Kinzua Quality Deer Cooperative

Interim Report: Deer Density and Impact 2009

Executive Summary: Deer density for the entire KQDC Project Area in 2009 (15.3 deer/square mile) continued the upward climb begun in 2007. Similarly, deer impact at coarse and fine grain levels also increased in 2009. Increases in deer density and impact were not significantly higher than in 2008, but were significantly higher than density and impact at the lowest levels in 2006. The trend in increasing density and impact was associated with reductions in DMAP licenses for the Project Area: once number of licenses dropped below 550, density and impact climbed. Abundance of all indicator species has increased since 2003 when antlerless licenses increased. Density in 2009 remained low and at target density, and impact remained in the light-moderate classification, but the trend for increasing density and impact may require increasing number of DMAP licenses to keep both within target ranges. Whether increasing DMAP licenses from 550 in 2008 to 800 in 2009 will halt increases in density and impact will be evaluated in 2010.

Density and impact in 2009 were significantly higher on the Private Sector (Bradford Watershed, Collins Pine, Forestry Investment Associates and RAM forest Products) than on the Public Sector (Allegheny National Forest). These differences persisted for both DMAP Units (DMAP Unit 134 was for the portion of the Demonstration Project north of state highway 59, DMAP Unit 135 was for the portion south of 59). Unlike on the Private Sector, density and impact on the Public Sector (ANF) have remained stable since declining to target level in 2006. The hypothesized reasons for differences between Public and Private Sectors are: 1) hunter access and familiarity with road systems are better on the Private Sector; 2) hunters make disproportionate use of Unit 2F and DMAP licenses on the two Sectors. The same number of DMAP licenses has been available to both DMAP Units, but the southern Unit (DMAP 135) is less than half the size of the northern Unit. Allocation of future DMAP licenses might better be allocated on a 60:40 split for North and South portions, respectively, to reduce density and impact on the Private Sector, especially north of highway 59. Restoring Unit 2F license numbers to pre-2005 levels (44,000 as opposed to 28,000 in 2009) might also help to keep density and impact within target levels.

Among ownerships, deer density was consistently highest on Collins Pine lands. Impact on Collins Pine lands was not higher than on other private forestlands, possibly because Collins Pine harvested a larger portion of its forestland (open overstory was significantly highest on Collins Pine lands) and provided more forage for a larger deer herd. By 2009, abundance of all indicator species, except beech, was highest on CP forestlands.

Introduction and Methods

Scales of Evaluation

As in the past, deer density and impact in 2009 are reported for the KQDC Project Area as a whole. As noted in previous years, because Allegheny National Forest (ANF) sites comprise ~ 54% of all sites, deer density and impact calculations for the Project Area are heavily influenced by ANF sites. Also, forest management and hunter access vary among the different ownerships. Beginning in 2008, density and impact were evaluated for individual ownerships (ANF, Collins Pine, Bradford Watershed, and Forest Investment Associates) and are reported at that scale for 2009 as well. Because forest management and hunter access are similar among private forestlands within the KQDC Project Area and differ from those on the ANF portion, Collins Pine and Bradford Watershed properties were combined as Private Sector unit (North), and Forest Investment Associates forestland was evaluated as a separate Private Sector unit (South) in the southern portion of the Project Area in 2009. Similarly, the ANF was evaluated north of highway 59 as a Public Sector (North) and south of state highway 59 as a Public Sector (South).

Collecting and Analyzing Deer Density Data

Methods for collecting and analyzing deer density in 2009 were identical to 2008, including separate analyses for the entire KQDC Project Area, for the four individual ownerships, and for the Public/Private Sectors north and south.

Density data were collected at 26 randomly-located sites within the Project Area (Fig. 1, Appendix 1) by trained personnel from the ANF (ANF), Collins Pine (CP) Forest Investment Associates (FIA), Keith Horn Consulting Foresters, and the Northeast Research Station, USDA Forest Service and by contracted consultants when there were not enough volunteers to get the job done.

At each site, deer density data were collected from four-foot radius plots spaced 100 feet apart along five 5,280 foot-long transects. Deer density data were obtained by counting pellet groups deer deposited over winter. Because deer numbers decline (deer mortality from hunting season, winter starvation/exposure) during the period of pellet group deposition (December–May), deer density estimates derived from uncorrected pellet group counts represent the average number of deer over winter (December-May). Because average density corresponds to the timeframe of high impact on tree seedlings, average deer density is the number referred to throughout this report, unless noted otherwise. Layout of transect lines, protocol for collection of deer density data, and analytical methods, including statistical tests, are provided in Appendix 1.

Deer Impact

Impact data were collected at 26 randomly-located sites within the Project Area (Fig. 1, Appendix 1) in 2009 according to methodology utilized in previous years. Impact data were collected by the same persons collecting deer density data and at the same time as deer density data. As with deer density, deer impacts were characterized for the entire KQDC Project Area and separately for the four largest ownerships, and for the Public/Private Sectors north and south.

At each site, deer impact data were collected from four-foot radius plots spaced 200 feet apart along five 5,280 foot-long transects. Deer impact data were obtained by characterizing levels 1-5 deer impact on six “indicator” tree seedling species. Because black birch and yellow birch are difficult to identify separately as seedlings, both were lumped into a “birch” category as a single indicator species. Layout of transect lines, protocol for collection of deer impact data, and analytical methods, including statistical tests, are provided in Appendix 1.

Canopy Closure

Germination and growth of indicator seedlings is directly influenced by the amount of light reaching the forest floor. With the high deer density extant on the KQDC area in the early years of the demonstration project, foresters could only get acceptable stocking levels and diversity of desired seedling species by fencing sites that were to be final harvested or shelterwood harvested. Concern has been expressed that low regeneration success, as indicated by annual deer impact surveys on the KQDC may be partly the result of lack of opening of the forest canopy and lack of stimulus for seedlings to grow. Also, because some of the KQDC ownerships have been taking down fencing, opening previously closed harvested sites to browse and density surveys, differences in deer impact among ownerships may be/have been influenced by canopy closure.

Methods for collecting and analyzing deer impact data were amended in 2008 to incorporate evaluation of the impact canopy closure might have as a potentially confounding factor on deer browsing on regeneration. Methodology was developed to evaluate relative amount of canopy closure among the 26 sites. Canopy closure data were collected on the same four-foot radius plots used to collect deer impact data. Each of the 26 sites was classified on the basis of percent plots that fell under open or closed canopy. Protocol for collecting information on canopy closure is detailed in Appendix 1. Canopy closure data were collected in 2009, providing two year’s worth of this kind of data. As with deer density and impact data, canopy closure was calculated for the entire KQDC Project Area, for each of the four landowner groups, and for the Public/Private Sectors north and south.

Results and Discussion

As in past years, deer density varied considerably among sites in 2009 (Table 1). And, continuing the trend begun in 2007, overall deer density in 2009 was higher than the previous year.

Table 1. Deer/square mile per site per year 2002-2009 and antlerless licenses offered preceding fall.

Site	2002	2003	2004	2005	2006	2007	2008	2009
A	20.4	24.8	16.7	5.8	10.1	7.1	10.1	8.7
B	15.5	30.5	30.7	5.4	3.6	14.4	3.8	4.7
C	20.5	43.1	17.0	29.8	11.0	14.0	16.5	22.4
D	15.3	26.6	17.6	15.1	10.0	18.9	20.2	24.6
E	50.5	48.6	32.8	15.3	21.1	3.4	5.4	14.0
F	29.9	19.8	21.2	18.6	4.8	22.0	17.0	17.3
G	10.8	13.6	12.7	6.0	2.9	7.0	4.3	3.6
H	8.6	29.2	31.9	17.3	2.9	3.9	6.7	11.2
I	33.8	30.7	22.1	19.7	14.4	16.4	25.9	26.3
J	48.3	54.9	47.6	31.5	21.5	11.6	28.2	11.1
K	42.5	44.3	38.2	27.2	20.6	20.3	29.3	26.3
L	14.6	31.1	34.8	14.1	1.5	7.0	14.8	16.7
M	32.6	41.9	29.4	15.0	8.6	18.1	10.1	10.8
N	13.0	30.1	24.3	5.4	3.5	3.8	11.7	8.2
O	41.6	20.6	26.4	16.1	24.1	13.9	11.9	17.3
P	32.5	37.0	28.0	9.6	12.7	12.5	27.6	27.4
Q	37.3	19.5	17.3	12.7	9.9	13.4	5.3	2.7
R	13.4	12.8	10.9	6.0	3.4	5.4	6.8	4.3
S	28.7	32.6	12.1	3.2	11.5	8.0	5.6	4.1
T	27.7	21.4	8.3	11.7	6.5	6.0	3.0	8.7
U	17.8	6.4	20.9	7.1	16.9	20.1	24.6	20.2
V	36.7	20.4	28.7	4.9	20.7	11.0	21.1	24.6
W	15.2	14.7	25.6	7.1	13.1	12.4	17.9	22.2
X	47.5	33.4	38.2	22.8	19.9	21.2	29.2	25.6
Y*	-	-	-	26.0	9.9	10.0	12.5	20.1
Z*	-	-	-	20.4	16.1	14.9	18.2	16.2
Mean ± 95% C.I.**	27.3±3.3	28.7±3.0	24.7±3.7	14.4±1.4	11.6±1.8	12.7±1.2	15.0±1.3	15.3±1.3
DMAP Licenses***	0	0	3,000	3,000	700	150	300	550
Antlerless Licenses****	13,000	18,000	44,000	44,000	30,000	28,000	28,000	28,000

* = Sites added in 2005; ** = Confidence interval ± 95% confidence of containing true mean; *** = DMAP licenses offered preceding fall; **** = Antlerless licenses offered preceding fall. Antlerless licenses allocated by county prior to 2003; allocated by Wildlife Management Units 2003 and later.

