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Abstract: ThePennsylvaniawhite-taileddeer(Odocoileusvirginianus)herdhasincreaseddramaticallyinthelastseveral despite greatly increased harvests. The high statewide deer density (11+ deer/kmz) causes serious losses to agricultural production, forest regeneration, and diversity of forest flora and fauna. High deer numbers are associated with an exc number of vehicle-deer accidents, and is implicated in the rapid increase in the incidence of Lyme disease in humans. C efforts to reduce deer densities locally and statewide (extended antlerless harvest seasons and special farm hunts) are not solving the damage problem. Other solutions should be considered, such as increasing the bag limit of antlerless deer, increasing hunting willingness to harvest more deer through hunter education programs, resolving land access problems, and developing m appropriate deer management units. Deer managers must be aware of the limitations of conventional harvest strategy to resolving deer damage problems, and of the need for improvisation to meet management needs.

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The restoration of white-tailed deer populations in the eastern United States from near-extinction in the late 1800s is agreatwildlifemanagementsuccessstory(Halls 1978, Downing 1987). However, deer populations continued to increase in many northeastern states after protection, and reached levels in the 1920s and 1930s that resulted in damage to forestry and agriculture, and with severe winters, deer starvation (Marquis 1975, Mattfeld 1984, Shrauder 1984). Deer populations have continued to increase in some northeastern states despite increasing numbers of hunters and more liberal harvest regulations (Townsend 1987).

Consequently, deer populations in some areas have exceeded biological carrying capacity (number of deer the land can support in good physical condition over an extended period of time) and cultural carrying capacity (maximum number of deer that can coexist compatibly with local human populations) (Ellingwood and Caturano 1988). In addition to damage to forestry and agriculture, too many deer results in damages to the vegetation of homeowners, state parks, national monuments and historic sites, reduced biodiversity, and increased numbers of vehicle-deer accidents.

At the same time, many hunters believe that there are too few deer. The difficulty of managing deer numbers to satisfy a diverse citizenry with differing perceptions of "too many" and "too few" deer is intensifying, and is exacerbated by the emergence of animal rights groups that decry any harvest of wildlife, for any reason. The issue of deer management is now highly polarized in many northeastern states. Agencies responsible for deer management are under intense pressure to resolve these diametrically opposed demands for deer management with an integrated, responsive program.

As a result of these actions, the deer herd grew quickly and was so overpopulated that there was a winter die-off of about
nomic-political arena, within which state resource agencies
100,000+ deer (Forbes et al. 1971). Limited antlerless (AL)
Technology and management expertise exist to solve thecrop damage became widespread by 1923. By 1938, the herd
problem of deer over-population. Unfortunately, the socioeco-
function, makes public or legislative support for solutions based on deer population control difficult to obtain. However, without a consensus resolution concerning deer population problems, the integrity of natural resource agencies and credibility of the wildlife profession are at risk.

In this paper, we review the history of deer population growth, management, problems, and harvest in Pennsylvania. We present the range of problems caused by high deer densities and discuss efforts to reduce deer numbers. Finally, we speculate on future problems that may hinder, and potential solutions that may help achieve acceptable deer densities in Pennsylvania.

HISTORY OF THE HERD AND CURRENT SIZE

Before settlement of Pennsylvania by Europeans, deer numbers were limited by extensive tracts of mature forest that supported moderate densities of deer, by predation (primarily by wolves [Cams lupus] and mountain lions *[Fells c*oncolor]), and by year-round harvesting by Native Americans (deCalesta 1992, Ellingwood and Caturano 1988, Marquis 1975, McCabe and McCabe 1984).

Following settlement of Pennsylvania by Europeans, deer numbers declined rapidly because of subsistence hunting for a growing human population, habitatchanges,andmarkethunting. Deer were nearly extirpated from the state by 1900. Although a deer harvest law was passed in Pennsylvania in 1721, there were no paid game wardens until 1896 (McCabe and McCabe 1984). The Pennsylvania Game Commission (PGC) began restocking deer from 1906-25, and a buck-only harvest law was passed in 1907. Extensive logging between 1890 and 1930 resulted in excellent forage for deer (Dorio and Marquis 1986).

deer harvest seasons were held occasionally between 1923-56 usually in the face of severe pressure against "doe hunting" (Pa. Game Comm. 1991). By 1950, the herd was substantially reduced by increased harvest and heavy winter starvation losses. Following the 1950 population low, the herd again began to build, and the PGC instituted annual AL seasons during 1956 in an attempt to keep the herd in check.

