agreement (proportion of respondents and SE) from Pennsylvania deer hunters to survey statements regarding antler point restrictions and hunter perception of antler size, 2002–2005. Agreement was the proportion of respondents who selected strongly agree or agree on a 5-point Likert scale.

	In the area I hunted most often last year, the bucks I saw had adequate antler size		The current harvest regulations for bucks will result in more bucks with larger antlers	
Survey	Agree	SE	Agree	SE
Pre-season 2002	0.41	0.01	0.68	0.01
Post-season 2002	0.34	0.02	0.69	0.02
Pre-season 2003	0.31	0.02	0.72	0.02
Post-season 2003	0.29	0.02	0.64	0.02
Pre-season 2004	0.34	0.02	0.67	0.02
Post-season 2004	0.29	0.02	0.57	0.02

Table 17. Agreement (proportion of respondents and SE) from Pennsylvania deer hunters to survey statements regarding effect of antler point restrictions (APRs) on deer hunting enjoyment and the reason, 2002–2005. Agreement was the proportion of respondents who selected strongly agree or agree on a 5-point Likert scale.

	APRs will reduce hunting enjoyment[a]		Because cannot shoot male with >7.6 cm antlers[b]		Because APRs are too complex[c]		Because might shoot illegal male[d]	
Survey	Agree	SE	Agree	SE	Agree	SE	Agree	SE
Pre-season 2002	0.30	0.01	0.72	0.01	0.47	0.01	0.81	0.01
Post-season 2002	0.28	0.02	0.70	0.02	0.47	0.02	0.81	0.02
Pre-season 2003	0.22	0.02	0.72	0.02	0.63	0.02	0.82	0.02
Post-season 2003	0.31	0.02	0.66	0.02	0.49	0.02	0.80	0.02
Pre-season 2004	0.24	0.02	0.75	0.02	0.51	0.02	0.84	0.02
Post-season 2004	0.37	0.02	0.64	0.02	0.44	0.02	0.69	0.02

[a] The statement was "Current antler restriction regulations will reduce my enjoyment of deer hunting."
[b] The statement was "My enjoyment of deer hunting in [year] will change because I cannot shoot any buck with 3 inches or more on one antler." Responses are from hunters who agreed with statement in footnote a.
[c] The statement was "My enjoyment of deer hunting in [year] will change because current regulations are too complex." Responses are from hunters who agreed with statement in footnote a.
[d] The statement was "My enjoyment of deer hunting in [year] will change because I will be too concerned about shooting an illegal buck." Responses are from hunters who agreed with statement in footnote a.

We concluded that implementation of APRs did not offset dissatisfaction with a reduction in deer density.

Biological Responses

Biological concerns about APRs center on 2 issues: 1) whether they protect antlered deer from harvest as designed; and 2) whether protected antlered deer survive to potentially be harvested in subsequent hunting seasons. The loss of protected animals due to hunting was described as the "shoot and sort" phenomenon by Carpenter and Gill (1987) where hunters would shoot deer and then determine whether they were legal to harvest. Boyd and Lipscomb (1976) reported on this phenomenon with the loss of 22 male elk with 3-point antlers in a 4-point area, concluding based on interviews with hunters that they had probably been shot because racks had appeared large enough to be legal. Schwartz et al. (1992) reported a decrease in the illegal harvest of female moose, but an increase in the illegal kill of male moose with implementation of a selective harvest for males. The illegal kill of males averaged 7% of the legal harvest, but because a radio-marked population was not used, Schwartz et al. (1992) acknowledged their methods accounted for a minimum proportion of the total illegal kill.

Unretrieved sub-legal males and mistaken kills are part of the cost of APRs (Carpenter and Gill 1987) and we found 5–8% of males were shot and unretrieved during hunting season (Table 6). However, our estimates of sub-legal kills may be overestimates because males protected by APRs were legal deer for about 9% of deer hunters (i.e., youth hunters, disabled hunters, and active military personnel). As a result, some mortalities categorized as sub-legal could have been legally killed but unretrieved. Regardless, about twice as many subadults were legally harvested, and almost 5 times as many survived the hunting season

Table 18. Agreement (proportion of respondents and SE) from Pennsylvania deer hunters to survey statements regarding perceived problems with antler point restrictions (APRs), 2002–2005. Agreement was the proportion of respondents who selected strongly agree or agree on a 5-point Likert scale.