ANF sites in **red**; Collins Pine in **green**; Bradford Watershed in **blue**; FIA in **purple**

Overwinter Deer Density: ***Entire Project Area***

Overwinter deer density for the 2 years preceding availability of DMAP licenses (2002 & 2003) was about double the desired level (10-15 deer per square mile)(Figure 1; Table 1). As DMAP licenses and hunter familiarity with the program increased, deer density was halved by 2005-2006. As deer density dropped after 2004, number of DMAP licenses available was reduced to prevent overharvesting the herd. However, the reduction in DMAP licenses may have been too aggressive: deer density rebounded 2007-2009 in response—at least partially—to low numbers of DMAP licenses.

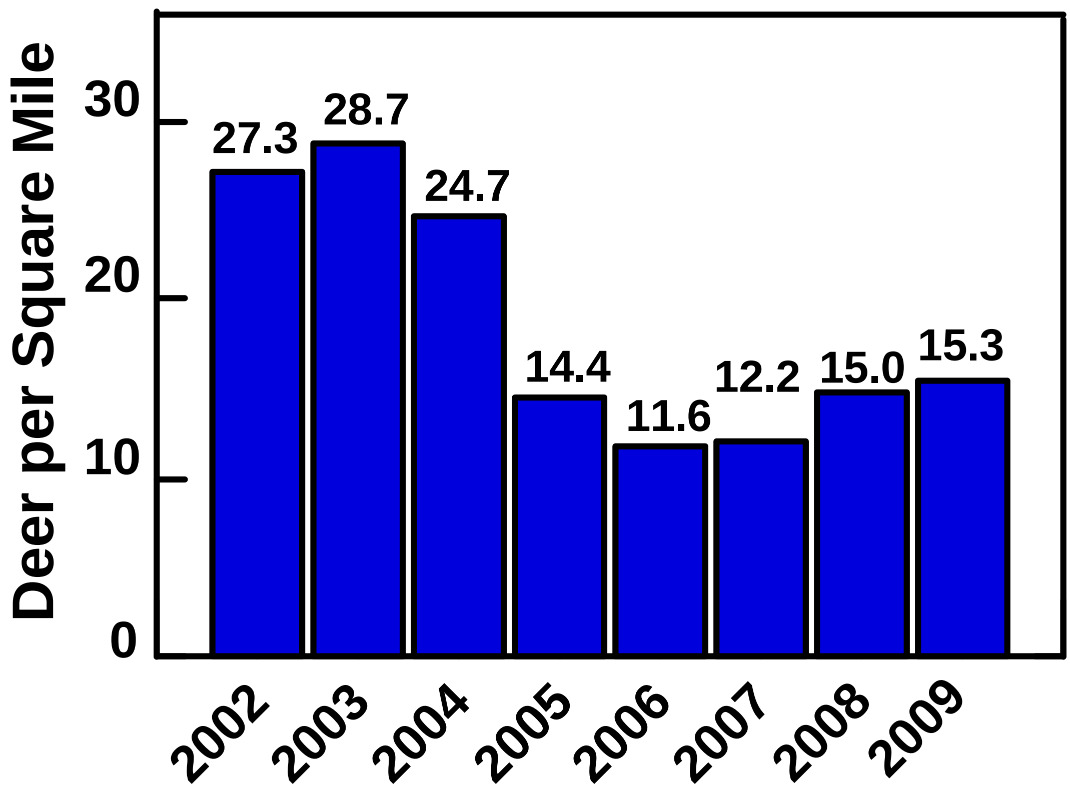


Figure 1. Changes in deer density 2002-2009—entire KQDC Project Area.

Deer density in 2009 was significantly lower (P<0.01) than the 2002-2004 period when the DMAP program was just getting underway. The gradual increase in deer density after DMAP license reductions began in 2007 culminated in the highest DMAP-era density in 2009: density was almost ~ 3.3 deer per square mile higher than in 2006 and 2007 when density was lowest on the Project Area; these differences were significant (P < 0.001). Deer density was higher in 2009 than in 2008, continuing the trend of increasing deer density begun in 2007 (Fig. 1) but the difference between the 2 years was not significant (P=0.68).

Overwinter Deer Density: *Public vs. Private Sectors*

Comparison of deer density between Public/Private Sectors (Figure 2) provides an evaluation of how hunter access and differential use of antlerless licenses can affect deer density (and impact). As noted above, hunter access historically has been better on the ANF (Public) Sector of the KQDC Project Area. Forest Service roads are known for the quality of construction and maintenance, for which the ANF is no exception. ANF roads are numbered and well-marked, and hunters have a history of high familiarity with the ANF road system. Therefore, it should be expected that a disparity in hunter pressure, and resulting deer density, would exist between Public and Private Sectors on the KQDC Project Area. With the exception of 2003, deer density was always higher ($P \leq 0.01$) on the Private Sector than on the Public Sector.

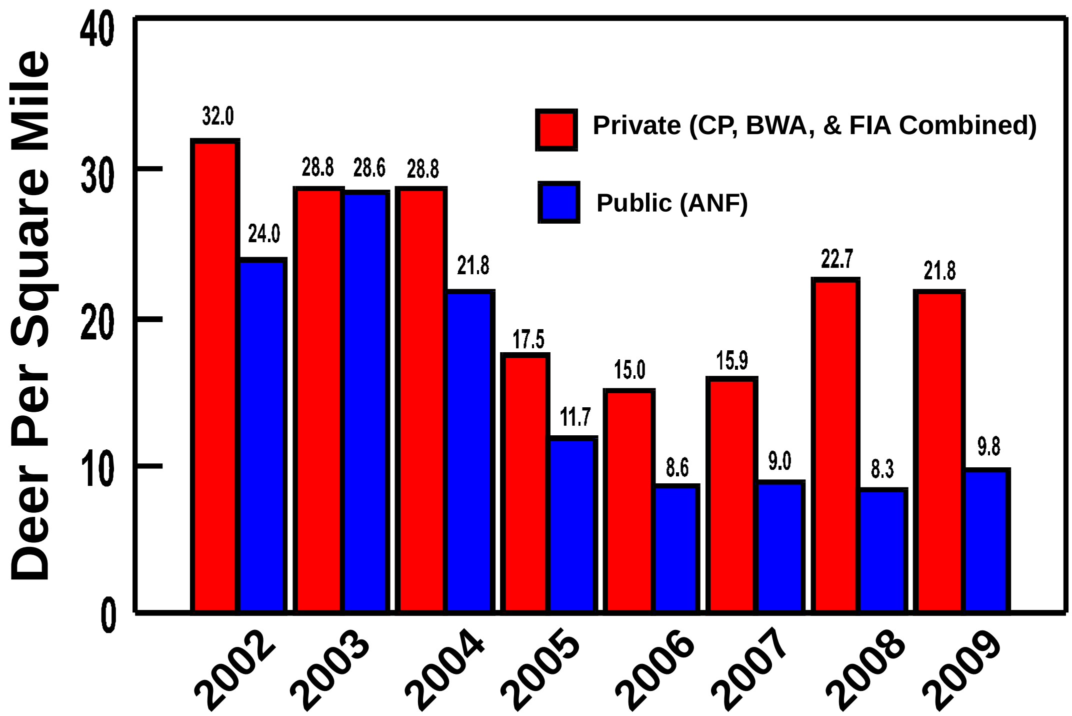


Figure 2. Changes in deer density 2002-2009—Private vs. Public Sectors.

For Private and Public Sectors, deer density declined significantly 2002-2006 ($P<0.01$). Deer density increased significantly 2007-2009 on the Private Sector ($P<0.01$) while remaining unchanged on the Public Sector ($P>0.46$).

Increase in deer density on the Public Sector from 2002 to 2003 may have been the result of high fawn recruitment and relatively low harvest in 2002 (Table 2). High density on the Private Sector in 2002 probably reflected the low hunting pressure prior to the start-up of the KQDC Project: subsequent significant declines in deer density may have reflected increased hunter awareness of road access and incentives to harvesting deer promoted by the KQDC Project.

Table 2. Changes in fawn recruitment and deer harvest 2002-2003 for Public and Private Sectors on the KQDC.