Despite the AL harvests the herd continued to increase, and in the 1960s the PGC established a deer management policy that included collecting carrying capacity data and emphasizing hunter education programs on deer management. Studies on carrying capacity resulted in the 1979 adoption of a system for projecting overwinter deer density goals for each county based on estimates of forage available on forestlands. The average goal density of deer in Pennsylvania was set at 8 deer/kmz, which interestingly enough, is the estimated average deer density existing in North America before settlement by Europeans (McCabe and McCabe 1984:27). The current average deer density in Pennsylvania is a little more than 11 deer/ km2, or 380 over goal. Dramatic increases in availability of AL deer tags, designed to reduce the deer herd to goal density, did not result in anticipated reductions of deer numbers during the 1980s. However, the 1986-90 harvests seem to have at least stabilized overwinter deer numbers (Fig. 1). The current overwinter deer population is estimated to be about 761,000 deer, which is about 218,000 above management objectives.

PROBLEMS CAUSED BY DEER OVERPOPULATION

Most of the problems caused by the Pennsylvania deer herd are associated with economic damage to farm and forest crops. Increasingly, however, a human-health dimension is emerging. Vehicle-deer accidents and the incidence of Lyme disease are on the rise, and both are related to deer density. Another emerging problem involves aesthetics and ecology. Browsing by deer creates landscaping-homeowner problems; upsets the balance of natural vegetation at state parks, national monuments, and historic parks; and increasingly, is being associated with reduced diversity of vegetation and other wildlife species.

Agriculture is the leading business in Pennsylvania. Nearly 54,000 farms, with 3.3 million ha in production contribute $3.5 billion annually to the state's economy (Pa. Dep. of Agric., unpubl. data). Deer damage occurs on over 609'0 of these farms and losses are primarily to corn, hay-alfalfa, vegetables, soybeans, fruits, and small grains (Pa. Game Comm. 1982). In 2 separate surveys of its members, the Pennsylvania Farmers Association reported that 40% of farms experienced heavy or extensive damage from deer, with estimated total annual losses of $36-86 million (Vogel 1989). Solutions include shooting depredating deer and erecting deer-proof fences around highvalue crops.

Pennsylvania is the leading hardwood manufacturing state. About 90,000 employees, with an annual payroll of $2 billion,