	Identify legal males[a]		Accidentally kill illegal male[b]		APRs easily understood[c]		APRs will improve herd[d]		Harvest larger male[e]	
Survey	Agree	SE	Agree	SE	Agree	SE	Agree	SE	Agree	SE
Pre-season 2002	0.66	0.01	0.55	0.01	0.71	0.01	0.54	0.01	0.62	0.01
Post-season 2002	0.58	0.02	0.46	0.02	0.67	0.02	0.59	0.02	0.65	0.02
Pre-season 2003	0.53	0.02	0.41	0.02	0.70	0.02	0.63	0.02	0.71	0.02
Post-season 2003	0.59	0.02	0.42	0.02	0.72	0.02	0.50	0.02	0.63	0.02
Pre-season 2004	0.51	0.02	0.38	0.02	0.75	0.02	0.58	0.02	0.68	0.02
Post-season 2004	0.59	0.02	0.39	0.02	0.74	0.02	0.40	0.02	0.53	0.02

[a] The statement was "It will be difficult to identify legal bucks with current antler restrictions."
[b] The statement was "It will be too easy to accidentally kill an illegal buck in the [current year] season."
[c] The statement was "Current antler restriction regulations are clear and easy to understand."
[d] The statement was "Deer herd quality will improve with current antler restrictions."
[e] The statement was "Current antler restriction regulations will improve my opportunity to harvest a larger buck in the future."

compared to unretrieved harvests. We concluded most hunters did not shoot first and ascertain legality later but adhered to the new regulations.

Killing of sub-legal males within the hunting season and any male outside the hunting season or with illegal weapons (i.e., illegal kills) is a concern with APRs. We failed to document illegal kills in the Centre County study area and most illegal kills in Armstrong County took place with subadults during the hunting season using an illegal weapon (e.g., rifle during archery season). With so few males illegally killed, we concluded the concerns of Carpenter and Gill (1987) about losses to sub-legal kills during the hunting season and illegal kills outside the hunting season were insignificant for this study.

Based on antler data collected prior to APRs, most adult males in this study had antler points that made them legal for harvest, but harvest rates did not increase and likely declined from approximately 0.80 (see Methods) to 0.59 (Table 5). Although simple in concept, counting antler points under field conditions can be difficult and could have been a reason for reduced harvest rate of adults after APRs were implemented. Also, 1 in 5 adult males were not legal for harvest (Appendix). Consequently, an additional effect of APRs was more males surviving to the 3-, 4-, and 5-year-old age classes. Less than 4% of the antlered population was composed of >2.5-year-olds under the previous regulations, whereas 11% were >2.5 years old under APRs (Fig. 5). Although our predicted age distribution (Fig. 5) required the strong assumption of a stationary population, when the PGC analyzed teeth collected from ≥2.5-year-old males harvested during the firearms hunting seasons (PGC, 2006–2007, unpublished data), the proportion of ≥3.5-year-old males in the harvest was 27% ($n = 5{,}093$) and we estimated 28% of the adult population was ≥3.5 years old.

The hunting harvest of antlered subadults was mostly additive mortality, and not compensatory, which was a concern expressed by Carpenter and Gill (1987). Once antlered deer survived the hunting season, they had a survival rate of 0.92 to the next deer hunting season, which was similar to what Bowman et al. (2007) reported for natural mortality (0.12) for adult males under a QDM program in Mississippi. We found that vehicle collisions were the most common source of mortality and starvation was the second most common. However, most (14 of 15) of the starvation mortalities came from a small portion of the Centre County study area, specifically the forested Moshannon State Forest and State Game Lands 33 in western Centre County. Therefore, statewide, we consider starvation to be atypical because it was rarely observed in regions where deer had access to agricultural lands.

Table 19. Mean, standard deviation, and factor loadings using a varimax rotation for responses (Likert scale where 1 = strongly disagree and 5 = strongly agree) to 10 survey statements measuring deer hunter perceptions of the effects of antler point restrictions in Pennsylvania, 2002–2005. Factor loadings near 1 and −1 indicate stronger association with the statement.

			Factor loadings		
Statement	$\bar{x}$	SD	Subadult survival	Sex ratio	Antlered harvest
The current harvest regulations for bucks will result in no increase in quality of bucks because the large bucks will be poached before season.	3.26	1.07	0.65	−0.13	0.10
The current harvest regulations for bucks will result in no increase in older bucks because hunters will still shoot sub-legal bucks.	3.16	1.05	0.87	−0.11	0.05
Hunters will shoot any antlered deer and leave them in the woods if they are not legal.	2.92	1.10	0.52	−0.13	0.11
The current harvest regulations for bucks will result in more older aged bucks.	2.34	1.04	−0.25	0.68	−0.02
I support a regulation that would increase the ratio of antlered bucks to antlerless deer in the statewide deer population.	2.28	1.19	−0.15	0.64	−0.05
In the area I hunted most often last year, I saw too many antlerless deer.	3.34	1.25	0.02	0.38	−0.03
The current harvest regulations for bucks will result in a buck to doe ratio closer to 1:1.	2.92	1.09	−0.16	0.69	−0.01
In the area I hunted most often last year, the deer population has had an acceptable ratio of antlered to antlerless deer.	3.46	1.11	0.0	−0.02	−0.21
Current antler restrictions will cause a dramatic decrease in the number of bucks harvested in the area I hunt.	2.58	1.06	0.08	−0.01	0.44
In the area I hunt, there will be very few legal bucks harvested.	2.61	1.03	0.16	−0.20	0.86