		Harvest*	
Year	**Fawn Recruitment****	**Public Sector**	**Private Sector**
2002	48.4%	69	8
2003	40.6%	126	44

* Deer harvested on the KQDC Project Area and brought to check stations
** Roadside routes used to calculate fawn recruitment intermix Private and Public Sectors: recruitment cannot be calculated separately for Public and Private Sectors

In 2003 the KQDC Project Area was partitioned into north and south areas (KQDC North and South) for administration of the new Deer Management Assistance Program (DMAP). North and south areas were divided by state highway 59 which bisected the KQDC Project Area from west to east. This Pennsylvania Game Commission (PGC) Program was initiated to provide forest landowners with additional antlerless licenses to reduce deer density and impact on forest regeneration. KQDC North (DMAP Unit 134) comprised 71.5% of the KQDC Project Area; KQDC South (DMAP Unit 135) comprised 28.5%. Comparison of deer densities between these two areas provides additional insights into impacts of access and deer management actions on deer density.

Differences in deer density between Public and Private Sectors for the entire Project Area were mirrored by differences between north and south areas (Figs. 3 & 4). Density was higher (P<0.1) on the Private Sector for all years on KQDC North (Fig. 3). Density was higher (P<0.09) on the Private Sector in KQDC South (Fig. 3) excepting 2002 (when there was no difference in density) and 2003 (when density was higher—P=0.03—on the Public Sector).

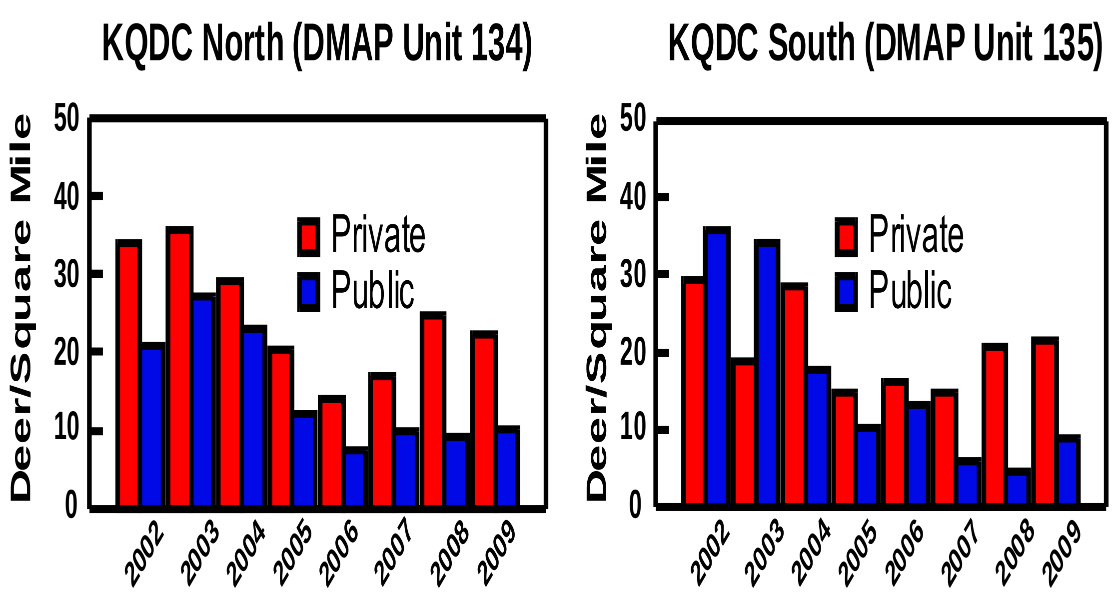


Figure 3. Comparison of deer density between Public and Private Sectors by DMAP Unit.

Comparison of deer density between KQDC North and South calculated separately for Public and Private Sectors reveals consistently different trends between Public and Private Sectors (Fig. 4). Whereas deer density declined 2002-2006 and remained low 2007-2009 on Public Sectors of KQDC North and South, it declined 2002-2006 then increased on Private Sectors of KQDC North and South. After 2005, availability of antlerless licenses (DMAP and Unit 2F) reached lowest numbers and then remained low (Unit 2F) or increased marginally (DMAP Units 134 and 135). Apparently, deer density was responding differently to lower availability of antlerless licenses after 2006 between Public and Private Sectors on the KQDC.

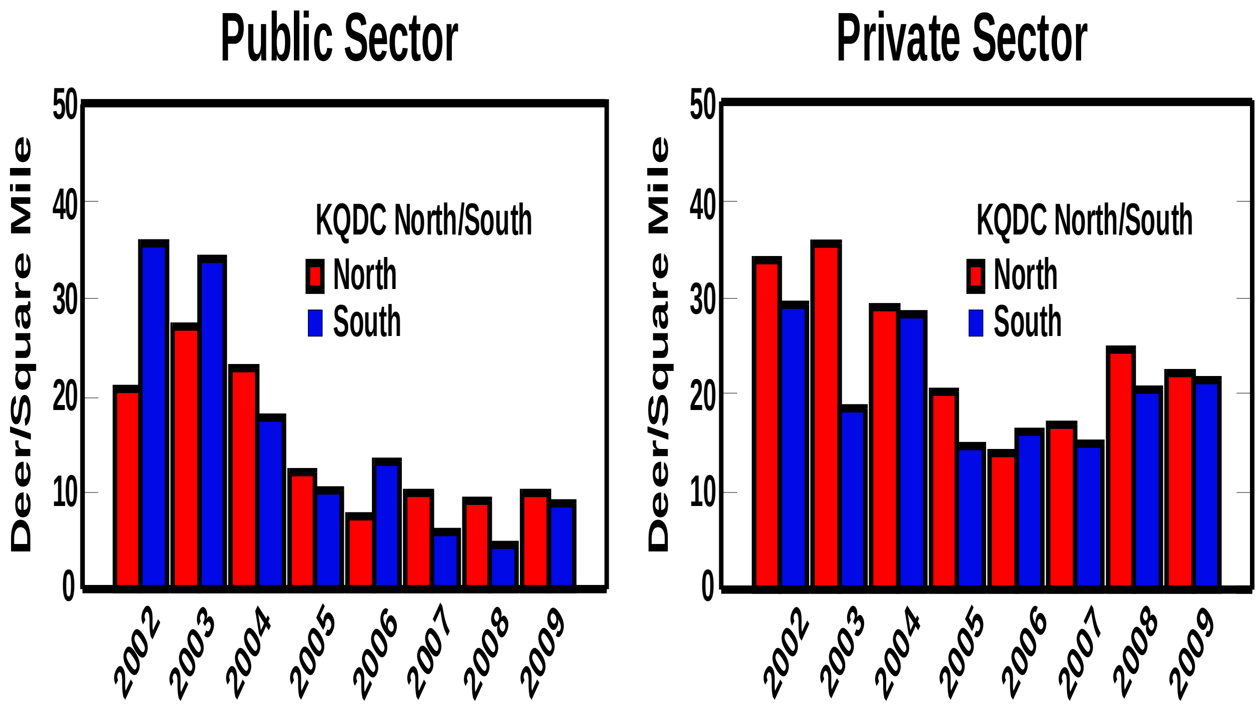


Figure 4. Comparison of deer density between KQDC North and South by Public and Private Sectors.

Prior to 2009, harvest reported to check stations for antlered and antlerless deer was disproportionately higher on Private Sectors than on Public Sectors in KQDC North *and* South. Harvest reported to check stations in 2008 for antlered deer was disproportionately higher on the Public Sector (Fig. 5) and disproportionately lower on the Private Sector. However, while harvest for antlerless deer was disproportionately higher on the Public Sector in KQDC North as in previous years, it was proportionately equal between Public and Private Sectors South. Overall, disparities in deer harvest between Public and Private Sectors contributed to the increase in deer density on Private Sectors and maintenance of low density on the Public Sector. The impact of similarity of harvest between Public and Private Sectors within KQDC South on deer density was minimized by the low harvest of antlerless deer in 2008.