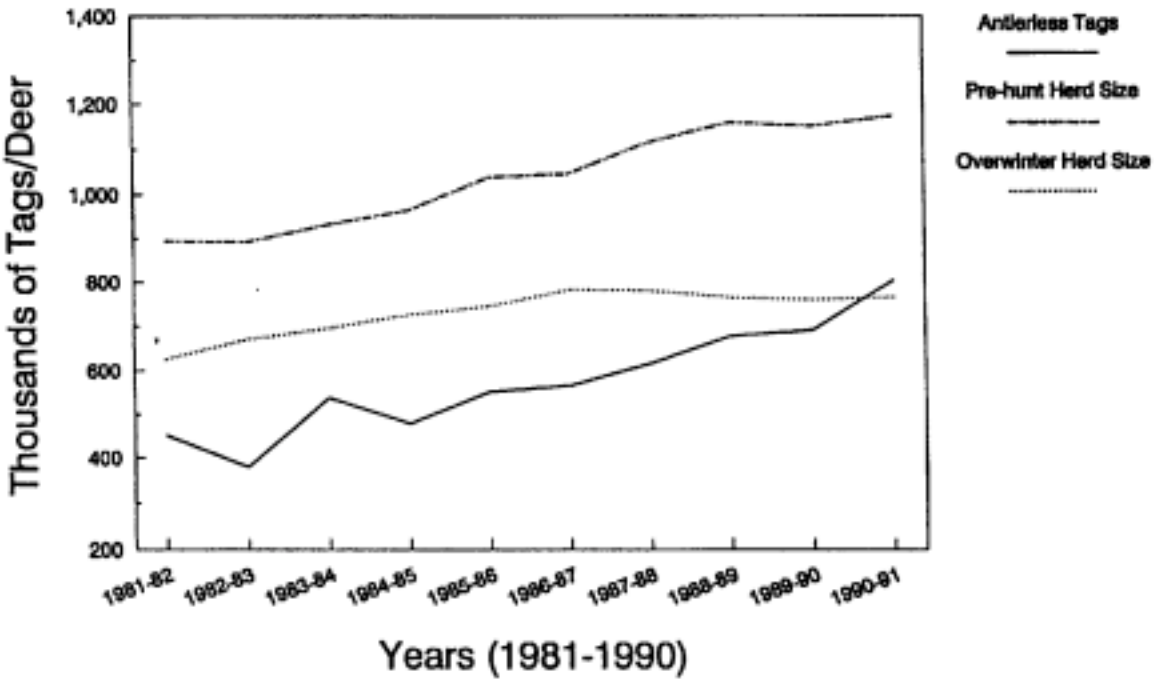

Fig. 1. Numbers of antlerless tags issued, prehunt deer herd size, and overwinter deer herd size in Pennsylvania 1981-90. Chronology hyphenated because presentation of tags issued and prehunt herd size is for fall of the same year, and overwinter herd size is for winter of following year.

process 1 billion board feet each year (Jones et al.1989). In the northeast and Pennsylvania harvested trees are replaced by natural regeneration, which comes from "advance regeneration" (seedlings of sufficient size and species composition to grow and replace harvested trees). Unfortunately, many commercially valuable hardwood species are also highly preferred foods of deer including oak *(Quercus spp.),* white ash *(Fraxinus americana),* and red *(Acer rubra)* and sugar maples *(A. saccharum)* (Marquis and Brenneman 1981, Horsley and Marquis 1983).

In northwestern Pennsylvania, hardwoodregeneration fails on as many as 50% of harvested sites because of excessive damage by deer. On other sites, regenerating forests are dominated by undesirable species such as beech *(Fagus grandifolia)* or black cherry *(Prunus serotina)* monocultures, that are vulnerable to insect predation and disease, and are ecologically undesirable (Marquis and Brenneman 1981). Studies in the northeast and Pennsylvania determined that it is difficult to regenerate sites with more than 7-8 deer/kmz (Alverson et al. 1988, Behrend et al. 1970, Tilghman 1989, Trumble et al. 1989). Annual losses to foresters from deer damage were estimated at$208 million annually in Pennsylvania (Vogel 1989).

Foresters spend $100-500+/ha toregenerate sites impacted by deer. Protection practices include the use of tubing, fencing, fertilization to speed up seedling-sapling growth, and herbicide-shelterwood treatments (Redding 1987).

Pennsylvania leads the nation in the number of deer killed annually by motor vehicles. This number steadily increased in the last decade, exceeding 42,000 reported accidents in 1990. This increase paralleled increases in deer numbers and interstate highway traffic volume (deCalesta 1990). An average vehicle repair bill from a collision with a deer is $1,000-2,000, representing over $40,000,000 in losses alone in 1990. Also, 1,716 people were injured in vehicle-deer accidents in 1988 (Pa. Dep. of Transp., unpubl. data). No effective and economical solution exists for this problem; however, it is apparent that a smaller deer herd would result in a direct reduction in the magnitude of the problem.

Another humdn-health issue related to high deer densities is Lyme dissease, a degenerative arthritic affliction that can also lead to kidney and heart failure. The white-tailed deer has been identified as a major vector of this disease which is transmitted by the deer tick *(Ixodes dammini)* (Booth 1991). The incidence ofLymediseaseinPennsylvania has increasedrapidly.Ninetyone **cases were reported in** 1988, 347 in 1988, and 450+ in 1989 (Pa. Dep. of Public Health, unpubl, data). Preliminary research suggested a correlation between high deer densities and incidence of Lyme disease (Anderson et al.1987). Elimination of deer from an island off Cape Cod was associated with an 80% reduction in numbers of deer ticks (Booth 1991). More research is needed to clarify the relationship among deer, deer ticks, prevalence of Lyme disease in humans, and the' m human epidemiology following reductions in deer herd

Because of their extensive browsing pressure, destroying and/or altering vegetation at many state national monuments, and historic sites. Examples from sides of Pennsylvania include Presque Isle State Park west (O. Derr, pers. commun.) and Gettysburg National tary Park/Eisenhower National Historic Site in the east, deer density varied from 25-44/km2 (Storm et al.1989). agers of these public lands realize that controlled deer h could help solve the problem, but find it impossible to get support and acceptance for that solution.