Table 20. Responses by a longitudinal panel of white-tailed deer hunters who completed all 6 surveys (finalists) compared to respondents who resigned from the panel (drop-outs) but responded to a follow-up survey at the conclusion of the study, Pennsylvania, 2002–2005. Agreement was the proportion of respondents who selected strongly agree or agree and disagreement was the proportion of respondents who selected disagree or strongly disagree on a 5-point Likert scale.

Survey statement	Respondent type	Agree	Neither	Disagree	No. respondents	χ^2_2	*P*
I support a statewide antler restriction.	Finalist	0.66	0.11	0.24	667	21.7	<0.001
	Drop-out	0.54	0.19	0.27	555		
I support an antler restriction in the wildlife management units I principally hunt for deer.	Finalist	0.64	0.11	0.25	666	21.6	<0.001
	Drop-out	0.52	0.19	0.29	553		
I support a regulation that would increase the ratio of antlered bucks to antlerless deer in the statewide population.	Finalist	0.56	0.18	0.25	666	10.2	0.006
	Drop-out	0.49	0.25	0.26	552		
Current antler restrictions are a good change in Pennsylvania's deer management program.	Finalist	0.53	0.22	0.25	666	3.7	0.161
	Drop-out	0.48	0.25	0.27	559		

Table 21. Proportion of a longitudinal panel of respondents who indicated less, the same, or more support after 3 years of antler point restrictions (APRs). The initial response was received in 2002 before the first year or APRs and the after response was obtained after the 2004 hunting season and included responses from panel members who did not complete all 6 surveys. All questions were presented on a 1–5 Likert scale (1 = strongly disagree, 5 = strongly agree). Differences of ≥0.06 between categories of before-after support were significant ($\alpha = 0.05$).

		Before-after support		
Survey statement	*n*	Less	Same	More
I support a statewide antler restriction.	1,136	0.29	0.48	0.23
I support an antler restriction in the wildlife management units I principally hunt for deer.	1,125	0.30	0.47	0.23
I support a regulation that would increase the ratio of antlered bucks to antlerless deer in the statewide deer population.	1,119	0.42	0.42	0.17
Current antler restrictions are a good change in Pennsylvania's deer management program.	1,141	0.31	0.49	0.21
I would rate the PGC's deer management program as: Excellent, Good, Fair, Poor, or Don't know.[a]	984	0.41	0.38	0.21

[a] PGC = Pennsylvania Game Commission.

The increased harvest of adult antlered deer and the increased proportion of adults in the antlered deer harvest under an APR harvest strategy were evidence the APRs allowed more subadults to survive to the adult age class. Carpenter and Gill (1987) stated the objective of stockpiling older males can be met only if hunter pressure were reduced through fewer and shorter seasons, hunter participation was reduced, and there were low natural mortality rates. Similarly, Unsworth et al. (1993) stated APRs must be accompanied with restrictions in hunter numbers or hunter access, and Bender and Miller (1999) and Young and Boertje (2008) reported limiting hunter density and access reduced the antlered harvest and thereby increased the male to female ratio of elk and moose. In contrast, no limitations on hunter numbers, access, or hunting opportunity for antlered deer occurred during this study. Pennsylvania's strategy of relying on hunter cooperation was likely successful because of the high harvest rates prior to APRs and the relatively young age structure of the male population.

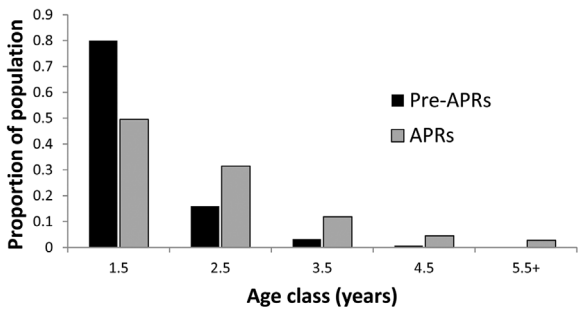

Figure 5. Estimated age structure of the male population of white-tailed deer before 2002 and after implementation (2003–2005) of statewide antler point restriction (APR) regulations in Pennsylvania.