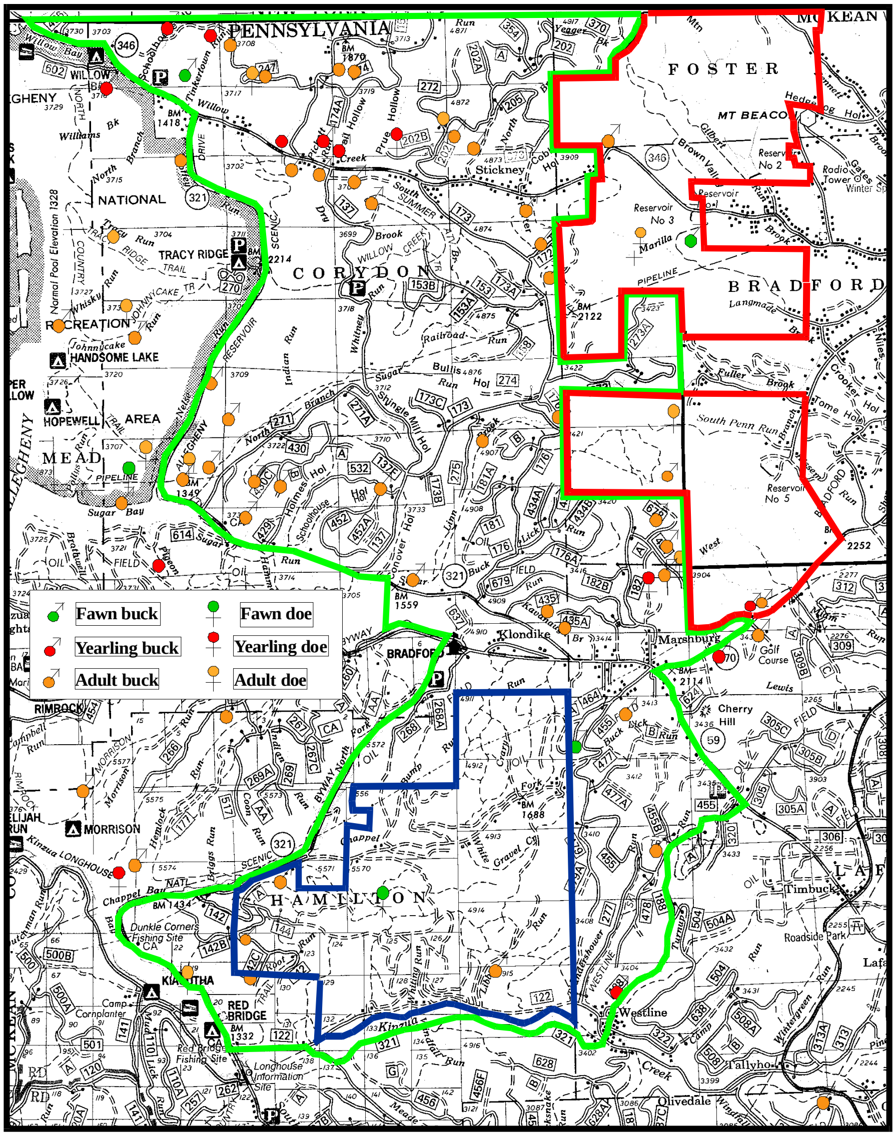


Figure 5. Known locations of deer harvested and brought to check stations on the Project Area in 2008. Area enclosed in green = Public Sector (ANF); area enclosed in red = Private Sector North (BWA & CP); area enclosed in blue = Private Sector south (FIA).

Impact of Antlerless and DMAP Programs on Density: Entire Project Area

Overwinter deer density seemed to be jointly influenced by numbers of DMAP and Unit 2F antlerless licenses, fawn recruitment, and deer harvest/winterkill (Table 3)—all from the prior fall-winter-spring. Initial and greatest reductions in deer density came in years following highest number of DMAP and Unit 2F licenses. Deer density began to climb from its low point in 2006 after large reductions in DMAP and Unit 2F licenses.

Table 3. Relationship between overwinter deer density and recruitment, harvest/winterkill and DMAP, McKean County, and Unit 2F antlerless licenses the preceding year for entire KQDC Project Area.

Year	Overwinter Density (as deer/mile^2)	Recruitment, Year Before* as % and as (deer/mile^2)	Harvest & Winterkill, Year Before** (as deer/mile^2)	DMAP Licenses, Year Before	Unit Licenses*** Year Before
2002	27.3	n/a	n/a	0	13,000
2003	28.7	48.4% (13.3)	11.9	0	18,000
2004	24.7	40.6% (11.8)	15.8	3,000	44,000
2005	14.4	23.7% (5.9)	16.3	3,000	44,000
2006	11.6	34.0% (4.9)	7.8	700	30,000
2007	12.2	42.4% (4.8)	3.8	150	28,000
2008	15.0	28.2% (3.6)	1.4	300	28,000
2009	15.3	50.0% (7.5)	7.2	550	28,000

* Recruitment rate calculated as: (Σ fawns counted roadside counts/ Σ antlerless and antlered adult (non-spotted) deer counted in roadside counts) (overwinter density) from previous year

** Harvest & Winterkill (combined) calculated as: ((Overwinter density previous year) (recruitment rate previous year) + overwinter density previous year) – overwinter density current year

*** For 2002 and 2003 prior years' Unit licenses were issued for McKean County; for subsequent years licenses were issued for Unit 2F, comprising 7 counties.

When harvest and winterkill combined (as deer/mile^2) exceeded fawn recruitment (as deer/mile^2) from the preceding fall, deer density declined from the preceding fall, and when harvest and winterkill were less than recruitment of the preceding fall, deer density increased from the preceding fall. For example, the increase in deer density from 2007 to 2008 (~23%) reflected the disparity between recruitment and harvest/overwinter kill: recruitment was more than double harvest/winter kill. The tiny increase in deer density from 2008 to 2009 reflected the cancelling effect on recruitment of harvest/winterkill, which was slightly lower than recruitment.

When number of available DMAP licenses was less than or equal to 550, deer density the following spring increased from the previous year's level. Conversely, when DMAP licenses available equaled or exceeded 700, deer density declined from the previous year's level.

Contributing to the higher harvest/winter kill in 2008-2009 was the increase in DMAP licenses and much better hunting conditions—there was snow cover, but not too deep—the entire rifle season, visibility was good, and temperature was in the 20-30s.

Prior to 2003, antlerless licenses used to harvest deer on the Project Area were issued for McKean County as a separate management entity. The increase in antlerless licenses issued between 2001 and 2002 (which would have affected deer density in the following springs of 2002-2003) was not associated with a drop in deer density. Rather, deer density increased slightly from 2002-2003 in spite of the increase in availability of antlerless licenses.

Concurrently with the advent of the DMAP program in 2003 the PGC switched from issuing antlerless licenses at the county level to issuing them at the Management Unit level: the KQDC Project Area is in Management Unit 2F which incorporates parts of seven counties (McKean, Warren, Venango, Forest, Elk, Jefferson, and Clarion). Whereas hunters could use antlerless licenses in 2002 and earlier only for McKean County, they could use their antlerless licenses after 2002 for any one of six counties, including McKean, likely diluting the number of licenses used to harvest a deer in McKean County (and on the Project Area).

The combination of 44,000 Unit 2F licenses issued in 2003 for the Management Unit encompassing the Project Area and the 3,000 DMAP licenses issued for the Project Area in 2003 was associated with a significant (P=0.05) drop in deer density in 2004. The same numbers of Unit 2F licenses and DMAP licenses were issued in 2004 and were associated with another significant reduction (P<0.001) of deer density, down from 24.7 deer/square mile in 2004 to 14.4 deer/square mile in 2005. Number of Unit 2F licenses and DMAP licenses dropped considerably in 2005 (DMAP licenses dropped from 3,000 to 700; Unit 2F licenses dropped from 44,000 to 30,000), but there was still an additional significant (P=0.006) drop in deer density, down from 14.4 in 2005 to 11.6 in 2006. The additional reductions in Unit 2F licenses (30,000 to 28,000) and DMAP licenses (700 to 150) from 2005 to 2006 were associated with an insignificant increase (P=0.394) in deer density from 2006 to 2007 over the entire Project Area. Increasing DMAP licenses slightly in 2007 (up to 300 from the 150 allocated in 2006) and keeping Unit 2F license numbers unchanged at 28,000 was followed by a significant increase (P=0.002) in density over the entire Project Area. Finally, increasing DMAP licenses from 300 in 2007 to 550 in 2008 while leaving Unit 2F licenses at 28,000 was followed by an insignificant (P=0.548) increase in density from 2008 to 2009.

Number of antlerless deer harvested with McKean County antlerless licenses in 2002 and number harvested with Unit 2F licenses in 2003 and brought to check stations were nearly identical—41 in 2002 and 43 in 2003 (Fig. 6). Number of antlerless deer harvested with DMAP licenses on the KQDC Project Area and brought to check stations in 2003 was 74, almost double the number harvested with Unit 2F licenses. In the following 2 years (2004 and 2005) numbers of Unit 2F and DMAP licenses declined, but still more deer were harvested with DMAP licenses and brought to check stations than were with Unit 2F licenses. Only after DMAP licenses dropped below 700 (2006-2008) were more antlerless deer harvested with Unit 2F licenses and brought to check stations than were harvested with DMAP licenses.

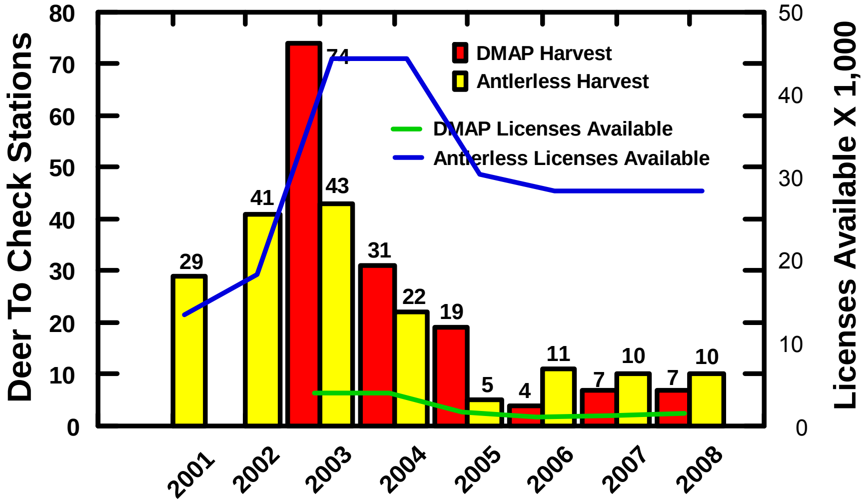


Figure 6. Comparison of number of deer harvested with DMAP and antlerless licenses with numbers of DMAP and antlerless licenses available to hunters.