Biological diversity of wildlife and vegetation on and priv lands is being negatively impacted by ex deer **browsing understory** vegetation. The reduced diversity of vegetation affe wildlife indirectly by reducing habitat quality. Papers in 2 rec Pennsylvania conferences ha discussed aspects of this probl (Finley and Brining 1989, LaBar 1987). Declines have occurred understory p species richness and abundance (herbaceous woody vegetation etation) in areas with high deer densi (deCalesta, unpublished data, Doric, and Marquis 1986, Redd 1987). The loss reduction of understory and shrub layer vegetation adversely a many wildlife species because of the removal of protectcover, sources, and nesting sites (Dorio and Marquis 1986, Wunz Yahner 1989, Yahner et al.1987). Species known to be adve affected include snowshoe hares *(Lepus americanus),* ruffed g *(Bonasa umbellus),* wild turkeys *(Meleagris gallopavo),* wooc *(Philohela minor),* and various songbirds including pil woodpeckers *(Dryocopus pileatus),* indigo buntings *(Passe cyanea),* cerulean warblers *(Dendroica cerulea),* wood pe *(Contopus* virens), phoebes *(Sayornis phoebe),* and cedar waxv *(Bombycilia cedrorum).* In a 10-year study of the impact of de forest vegetation and wildlife, densities above 8 deer/Ian z associated with reductions in diversity of woody vegetation, forbs songbirds of 80%a, 8%, and 14%, respectively (deCalesta, un data).

CONTROL EFFORTS

Most efforts to control the negative impacts of deer on wildlife and vegetation are directed atprotectingvegetation excluding devices (i.e., fences, tubes, repellents), deferring deer da onto other crops intentionally planted as lure crops, overwhelming with a surplus of food, or reducing deer population density l recognized damage threshold levels. Harvesting deer by hunting only viable population reduction technique. Use of reprodu inhibitors or reintroduction of natural predators are not fe (Ellingwood and Caturano 1988, Matschke et al. 1984).

In all states, including Pennsylvania, the primary manage technique to control deer damage is regulated harvest by lic hunters (Denney 1978, Matschke et al. 1984). Ex

cluding devices are often utilized on individual land ownerships (public and private) on a case-by-case basis. However, such applications address only the symptom (deer damage) and not the cause (deer overpopulation), and thus provide only stopgap rather than enduring resolution of the problem. In this paper we limit discussion to population reduction techniques at local and countywide levels in Pennsylvania.

Pennsylvania has experienced yearly increases in the number of bucks and antlerless deer harvested since the 1950s. The goal and overwintering deer densities were established and tracked beginning in 1981. The picture has been of unchanging goal density and increases in overwinter density of deer statewide (Fig. 2). Comparison of deer harvest with deer numbers (Fig. 3) reveals the reason for this apparent inconsistency. Preharvest herd size has increased in spite of increased harvests because deer reproduction is keeping deer numbers slightly ahead of mortality induced by hunting, automobile collisions, and other causes.

Since the mid-1950s, the PGC has attempted to increase totaldeer harvestby issuing increasing numbers of tags allowing hunters to harvest antlerless (AL) deer during a 3-day AL hunt held after the regular buck hunt. These tags could be used only if hunters were unsuccessful during the general buck deer season. In 1983, the PGC did not sell all the tags for AL it had allocated, and this trend continued for several years. Apparently, a saturation point was reached with hunters at about 500,000 AL deer tags. The herd was still increasing, so the PGC initiated a "bonus" AL deer program in 1988. Under this system, AL deer tags (issued and sold on a county basis) remaining unsold after an initial sales period of 3 weeks became available for purchase by anyone with a Pennsylvania deer license. Hunters with bonus tags could harvest an antlerless deer during the AL season even if they had harvested an antlered deer during the regular season.