Regulations, however, can constrain hunter participation (Miller and Vaske 2003), and Pennsylvania observed a decrease in hunter effort in the initial year of APRs. Statewide hunter-days declined between 2001 and 2002 because of approximately 65,000 fewer hunters, but the long-term decline in deer hunting participation has not changed since the 1980s (Fig. 6). The stability of hunter-days from 2002 to 2005 (Table 10) was likely due to new regulations that made antlerless deer seasons longer and concurrent with antlered deer season, and included a Saturday.

Another concern raised by Carpenter and Gill (1987) was that stockpiling older males may result in increased natural mortality of younger age classes. No increase in natural mortality was observed in this study or by Bowman et al. (2007) in Mississippi. Bowman et al. (2007) reported the natural mortality rate of

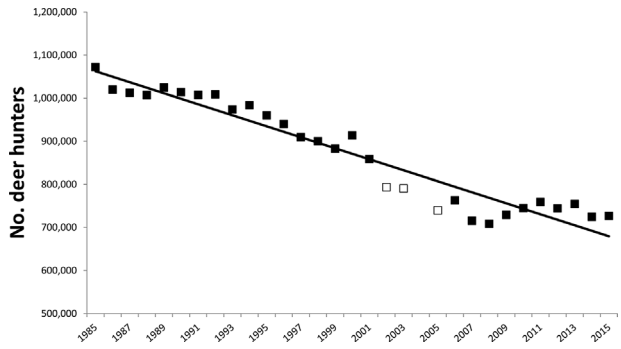

Figure 6. Number of white-tailed deer hunters in Pennsylvania, 1985–2014, based on the Pennsylvania Game Commission's (PGC) annual Game Take Survey of 2% of hunting license buyers (PGC, unpublished data). Hunter numbers during this study are represented by open squares (no survey was conducted in 2004).

yearling males to be the lowest among all age classes, and the ≥5.5-year-old age class had the highest mortality. Pennsylvania's goal was to increase the number of subadult males surviving to the 2-year-old age class. However, the APRs resulted in more males surviving to the ≥3-year-old age class.

Hunter Reactions

Reduction of deer density.—The survey period between 2002 and 2005 contained multiple deer hunting regulation changes in Pennsylvania, including both APRs and various regulatory changes to reduce overall density of deer by focusing on harvest of females (i.e., lengthened antlerless seasons, new antlerless seasons, and increased antlerless license allocations). Consequently, hunter opinions about APRs were likely confounded with other regulation changes. It was impossible to make changes in APRs without changes in seasons and bag limits for antlerless deer because 1) even if deer density met management goals prior to implementing APRs, the increased number of antlered deer would necessitate a reduction in density of antlerless deer; and 2) in Pennsylvania, deer populations needed to be reduced because populations exceeded management goals in all WMUs (B. D. Wallingford and M. D. Grund, PGC, unpublished report). The regulation changes (antlered and antlerless concurrent seasons and increased antlerless licenses) were effective in reducing deer abundance (Table 10), and the effects of declining deer abundance on hunter attitudes were apparent in the results of the random surveys. We hypothesized that dissatisfaction with overall reduced deer density could be offset with more, older-aged, antlered deer, but this change did not occur.

Seeing and potentially harvesting game are more important than the actual harvest for most hunters (Duda et al. 1996). Gigliotti (2000) reported seeing deer was better correlated with satisfaction than harvest success. However, Heberlein and Kuentzel (2002) found harvesting a deer had the largest direct effect on satisfaction, whereas seeing deer had the second largest effect. Langenau et al. (1981), Hammitt et al. (1990), and Holbrook and McSwain (1991) reported deer seen and deer harvested were important factors to hunter satisfaction. In Pennsylvania, Miller and Graefe (2001) found that successful harvest predicted satisfaction among archery, rifle, and muzzleloader deer hunters. The reduction of deer density and antlered harvest in the first year that APRs were implemented likely adversely influenced hunter attitudes toward APRs.

Decline in satisfaction was expressed in the sharp decline in overall rating of the PGC deer management program after the third year of APRs. We believe these changes in overall satisfaction with deer management reflected the effects of 2 confounding factors: implementation of APRs and the corresponding decrease in deer population size via increased antlerless harvests. Although fewer people agreed that APRs were a good change, overall support for APRs did not decline during the survey period (Fig. 4). Also, APRs in conjunction with population reduction did not produce the quantity or quality of antlered deer hunters expected. Despite more adult males in the population and harvest, more hunters agreed males had adequate antler size before APRs began (Table 16). Decreasing populations during the survey period reduced the number of males, including sub-legal subadults that could be observed even if not legally harvested. Thus, the decline in the overall rating of the deer management program seems to be related more to population reduction, or some other factor, rather than APRs.