In 2001 and 2002 when only McKean County antlerless licenses were available and DMAP licenses were not available, **5.7%** of hunters harvested two antlerless deer. In 2003-2008 when DMAP licenses were available, **8.2%** of hunters harvested and brought to check stations two or more antlerless deer. Since 2003, 142 deer were harvested with DMAP licenses and brought to check stations and 101 were harvested with Unit 2F licenses and brought to check stations.

During 2003-2008, of the 43 hunters who brought two or more antlerless deer to check stations, 31 harvested deer with DMAP Licenses and 12 harvested deer with Unit 2F antlerless licenses. Ten of the hunters harvesting two or more antlerless deer used only DMAP licenses, whereas only one of the hunters harvesting two antlerless deer used Unit 2F antlerless licenses. Of the seven hunters harvesting two or more antlerless deer with both a DMAP license and a Unit 2F license, five used the DMAP license first and two used the antlerless license first.

Impact of Antlerless and DMAP Programs on Density: Public vs. Private Sectors

The different responses in deer density to low availability of antlerless licenses (Unit 2F and DMAP) after 2005 between Public and Private Sectors provides an opportunity for gaining additional insights into impact of antlerless licenses on deer density. Individual roadside routes were not laid out within Private and Public Sectors, so fawn recruitment cannot be evaluated as a factor in differential response of deer density to harvest on Public and Private Sectors. However, locations of harvested antlerless deer from Public and Private Sectors of KQDC North and South provide additional insights into effectiveness of antlerless licenses to reduce deer density. Unequal distribution of antlerless harvest between Public and Private Sectors, especially on KQDC North, is graphically represented by Figure 7. Disparity also existed between North and South Private Sectors: although the North Private Sector was 1.5X the size of the South

Private Sector, 1.2 times as many antlerless deer have been brought to check stations in the South Private Sector than in the North Private Sector.

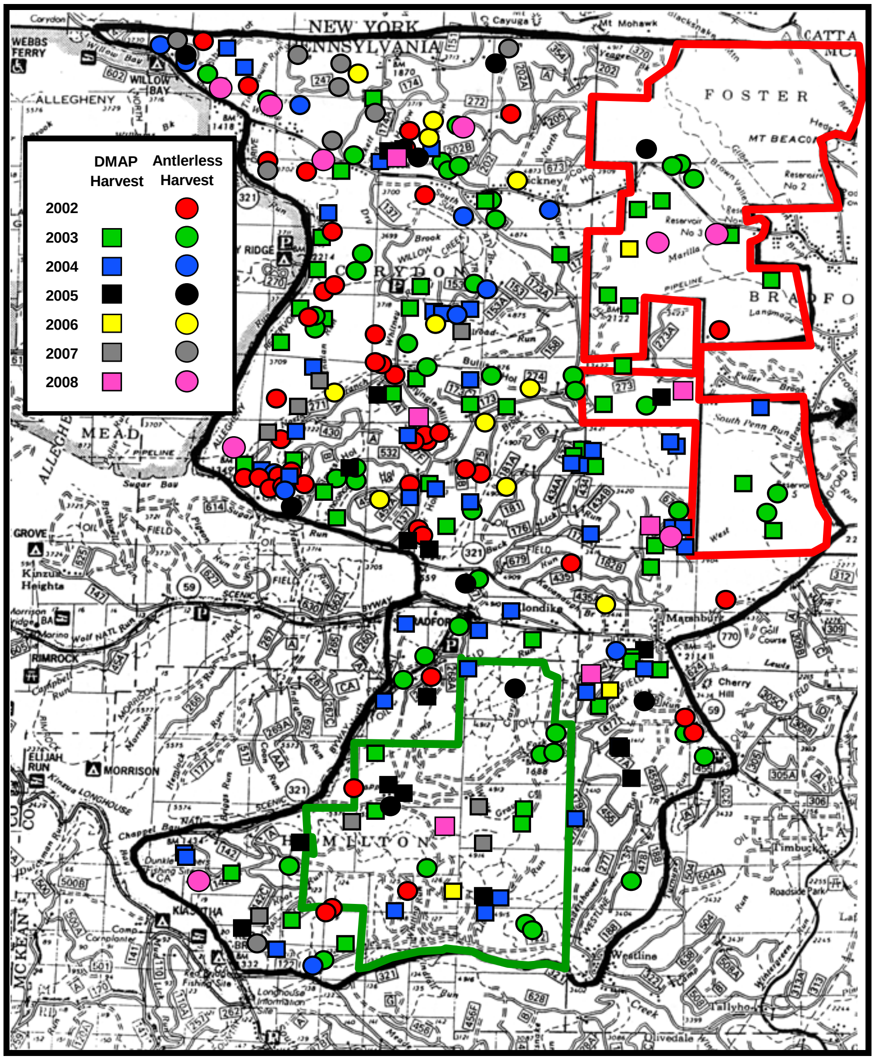


Fig 7. Distribution of deer harvested with antlerless (McKean CO. and Unit 2F) and DMAP licenses between Public (ANF bordered by black) and Private (KQDC North bordered by red, KQDC South bordered by green) Sectors 2002-2008. Deer harvested with McKean County/Unit 2F antlerless licenses = circles, deer harvested with DMAP licenses = squares.

With the advent of the DMAP program in 2003, deer density declined significantly on the Public Sector from 2003-2004 (P=0.014), but remained unchanged on the Private Sector (P=0.99) across the Project Area. With the passage of time and as hunters became more familiar with the DMAP program, deer density declined significantly (P<0.06) from year to year on Public and Private Sectors from 2004 until 2006.

As numbers of DMAP licenses dropped and remained low 2006-2008 (and number of Unit 2F antlerless licenses was unchanged), deer density increased significantly ($P<0.001$) on the Private Sector between 2006 and 2008-2009 and between 2007 and 2008-2009 but remained relatively unchanged on the Public Sector ($P>0.13$) (Fig. 4).

These results suggest that hunters may have used Unit 2F antlerless licenses proportionately more on the Public Sector than on the Private Sector, resulting in maintenance of low deer density on the Public Sector. Initial reduction in deer density on the Private Sector was reversed with the decline in DMAP license availability, suggesting that DMAP licenses were more effective than Unit 2F antlerless licenses for reducing deer density on the Private Sector.

These hypothesized differential responses of deer density between Private and Public Sectors to availability of Unit 2F antlerless and DMAP licenses may be evaluated by comparison of numbers of antlerless deer harvested with these licenses and brought to check stations. Proportion of deer harvested with McKean County/Unit 2F antlerless licenses was higher than proportion of total KQDC area for the Public Sector and lower than proportion of KQDC area for the Private Sector (Table 4) for the northern portion of the KQDC Project area (DMAP Unit 134, comprising 71.5% of the Project Area). However, on KQDC South, deer were harvested disproportionately higher on the Private Sector than on the Public Sector. Unit 2F antlerless licenses were more effective in reducing deer density on the Public Sector than on the Private Sector on KQDC North, but the opposite was true for KQDC South.

Table 4. Relative proportions of KQDC Project Area by Public/ Private Sector and deer harvested with McKean CO/Unit 2F antlerless licenses and brought to check stations 2002-2008.

Public/Private Sector	% KQDC North Area	% KQDC North Antlerless Harvest	% KQDC South Area	% KQDC South Antlerless Harvest
Public	71.7%	84.5%	51.6%	46.7%
Private	28.3%	15.5%	48.4%	55.3%

When use of DMAP licenses to harvest antlerless deer is examined, the disproportionate harvest of antlerless deer with Unit 2F licenses between Public and Private Sectors was narrowed on KQDC North, where hunters harvested antlerless deer in closer proportion to size of area (Table 5). However, unlike with Unit 2F antlerless licenses, hunters used DMAP licenses to harvest proportionately more antlerless deer on the Public Sector on KQDC South. DMAP licenses were more effective in reducing deer density on the Public Sector than on the Private Sector in KQDC north *and* south areas.

Table 5. Relative proportions of KQDC Project Area by Public/ Private Sector and deer harvested with DMAP licenses and brought to check stations 2003-2008.

Public/Private Sector	% KQDC North Area	% KQDC North Antlerless Harvest	% KQDC South Area	% KQDC South Antlerless Harvest
Public	71.7%	77.9%	51.6%	55.6%
Private	28.3%	22.1%	48.4%	44.4%

Numbers of DMAP licenses allocated to KQDC North and South each year were equal, but acreage for each area was not: each area received 50% of the year's DMAP allocation, but KQDC North was 2½ times the size of KQDC South. Unit 2F licenses were not similarly divisible: Unit 2F licenses were available for use equally between KQDC North and South areas.

Therefore, the unequal response of deer density between Public and Private Sectors during reductions of antlerless licenses 2006-2009 seemed to result from: 1) hunters disproportionately used Unit 2F licenses to harvest antlerless deer on the Public Sector in KQDC North, which, because of its much greater share of the KQDC Project Area, resulted in more antlerless deer being harvested on north and south Public Sectors combined; and 2) overall major reductions in number of DMAP licenses negated the differential use of DMAP licenses between Public and Private Sectors: too few deer were harvested with many fewer DMAP licenses.