The bonus system continued the upward trend in numbers of deer harvested. The record season of 1990-91 produced 415,561 deer (170,101 bucks and 245,460 AL deer) harvested by over a million hunters, representing an increase of 158% over the 1983 total Pennsylvania deer harvest of about 263,500. Although much of this increase relates to increased harvest of AL deer, it is important to note that the buck harvest was up as well (Fig. 3). These 415,561 deer harvested represented 35% of the estimated statewide prehunt deer population of 1.2 million. With this heavy harvest the deer density has stabilized but it remains at 38% above the target goal density. An additional 218,000 deer must be harvested to achieve statewide goal density for 1990. Only 6 of 66 counties had deer densities at or below goal density in 1991. The PGC can extend the 3-day AL deer harvest season if the AL deer harvest is deemed inadequate, and there was a 1-day extension in 1990.

The PGC issues permits for farmers to shoot depredating deer. A survey of farmers by the Pennsylvania Farmers Association indicated that 38% of the respondents used this approach to reduce deer damage (Eckhaus, pers. commun.).

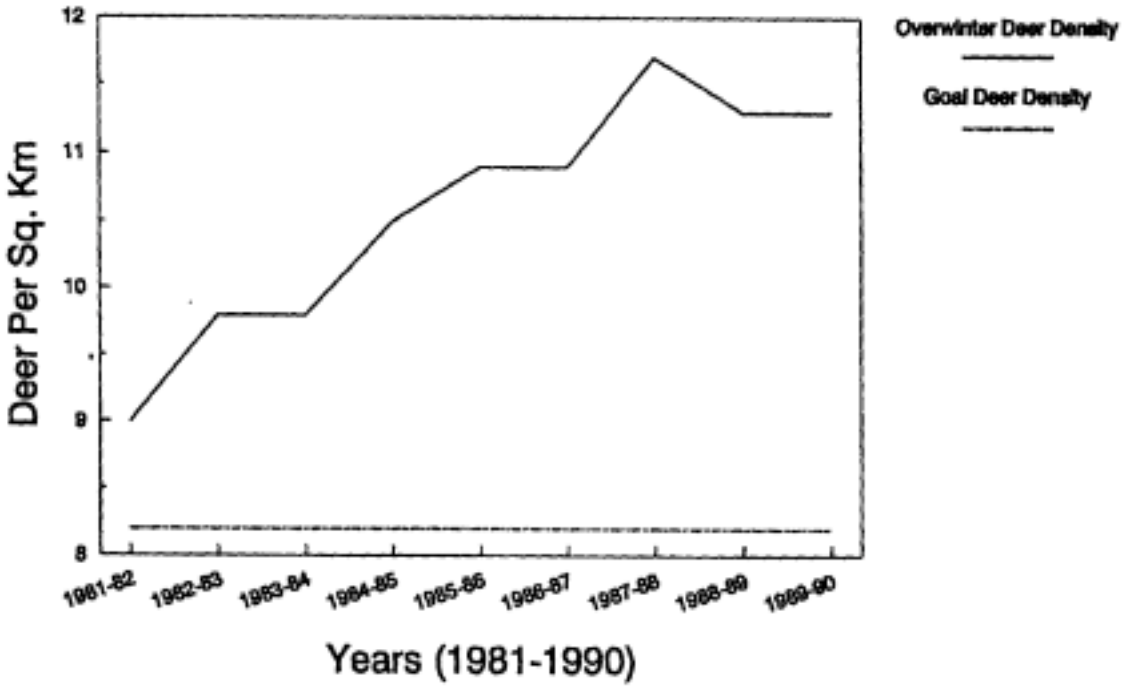

Fig. 2. Statewide goal deer density and overwinter deer density in Pennsylvania 1981-90. Chronology hyphenated because presentation of goal density is for fall, and overwinter deer density is for winter of following year.