Support for APRs and hunter concerns.—Despite management program changes during this study to reduce the deer population, the random sample surveys indicated the proportion of hunters supporting APRs as a statewide regulation remained ≥0.60 throughout the study (Fig. 4) and support for APRs after 3 years was equal to support at the beginning of the study. The first year of APRs required the greatest opportunity cost for hunters (giving up harvest of yearling males; Manfredo et al. 2004) because there was low out-of-season mortality and antler growth between 1 and 2 years of age allows most subadult males to be legal to harvest under APRs the following year (Strickland and Demarias 2007). Surveys in other states with APRs also indicated strong support for the regulations (C. J. Kandoth, D. Leskie, and A. Riviello, New Jersey Division of Fish and Wildlife, unpublished report; S. Haskell, Vermont Department of Fish and Game, personal communication).

The proportion of hunters concerned about pre-season poaching and the perceived loss of sub-legal males in season remained stable and did not change with increased experience with APRs. Approximately 33% of respondents believed hunters would shoot any antlered deer and leave it in the woods if not legal (Table 14). In this way, Pennsylvania hunters were concerned with the same issues that Carpenter and Gill (1987) presented in their shoot and sort theory. New Jersey hunters were concerned with compliance with APRs and agreed that identifying legal antlered deer in APR zones would be difficult, especially while intentionally moving deer on cooperative hunts (i.e., deer drives; Kandoth et al. 2010). Similarly, Monzingo (1999) reported 70% of moose hunters believed APRs would increase the number of illegal moose kills, and 75% of moose hunters believed APRs increased their chances of making a mistake. However, empirical data from a radio-marked sample of ungulates to corroborate this hunter belief were lacking from these studies. Schwartz et al. (1992) reported an illegal kill of only 7% of the legal moose harvest, with most illegal males mistakenly identified as larger males with ≥3 tines on 1 brow palm. Likewise in our study, estimates of mortality of radio-collared males did not match the apprehension hunters had for the illegal killing of sub-legal males during season (Table 6).

Hunters supported regulations designed to increase the antlered:antlerless ratio; however, the proportion of hunters that believed APRs would increase this ratio was only 0.29–0.42 and did not change over time (Table 15). Empirical data (Tables 2, 8, and 10; Fig. 5) indicated regulation changes increased the antlered:antlerless ratio, but hunters were not satisfied with antlered:antlerless ratios before APRs and satisfaction did not increase after APRs were implemented. Most hunters disagreed when asked if they saw too many antlerless deer (Table 15). It is unlikely that observations by individual hunters are sufficient for them to perceive a change in sex ratio. Based on our survey responses, hunter support for APRs was not due to the actual or perceived increase in the proportion of antlered deer in the population because satisfaction with the number of antlered deer seen did not increase and satisfaction with overall deer sightings declined.

Pennsylvania's APRs were simple compared to harvest criteria such as estimating beam length, antler spread, or a combination of antler characteristics. Pennsylvania hunters only had to count antler points. Accordingly, the majority of hunters consistently agreed APRs were clear and easy to understand (Table 18). We agree with Miller and Vaske (2003) and Cornicelli (2009) that regulations should not constrain hunter participation or be difficult to understand, because both factors could further exacerbate declining deer hunter numbers, and result in lower hunter satisfaction. More complex or subjective methods of reducing subadult harvest rates have been self-imposed and applied on small management areas (Kroll 1991, Bullock et al. 1995).

The comparison of panel members surveyed before APRs and 3 years after APRs tested several predictions regarding whether hunters perceived the biological effects of APRs through their hunting experience. Assuming that APRs were biologically successful, we predicted an increase in support for 1) statewide APRs, 2) APRs in the WMU they principally hunt for deer, 3) a regulation to increase the ratio of males to females, 4) the new APRs as a positive change to Pennsylvania's deer management program, and 5) Pennsylvania's deer management program. In contrast to expectations, after 3 years of APRs, almost half of hunters did not change their opinion for 1, 2, and 4 above, whereas the majority of hunters reduced their support for 3 and 5 (Table 21).

We expected support for increased male:female ratios with APRs, but support decreased probably because hunters knew the change in sex ratio was also being accomplished through increased antlerless harvest to reduce overall deer density. Similarly, 41% gave lower ratings to the overall deer program, and only 21% gave higher ratings (Table 21). Again, because support for APRs remained high, we attributed this drop in support to herd reductions; declining deer populations likely confounded survey results because hunters need to see and harvest deer for satisfaction (Langenau et al. 1981, Hammitt et al. 1990, Holbook and McSwain 1991). If deer abundance had remained constant, it is possible support for APRs could have increased.