In summary:

- number of antlerless deer harvested and brought to check stations increased significantly when DMAP licenses increased and decreased when DMAP licenses were significantly reduced
- hunters made differential use of Unit 2F and DMAP licenses on Public and Private Sectors of KQDC North and South
- when more than 550 DMAP licenses are allocated for the entire Project Area, they are more effective than Unit 2F licenses in reducing in deer density on KQDC North and South. However, when fewer than 550 DMAP licenses are available, Unit 2F licenses are more effective in reducing deer density, primarily on KQDC North
- hunters harvesting two or more antlerless deer used more DMAP licenses than Unit 2F licenses to harvest deer brought to check stations
- hunters harvesting multiple antlerless deer used DMAP licenses twice as often than Unit 2F licenses to harvest the first deer
- by a ten to one ratio, hunters used only DMAP licenses to harvest multiple antlerless deer than hunters using only Unit 2F licenses.

Effective use of antlerless licenses for harvesting antlerless deer within the Project Area is constrained by inability to manipulate number of Unit 2F licenses. Also, hunters may use Unit 2F licenses to harvest antlerless deer within a 7-county area in Pennsylvania, resulting in a minimized capability for reducing deer density specifically on the KQDC Project Area.

The KQDC Leadership Team *can* reduce density the deer herd by increasing number of DMAP licenses. It remains to be seen whether the 800 DMAP licenses available for the KQDC Project area in 2009 (an increase of 250 above the 2008 allocation) will result in a reversal of the increasing herd density. **However, judicious adjustment of number of DMAP licenses appears to be the only way to effectively control deer density and keep it with the target zone.** Increasing DMAP licenses will increase antlerless harvest and reduce deer density. Because deer density on the Private Sector in KQDC North has consistently (and significantly: P<0.001) been higher than density on the Private Sector in KQDC South after reduction in DMAP licenses after 2006, more DMAP licenses may be needed to control deer density in KQDC North than KQDC South. Accordingly, the Leadership Team may wish to increase the ratio of DMAP licenses apportioned to KQDC North and South from 50:50 to 60:40 in the future. Monitoring responses of deer density to such changes in DMAP allocations will be essential to direct future adaptive management of deer density via control of DMAP license availability.

Overwinter Deer Density: *Ownerships*

Deer density within all ownerships declined significantly (P<0.04) from pre-DMAP and pre-Unit 2F license availability (2002-2003) until 2006/2007 when availability of DMAP licenses the prior hunting season began to decline below 700 (Fig. 8). In the 2007-2009 period when DMAP licenses were less than 700, deer density increased 2007-2009 on FIA and BWA sites (P<0.06) but did not increase on CP or ANF sites (P>0.0.35: note however that deer density on CP sites in 2008 was higher—P<0.08—than in either 2007 or 2009).

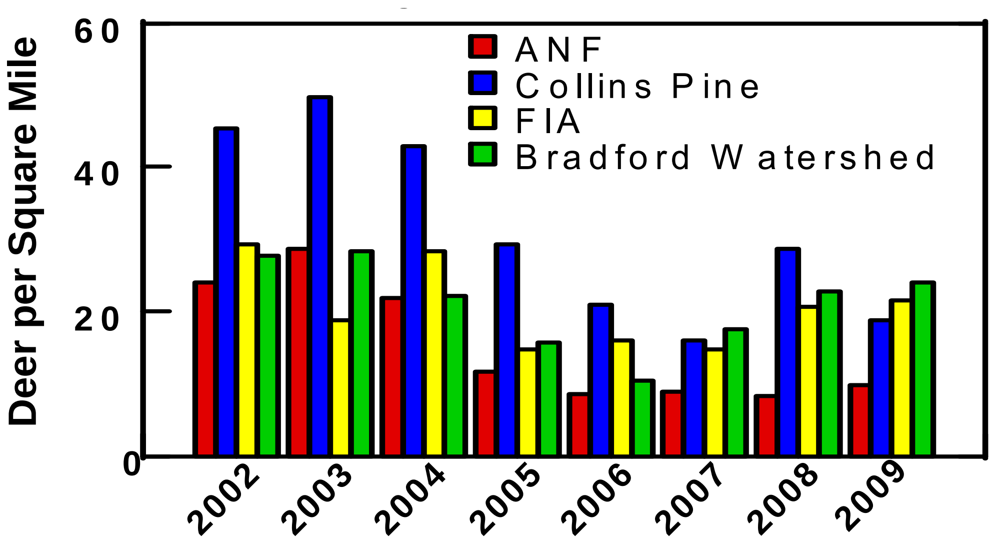


Figure 8. Changes in deer density 2002-2009 among ownerships.

Deer density and impact are evaluated on only two sites on CP lands: with only two sites for evaluation the opportunity for variation to confound results is greater than with the higher number of sites on other ownerships (4 on BWA, 6 on FIA, 14 on ANF). When CP lands are combined with BWA into the Private Sector on KQDC north (see pages 7-8 above) density averaged over the 6 sites did increase significantly from 2007 to 2009. Also, the poor hunting season in 2007 (rain and fog the entire opening day) may have discouraged hunters from hunting on CP lands: no deer harvested on CP lands were brought to check stations in 2007: Fig. 9). With low deer harvest in 2007, deer density would be expected to rise significantly on CP lands.

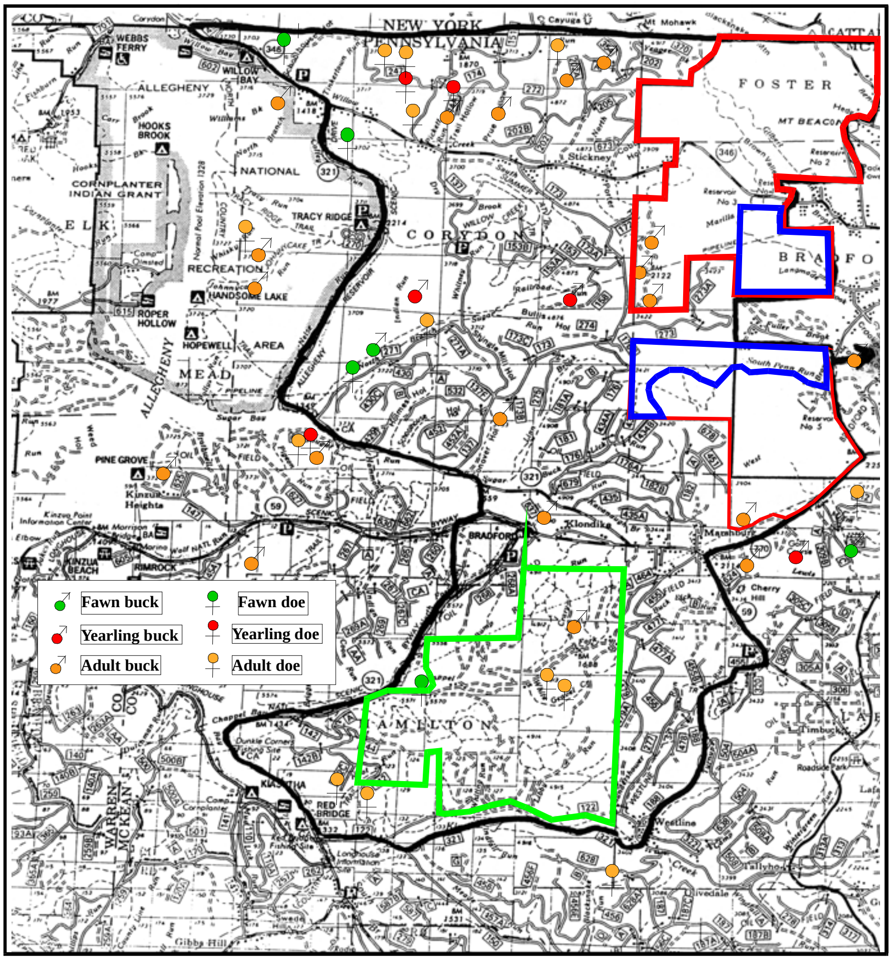


Figure 9. Reported locations of deer harvested and brought to check stations on the Project Area in 2007. Area enclosed in black = ANF; area enclosed in red = Bradford Watershed; area enclosed in blue = Collins Pine; area enclosed in green = Forest Investment Associates.

In 2008, as in 2007, the majority of deer brought to check stations were harvested from ANF lands rather than from CP, BWA, or FIA lands (Fig. 10). Low harvest on CP, FIA, and BWA in 2008 would result in increased density in 2009.