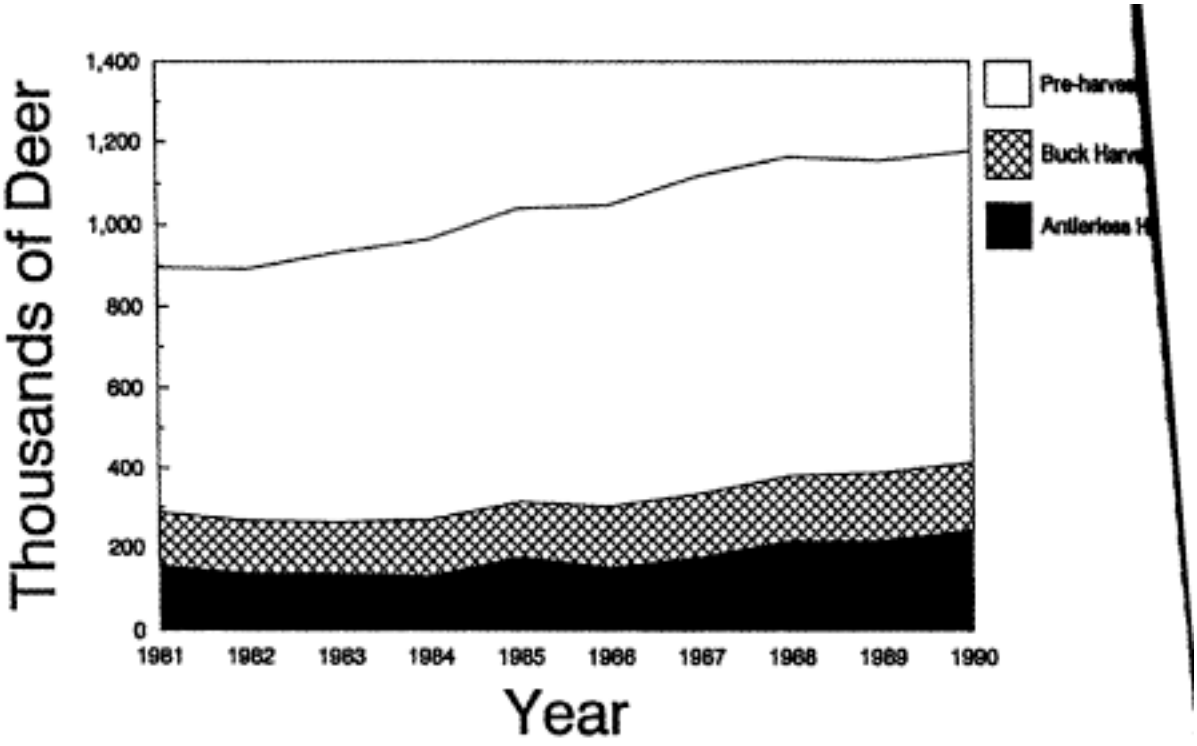

Fig. 3. Numbers of deer before harvest, bucks harvested, and antlerless deer harvested in Pennsylvania, 1981-90.

Some individual farmers shot in excess of 100 deer in an effort torelieve crop damage. This approach is not popular with many farmers because it does not provide long-term relief and requires too much of their time (Erickson and Giessman 1989).

Deer damage continues at unacceptably high levels on farms, even when farmers shoot depredating deer and use exclusion fencing provided by the PGC, and with the increased statewide harvest fostered by the bonus program. In an effort to resolve the problem of deer damage to farms, the PGC initiated a "hot spot" deer-damage farm program in the 199091 deer season. The objective of the program was to direct hunters who had not filled their AL deer tags to hunt on hot spot farms during a special season in January. There were 63 5 farms in 52 of 67 counties enrolled in the 1990-91 program.

Based on the results of a survey of farmers, the program was moderately successful (Boyd 1991). An average of 5 deer was harvested per participating farm, but 24% of farmers indicated that no deer were taken on their farms. The primary dissatisfaction with the program was that too few deer were harvested. Most landowners said they would participate again, especially if improvements were made. Farmers indicated that enrolling more surrounding land in the program (perhaps working at the township level), and conducting the hunt when crop damage was occurring or when more deer were on the farm property would increase harvests. The main conjecture given by farmers for poor success was that adjacent or surrounding land not under the farmers' control was posted to hunting, and that deer merely retreated into these havens when the hunt began. Despite these problems, the PGC has decided to continue the program and extend the season length from 1 32 days in the 1991-92 season.