During this study, hunters had experience with 3 years of APRs, so they were familiar with field difficulties of identifying legal and sub-legal antlered deer, and they anticipated fewer antlered deer would be harvested. Despite concerns of shooting a sub-legal male, which hunters identified as the strongest reason APRs would reduce hunting enjoyment, almost half the respondents had the same level of support for a statewide APR before experiencing them as they did after experiencing them for 3 years (Table 21). Thus, hunters' experience with herd reductions resulted in decreased support of deer management in general and changes to sex ratios; however, experience with APRs did not change hunters' support of this selective harvest strategy. Rather, hunters apparently adopted beliefs about APRs and their effect on deer populations before ever experiencing them. Further, they retained their opinions through the first 3 seasons, suggesting a paradox between hunter perceptions and the biological reality of APRs. This finding was corroborated by the factor analysis (Table 19) where hunters who did not support APRs were concerned with illegal harvest and reduced harvest of antlered deer. Apparently, these opinions were fixed prior to implementation of APRs and changed little with experience.

Social scientists refer to the phenomenon of accepting information consistent with beliefs and discounting contradictory information as biased processing or confirmation bias, which may occur when new information is processed to confirm and protect existing beliefs (Teel et al. 2006). Biased processing is more likely to occur when new information is incorporated with well-formed beliefs from existing knowledge, attitudes, or values (Jussim 1991, McCaffrey et al. 2008). In contrast, the ability of new information to change attitudes and opinions is greater when there is not already a well-formed belief (Wilson and Bruskotter 2009). Hunters in our surveys appeared to have well-established, preconceived beliefs about the effects of APRs, despite the evidence from radio-collared deer.

Support for APRs in the first year was based purely on the anticipated population effect, but in subsequent surveys hunters had the benefit of experience and observations of sub-legal antlered deer. We anticipated the measure of support would be based on hunter perception of seeing more legal, adult antlered deer and would increase over time. The adult proportion of the antlered harvest increased from about 20% prior to APRs to about 50% during the study, but success rates of deer hunters for antlered deer during the 4 years of our study declined 18% from the 4 years prior to APRs (i.e., 0.22 in 1998–2001 before APRs to 0.18 in 2003 after APRs; PGC Game Take Survey, unpublished data; Tables 8 and 10). The decline in hunter success was similar to the 23% decline in overall deer populations (Table 10). As a result, most of the decline in success rates of deer hunters for antlered deer seems related to overall deer population reduction. Hunters should have perceived a difference in age structure of antlered males based on their personal field observations, yet hunter opinions about APRs did not reflect the changes. Hunters either ignored their observations or they did not perceive enough change to influence their opinions.

MANAGEMENT IMPLICATIONS

We concluded biologically that APRs were successful because they lowered subadult male harvest rates, increased the number of adult males in the population, and increased the number of adult males harvested. Most (90%) of subadults not harvested were then available for harvest as adults during subsequent hunting seasons. From a social perspective APRs were successful because >50% of hunters supported them after 3 years. Hunters complied with APR regulations and out-of-season mortality was low. We propose that simple, enforceable, and regionally specific APR criteria that protected most subadults from harvest but provided ample opportunity to harvest adults maximized compliance by hunters. However, we suspect that hunters were less likely to support APRs based on empirical data or experience rather than their *a priori* perceptions of APRs, indicating that prior education of hunters (Carpenter and Gill 1987) is likely important to ensure success when implementing APRs. Some perceptions of hunters did change with experience; specifically, hunters became more confident in identifying legal males and less concerned with accidentally shooting sub-legal males. Based on our criteria, APRs in Pennsylvania were a deer management success (Table 1) but were not considered by hunters as an acceptable trade-off for lower densities of deer.

Despite the majority of hunters supporting APRs, lack of increasing support after 3 years of APRs should be a concern to deer

managers, especially if deer populations are above management goals. Hunters apparently did not perceive or accept many of the population effects of APRs (e.g., increased ratio of adult males to adult females and increased harvest of adult males) when combined with population reduction to balance deer density with habitat conditions. Thus, APRs may not provide what hunters want and expect, or the APRs implemented in Pennsylvania did not create sufficient changes in the demography of the deer population to be readily perceived by hunters.

Sharing the empirical results of APRs could bridge the difference between population effects and what hunters expect to see from APRs (Carpenter and Gill 1987), with the caveat that, once formed, hunters' opinions are apparently difficult to change. Ajzen and Fishbein (1977) theorized behavioral intentions result from an individual's attitude and evaluation of the judgments of influential peers. Consequently, more sophisticated methods of communicating the effects of APRs to hunters is likely needed (Diefenbach and Palmer 1997, Holsman 2000), rather than the traditional paradigm of simply providing information to stakeholders in the belief that eliminating an information deficit will resolve management conflict (Ziman 1991).