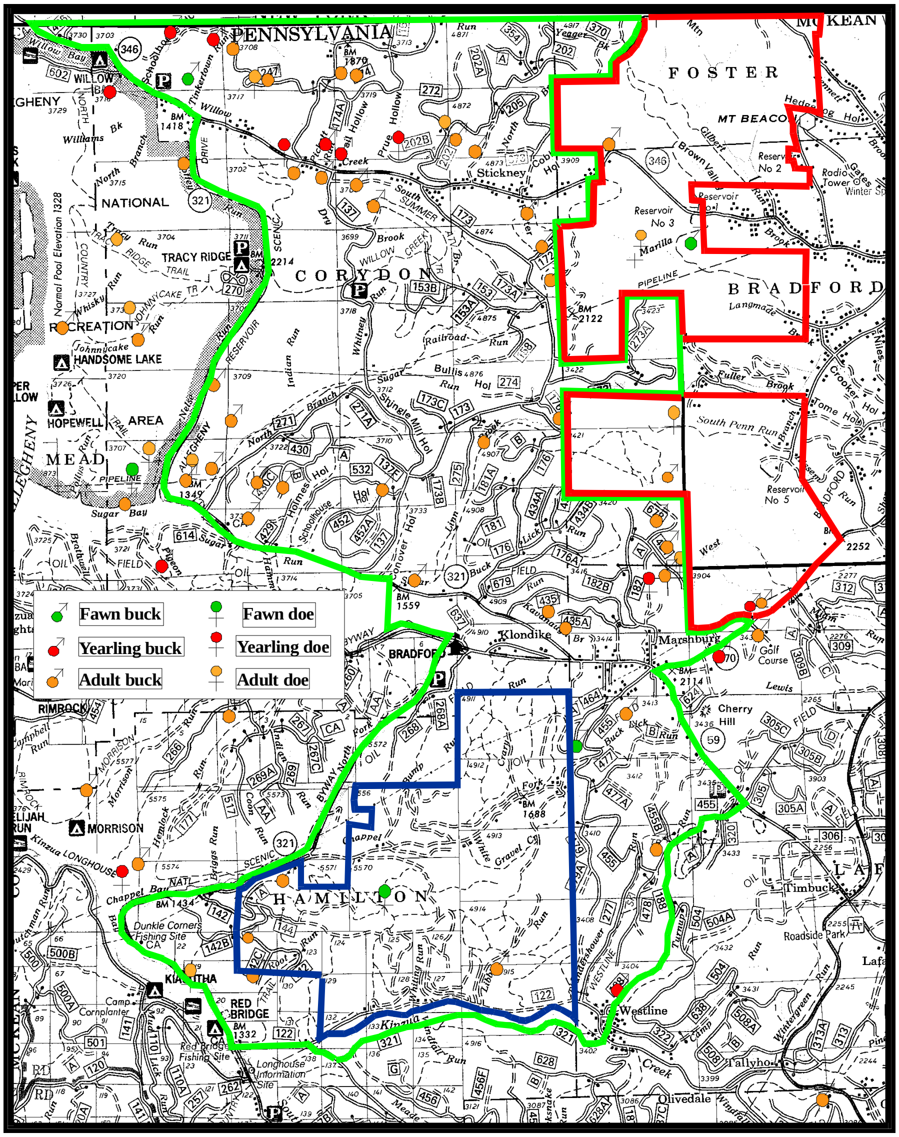


Figure 10. Known locations of deer harvested and brought to check stations on the Project Area in 2008 by Public and Private Sectors. Area enclosed in green = Public Sector (ANF); area enclosed in red = Private Sector North (Bradford Watershed & Collins Pine); area enclosed in blue = Private Sector south (Forest Investment Sites).

Large Among-year Differences Within Individual Sites

Year-to-year differences in overwinter density within sites varied considerably 2002-2009 (Table 1). Increases on 6 sites from 2002 to 2003 were greater than 50%. Because calculated recruitment has never exceeded 50%, sites exhibiting year-to-year increases greater than 50% could be viewed as sites where immigration occurred from the surrounding landscape to boost density.

The obverse may not be true for decreases in deer density: increases in deer harvest resulting from availability of 700 or more DMAP licenses, rather than emigration, may have been responsible for large decreases in deer density. From 2003 to 2005 (when 3,000 DMAP licenses had been available for two years to reduce density), deer density was lower on 23 of the 24 sites for which data were available.

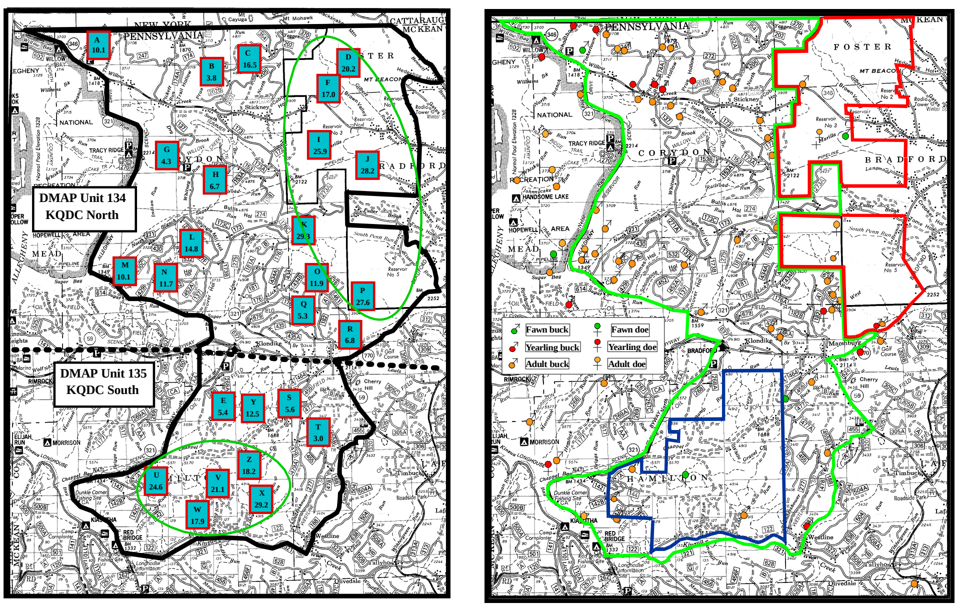
Seven sites (H, I, J, L, N, P, and V) exhibited 2007-2008 increases too high to be attributable to recruitment (average increase = 106.1%). Four sites (E, H, I, and N) were within the ANF portion of the KQDC, one (J) was within the Collins Pine portion, two (F and I) were within the Bradford Watershed Authority portion, and one (V) was within the FIA portion. These increases were off-set somewhat by smaller decreases on sites B and Q (average ~ 67.0%). These wide swings in increases and decreases in local deer density may more likely represent year-to-year movement shifts of deer in response to altered availability of forage and/or cover than to changes related to recruitment or mortality. With the return to higher DMAP licenses (550 in 2008), increase in density from 2008 to 2009 exceeded 50% on only three sites.

The large between-year differences in deer density within individual sites probably do not represent temporary, within-year shifts in deer density related to hunting season and hunting pressure because the period of pellet group deposition from leaf-off to data collection represents a far longer period of time (~160 days) than the hunting season (~12 days). Pellet groups deposited during hunting season would be far fewer than during the period from the end of hunting season to the time of data collection. It is unknown whether the large intra-site increases and decreases in deer density 2007-2008 resulted from deer making small shifts in home range loci: sites with large increases in density were not adjacent to sites with large decreases in density. As noted above, with more DMAP licenses available in 2008, there were only 4 sits where density swings exceeded 50% (three sites increased in density, one decreased in density).

If the large between-year increases in deer density within individual sites reflect (seasonal) deer home range shifts, they contradict conventional deer biology wisdom which dictates that deer to not shift home ranges in response to seasonal or year-to-year differences in habitat conditions. Recent research utilizing GPS collars on white-tailed deer wherein locations of collared deer were obtained hourly among seasons (William Porter, ESF white-tailed deer researcher, personal communication) revealed that white-tailed deer depart from the model of remaining within individual home ranges year-round – in some years a number of female deer (and presumably uncollared female progeny in their family groups) shifted home ranges during winter to include areas never before included in established, year-round home ranges. These movement shifts did not represent movement to traditional winter deer yards. If home range fidelity by white-tailed deer is overshadowed by opportunistic shifting of home ranges within and/or between years, the management implications are troubling. Attempting to overwhelm local deer herds with an excess of forage by harvesting large areas may not work if deer within local landscapes are able to detect occurrence of tree harvest and expand/alter home ranges to utilize new sources of forage (tree tops and regeneration stimulated by opening the overstory) and greatly increase local deer density.