Can hunters sustain the current (or a slightly higher) le of harvest to reduce the herd to goal densities at local statewide levels? There are some disturbing signs (Fig. 4). The number of resident hunters is declining. The marked decline; hunter education trainees forebodes an eventual additional drop in resident hunter numbers. The pre-1985 drop in nonresident hunters has reversed itself, but nonresidents comprise less than 8% of hunters in Pennsylvania. With fewer hunters in The future to keep pruning the deer herd, it may be impossible achieve goal density under current harvest regulations.

We perceive a trend that may hinder the willingness hunters to help bring the state's deer herd to goal densities There is a growing attitude among many hunters that there a not nearly as many deer in Pennsylvania as there were yea ago. There is no reason to believe this if one reviews the PC deerpopulationestimates,harvestfigures,vehicle-deeraccide numbers, and deer-damage complaints. It is possible that de numbers are declining in localized areas, (i.e., some popul state game lands which are often heavily hunted), a trend fluc will probably continue as more private land is posted agair hunting. However, this perception by hunters is a serious three to deer management, and it may become more entrenched deer numbers drop towards goal density. Dealing with fluc problem will require an aggressive hunter education progra such as that proposed for New York by Decker and Connel (1990).

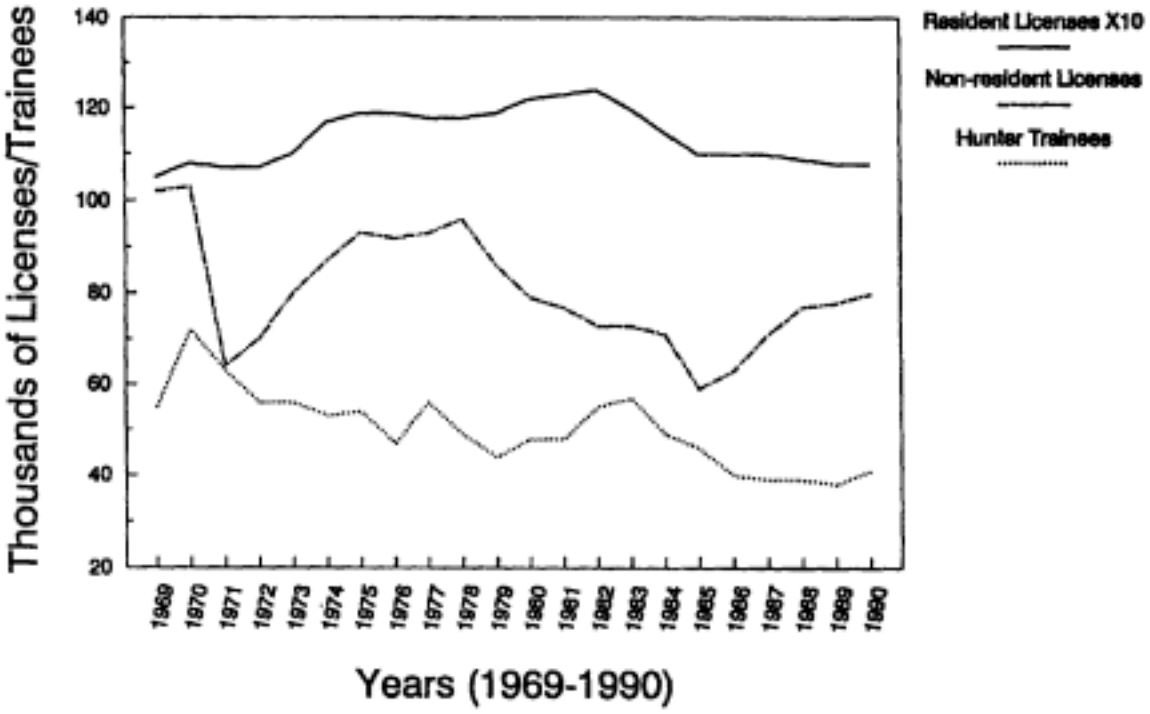

Fig. 4. Numbers of resident licenses sold, nonresident licenses sold, and persons taking hunter-training courses in Pennsylvania, 1969-90. Numbers of resident licenses sold should be multiplied by 10 for actual number.