Our research focused on a regulation to increase the age and abundance of large-antlered deer, but deer management is about making decisions to meet societal objectives. Antler point restrictions advanced deer population management because limiting the antlered harvest with APRs did not reduce the opportunity for hunters to hunt antlered or antlerless deer. However, this study suggests that the biological effects of APRs believed to increase the hunting satisfaction of most hunters may not be sufficient to offset reduced hunter satisfaction when deer densities are reduced.

SUMMARY

1. Antler point restriction regulations implemented in Pennsylvania reduced harvest rates from approximately 80% of all antlered deer to 0.31 for subadults and 0.59 for adults. The reduction in post-APR adult harvest rate allowed more 2.5-year-old males to survive the hunting seasons. As a result, adult male harvests increased despite lower deer populations.
2. Thirty-three of 274 (12%) subadults and 9 of 140 (6%) adults were illegally harvested during the hunting seasons. With so few males illegally killed, we concluded the concerns of Carpenter and Gill (1987) about losses to sub-legal kills during the hunting season and illegal kills outside the hunting season were insignificant for this study.
3. For deer that survived the hunting season, the probability of surviving to the next hunting season was 0.92. Therefore, harvest of antlered subadults was mostly additive mortality.
4. The proportion of hunters supporting APRs as a statewide regulation prior to implementation and after 3 years remained $\geq$0.60 despite increased antlerless harvests to reduce overall deer density beyond what was required to offset the increase in males due to APRs.
5. The proportion of hunters concerned about pre-season poaching and the perceived loss of sub-legal males in season remained stable and did not change with increased experience with APRs.
6. Sub-legal kills were not a major source of mortality in either age class and we observed a decline in the proportion of respondents agreeing that shoot and sort would be pervasive.
7. Forty-two percent of hunters became less supportive of a regulation to increase ratio of antlered to antlerless deer, and only 17% became more supportive. Because hunters remained supportive of APRs, we expected support for increased male: female ratios to increase, but support may have decreased because hunters knew the change in sex ratio was also being accomplished with increased antlerless harvests and population reduction.
8. Experience with APRs did not change hunters' support of this selective harvest strategy; and hunters retained their opinions through the first 3 seasons, indicating biological success did not affect hunter perceptions.
9. Antler point restrictions were biologically successful because more subadult antlered males survived, and harvest of adult antlered males increased. Antler point restrictions were socially successful because >50% of hunters supported APRs. Based on our criteria, APRs in Pennsylvania were a deer management success.

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APPENDIX

Cumulative percentage of subadult (1.5-yr-old) male deer that would not be legal to harvest when antler point restrictions (APRs) required 2, 3, 4, or ≥5 points on at least 1 antler and percentage of adult (≥2.5-yr-old) male deer that would not be legal to harvest, Pennsylvania, 2000–2001.