PROGNOSIS

The Pennsylvania deer herd may be stabilized for the time being. That is the good news. The bad news is that deer numbers appear to be well above biological and cultural carrying capacities. Damage is occurring at relatively high levels to commercial and natural resources. The problem is complex, and will require considerable time and effort to resolve.

The only way to reduce the large-scale, serious problems caused by high deer densities in many states is to reduce the overall deer density to the target density of 8/kml through adequate deer harvests (Ellingwood and Caturano 1988). Because it is not likely that resident hunter numbers will significantly increase over current numbers in Pennsylvania, the solution to increased deer harvests must be found in some combination of increased nonresident hunter participation, increased hunter success rates, and increased numbers of deer harvested per hunter. The possibility of increasing numbers of nonresident hunters through incentives such as reduced license fees is one approach.

Another candidate for increased harvest is improvement of the low success rate of AL deer hunters. In the past, this rate has been about 1 AL deer harvested for every 3 AL deer tags issued. However, during several seasons in the 1980s, the rate dropped to about 1 AL deer per 4 AL deer tags issued. Potential solutions aired by the PGC at "town hall" meetings included: (1) conducting the AL deer harvest during the regular buck season; (2) including Saturday hunts within AL seasons (now held only during weekdays); (3) allowing Sunday hunting (currently illegal in Pa.); and (4) extending the length of the AL deer season.

One option for increasing AL harvest not considered by the PGC is to let individual hunters harvest more than 3 deer. Currently, this is the maximum number of deer a hunter may harvest, and it is restricted to the few individuals who get second bonus tags. Other eastern states allow hunters to harvest many more deer. New Jersey recently achieved its harvest objectives for 60 of 61 management units after greatly increasing the number of deer that can be harvested by a hunter (from 3 to 20 deer) and season length (from 36 to 98 days) (Burke and Ferrigno 1989). Other possibilities include holding a special AL season *before* the regularbuck season, opening AL deer and buck seasons on the same day (when the greatest number of hunters is afield), and allowing hunters to harvest a buck and one or more AL deer on the same day.

Another aspect of the inadequate harvest dilemma is access of hunters to lands where deer population density is too high. Posted land prevents adequate harvest of deer in the general area, serving as a haven for deer during hunting season, and exacerbating deer damage problems on surrounding lands. In the northeast United States, most land is in private ownership and may be posted against hunting. Although no specific data are available, it is generally perceived that the acreage of land posted increases each year.

Potential solutions to the access problem include: (1) expanding and improving landowner education-public **rela**

tions programs; (2) providing access *incentive or* disincentive programs (including tax relief for landowners who keep their land open to hunting and additional taxes levied against those who do not); and (3) requiring landowners who post their land to fence their property, thus providing relief to surrounding landowners from depredating deer. All but the first of these solutions are politically sensitive and unlikely to be implemented. Unfortunately, these are the same solutions with the best potential for success.

A last problem needs to be addressed to deal more successfully with the hot spot hunting program. This program needs to be improved and expanded to include more farms. If improvements and expansion are not possible, perhaps a new approach (i.e., allowing farmers to issue kill permits to designated people for deer harvest *when* the problem is occurring on their farms, as proposed by the Pa. Farmers Association) could be implemented.

The proposed solutions to Pennsylvania's deer problem will be only partly effective under the current framework of county deer management. Under this system, deer are managed county-by-county irrespective of the factors that most influence their density and damage (i.e., habitat, access, and pattern of land ownership). Pennsylvania is the only state that manages its deer by county management units, and it has significantproblems with deer damage to farms, forests, and automobiles--all because there are too many deer. The PGC was preparing to switch to noncounty-based management units (Sheffer 1987), but has since tabled the plan (Palmer 1989).

Effective solutions to the problems caused by high deer densities in Pennsylvania need to be developed and implemented. The problems are extensive, growing, and trying the patience of landowners and resource managers. The slow rate of progress has opened the door to solution by legislative intervention. We firmly believe that deer management by legislation is not the way to proceed. Deer management should be conducted by an authorized, public, professional wildlife agency with wildlife biologists *and* interested parties having input in the decision-making process. To this end, the PGC must remain firm in its efforts to resolve this issue in a biologically and socioeconomicallysoundmanner. Professional biologists, resource managers, and interested organizations should continue to provide input and support for those efforts.

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