		No. antler points of subadults[a]						
County	Regulation[b]	≤1	≤2	≤3	≤4	*n*[c]	Protected adults	*n*[c]
Adams	3-pt APR	22.8	51.5	81.3	98.0	342	19.2	78
Allegheny	Special	7.7	23.9	53.8	90.3	247	1.1	46
Armstrong	4-pt APR	7.6	28.3	60.8	93.1	870	7.5	93
Beaver	4-pt APR	5.6	24.0	57.6	93.6	1,045	21.3	136
Bedford	3-pt APR	33.7	60.8	86.1	98.7	1,032	21.6	268
Berks	3-pt APR	11.5	32.2	66.0	96.0	1,017	7.7	182
Blair	3-pt APR	25.4	55.7	83.8	98.9	548	14.2	113
Bradford	3-pt APR	12.9	40.6	75.2	96.7	2,091	7.0	442
Bucks	Special	10.1	36.8	75.2	98.6	435	0.0	165
Butler	4-pt APR	4.7	25.7	58.1	93.7	1,073	29.5	95
Cambria	3-pt APR	13.6	38.4	71.1	97.1	969	6.9	130
Cameron	3-pt APR	40.0	73.1	93.7	100.0	164	14.5	152
Carbon	3-pt APR	30.0	58.5	79.8	98.0	400	20.3	192
Centre	3-pt APR	35.9	65.6	89.8	99.2	1,880	20.5	498
Chester	Special	8.9	32.0	67.3	96.8	716	1.9	296
Clarion	3-pt APR	12.3	37.2	65.5	95.0	716	9.5	105
Clearfield	3-pt APR	25.1	57.2	85.2	98.9	1,744	15.7	408
Clinton	3-pt APR	34.8	66.3	89.3	99.1	549	15.4	267
Columbia	3-pt APR	9.1	33.1	65.9	94.6	803	10.1	217
Crawford	4-pt APR	8.8	31.2	67.1	96.1	2,295	17.9	351
Cumberland	3-pt APR	27.5	52.7	81.2	97.2	393	14.8	122
Dauphin	3-pt APR	8.9	30.6	67.5	97.0	779	12.7	165
Delaware	Special	12.7	50.8	81.0	98.4	63	4.0	27
Elk	3-pt APR	37.7	70.7	91.6	99.5	549	19.4	248
Erie	4-pt APR	8.2	33.0	68.4	95.0	1,628	22.3	238
Fayette	3-pt APR	12.0	35.3	67.8	95.4	283	11.4	70
Forest	3-pt APR	36.5	70.0	90.4	99.0	908	19.3	327
Franklin	3-pt APR	31.3	61.0	87.1	98.8	428	19.7	132
Fulton	3-pt APR	42.3	72.4	91.9	99.1	456	29.2	106
Greene	3-pt APR	21.2	46.5	78.1	97.9	822	7.5	214
Huntingdon	3-pt APR	33.8	62.7	88.0	98.8	1,730	27.7	564
Indiana	4-pt APR	8.0	28.2	61.3	94.5	1,337	24.1	137
Jefferson	3-pt APR	14.7	42.1	72.6	96.7	943	14.1	142
Juniata	3-pt APR	23.5	49.3	75.5	97.3	473	15.5	97
Lackawanna	3-pt APR	22.6	57.9	85.0	98.9	541	15.3	157
Lancaster	3-pt APR	9.0	31.2	62.1	94.5	420	6.1	115
Lawrence	4-pt APR	4.1	16.5	43.5	92.9	393	16.3	43
Lebanon	3-pt APR	13.3	33.7	70.8	97.7	511	11.5	87
Lehigh	3-pt APR	7.7	25.6	63.9	94.2	363	5.2	77
Luzerne	3-pt APR	19.3	51.3	80.3	98.0	1,145	21.0	400
Lycoming	3-pt APR	24.5	56.9	82.2	98.5	858	12.2	409
McKean	3-pt APR	35.8	71.7	92.6	99.1	1,276	13.7	542
Mercer	4-pt APR	6.1	22.4	56.1	92.2	1,145	28.9	128
Mifflin	3-pt APR	30.6	58.5	83.1	98.2	504	26.0	150
Monroe	3-pt APR	31.0	63.6	88.9	99.0	583	23.7	232
Montgomery	Special	8.8	30.4	60.3	94.6	204	0.0	93
Montour	3-pt APR	9.6	29.5	61.0	97.3	146	8.1	37
Northampton	3-pt APR	12.7	38.3	73.3	98.1	371	5.6	107
Northumberland	3-pt APR	8.6	28.4	59.6	94.0	384	7.1	84
Perry	3-pt APR	20.4	42.8	74.3	97.2	1,477	20.0	245
Philadelphia	Special	0.0	0.0	50.0	100.0	2	4.3	2
Pike	3-pt APR	40.3	73.5	92.9	99.8	506	17.0	395
Potter	3-pt APR	28.2	64.2	89.6	99.3	1,362	19.4	479
Schuykill	3-pt APR	17.0	44.1	75.9	97.2	984	13.2	243
Snyder	3-pt APR	12.5	38.8	73.0	96.2	289	12.0	75
Somerset	3-pt APR	22.8	49.9	77.1	96.9	943	9.0	178
Sullivan	3-pt APR	24.7	57.7	86.7	98.6	788	9.8	338
Susquehanna	3-pt APR	23.2	57.4	87.3	99.2	1,130	12.5	271
Tioga	3-pt APR	21.2	53.5	84.5	98.5	1,922	11.5	602
Union	3-pt APR	18.0	42.7	70.4	96.8	433	21.2	137
Venango	3-pt APR	16.0	44.6	78.0	97.3	1,766	8.8	297

(*Continued*)

County	Regulation[b]	No. antler points of subadults[a] ≤1	≤2	≤3	≤4	*n*[c]	Protected adults	*n*[c]
Warren	3-pt APR	27.7	60.8	87.9	98.7	2,249	12.4	668
Washington	4-pt APR	7.5	28.4	63.8	94.6	1,539	17.4	236
Wayne	3-pt APR	32.3	66.3	91.7	99.6	920	10.4	327
Westmoreland	4-pt APR	13.6	37.5	65.7	95.6	1,074	22.5	191
Wyoming	3-pt APR	15.8	50.7	80.8	98.2	609	9.3	172
York	3-pt APR	8.4	35.1	67.9	97.3	784	7.0	158

[a] Right or left antler with greater number of points.
[b] Definitions for antlered deer legal for harvest: at least 3 points on 1 antler (3-pt APR), at least 4 points on 1 antler (4-pt APR), and at least 1 antler 7.6 cm long (Special).
[c] No. deer examined.