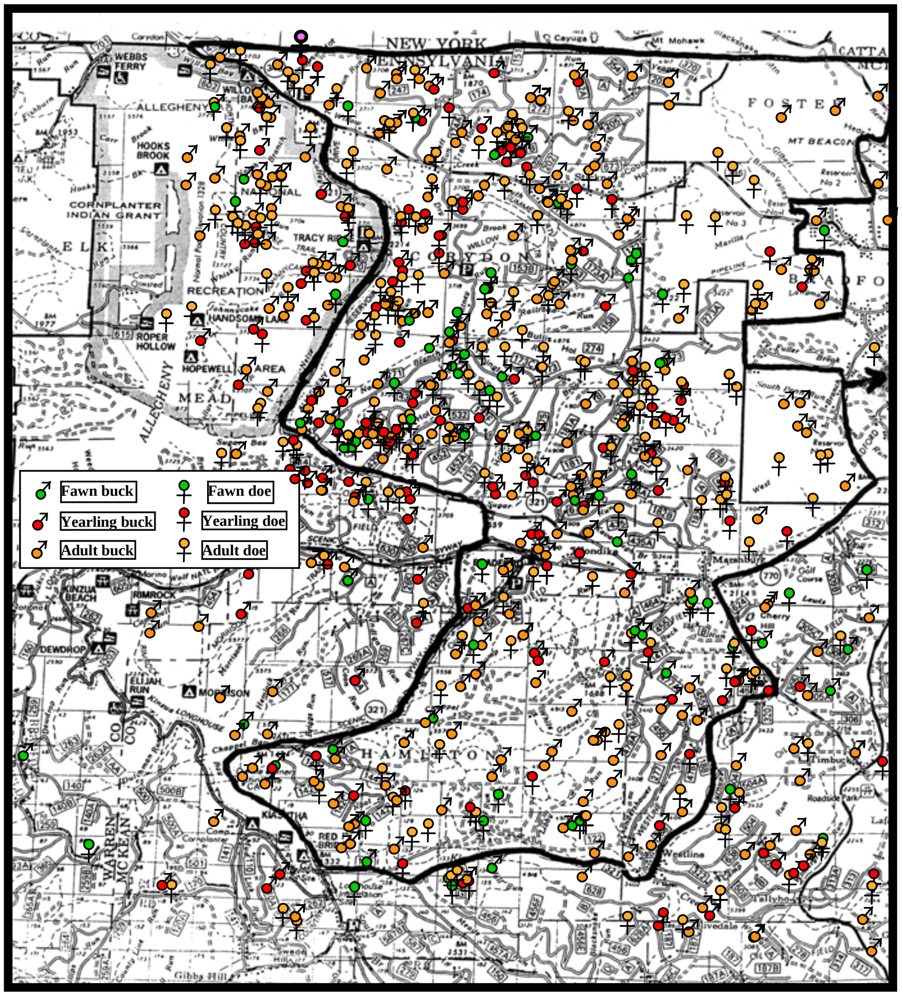
Attempting to reduce deer impact within small locales by reducing number of deer in local matriarchal groups and assuming no immigration from adjacent matriarchal groups will not work if the adjacent deer matriarchal groups do shift home ranges to take advantage of new sources of forage. If either or both of these scenarios are correct, management actions designed to reduce abundance of local deer herds prior to timber harvest may need to change. It might be necessary to increase deer harvest over surrounding landscapes larger than previously thought. Likewise, increasing forage by timber harvest on small areas may not overwhelm ability of deer to impact regeneration if deer immigrate to such forage areas.

As in 2008, areas with higher deer density in 2009 (circled in green, Fig. 11A) correlate with areas (Fig. 11B) where there were few deer harvested and brought to check stations in 2008. Areas with high deer overwinter density in 2009 were grouped in two loci, one encompassing all CP and BWA sites and one encompassing five of the six FIA sites. This information will be provided to hunters (Fig. 11A) for the 2009 deer season.



Figures 11A & B. Highlighted areas (green circles) of high deer density mapped for hunters for the 2009 rifle season (left figure); symbols identify loci of deer harvested in 2008 and brought to check stations (right figure, CP/BWA lands outlined in red, FIA lands outlined in blue).

The low numbers of reported harvest on non-ANF portions of the Project Area in 2009 is a continuation of the trend wherein few deer were brought to check stations from non-ANF areas (Fig. 12) relative to numbers brought from the ANF portion. Areas of low (reported) deer harvest on the Project Area (Fig. 11B) represent non-ANF portions.



Figures 12. Locations of deer harvested and brought to check stations on the Project Area 2001-2008.

Little timber harvest has occurred outside fenced areas within ANF sites on the Project Area, whereas non-ANF ownerships have been experimenting with taking down fencing protecting regeneration sites and in some cases not fencing new regeneration sites. Large increases in deer impact in 2008 (see below) were highly correlated with increases in deer density: highest increases in impact occurred on non-ANF sites where highest increases in deer density also occurred.

Results and Discussion – Deer Impact

Scale of Evaluation

For the same reasons given for evaluating deer density at three scales—entire Project Area, Public vs. Private Sectors, and individual ownerships—deer impact is also presented at (the same) three scales.

Coarse Grain Impact: Percent Plots No Regeneration and Percent Plots no Impact

Percent plots no regeneration/no impact, entire project area. - As deer density declined 2002-2006, *percent plots with no regeneration* declined and *percent plots with no impact* increased (Fig. 13; Tables 6 & 7). However, as deer density bottomed out 2006-2007 and then increased 2008-2009, *percent plots with no regeneration* remained stable 2007-2009. For the same time frame, *percent plots with no impact* declined significantly ($p<0.01$) from the high in 2006. There was far less variation among percent *plots no regeneration* than among *percent plots no impact* during the significant decreases and increases in deer density 2002-2009. This result suggests that deer density has a greater influence over level of impact on existing tree seedlings than upon suppression or enhancement of production of new tree seedlings.

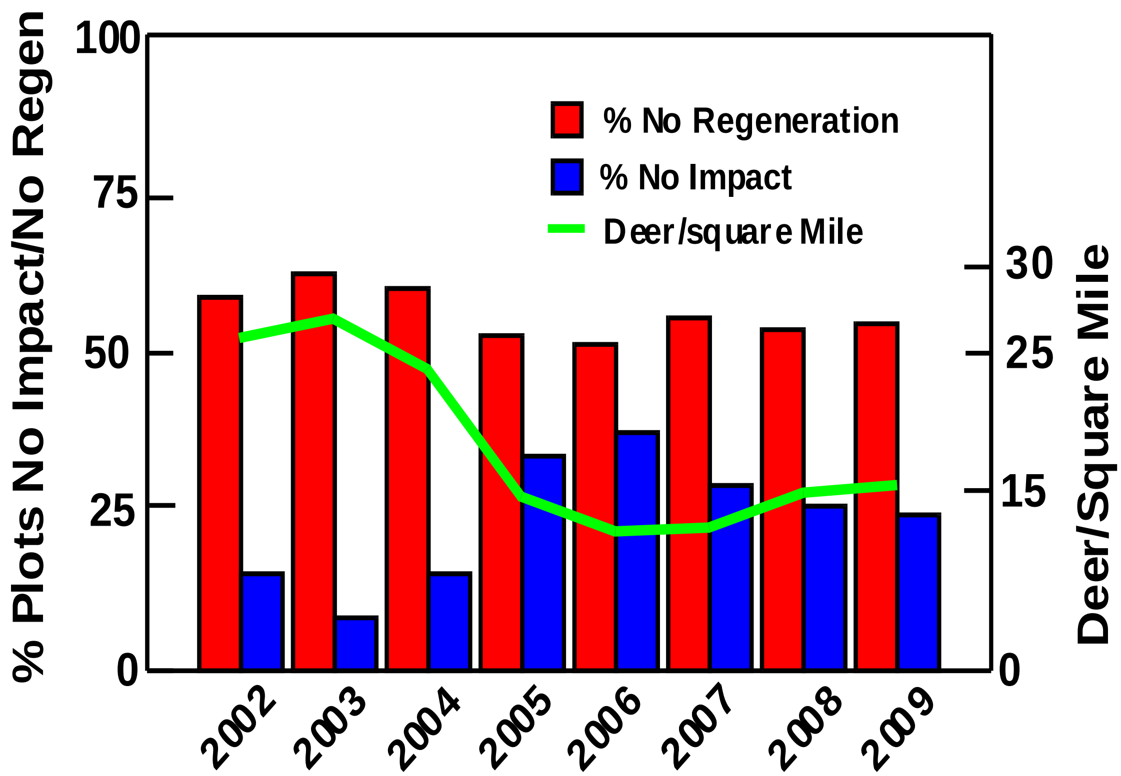


Figure 13. Percent plots no regeneration/no impact vs. deer density 2002-2009 across entire KQDC Project Area

There were considerable among-year differences in *percent plots no impact* (Table 6), reflecting changing levels of impact in response to changing levels of deer density. Some of the year-to-year differences reflected large differences, many (9) exceeding 100% increases in the 2004-2005 period when deer density dropped by the greatest amount, during which only two sites exhibited decreases in *percent plots no impact*. As deer density began to climb after 2006, most sites (21 of 26) exhibited decreases in *percent plots no impact* 2007-2009: the five that did not were all ANF sites where deer density remained low (below 9 deer/square mile for four sites, the remaining site was 17.3 deer per square mile) 2007-2009.

Table 6. Percent plots no impact 2002-2009.

Site	2002	2003	2004	2005	2006	2007	2008	2009
A	0.0	0.0	0.0	21.5	29.2	58.5	18.5	20.3
B	-	0.0	23.3	44.9	53.2	36.0	32.1	53.8
C	39.3	2.3	1.5	40.6	25.3	32.6	32.3	28.7
D	0.0	12.6	28.4	33.7	54.5	34.8	22.3	19.2
E	-	10.8	25.3	63.2	41.5	54.6	50.0	36.7
F	3.8	11.8	13.8	28.5	31.9	29.7	22.3	13.6
G	6.2	14.6	0.8	15.6	40.8	23.1	20.8	48.5
H	30.4	11.7	0.0	37.0	23.8	31.9	30.0	19.3
I	0.8	9.3	14.6	21.5	36.2	46.2	9.2	15.4
J	-	0.0	20.0	10.9	32.3	26.2	30.8	12.3
K	-	4.5	34.8	13.1	40.6	24.8	3.1	9.9
L	51.7	18.2	21.3	39.6	38.4	45.8	41.6	17.2
M	7.1	2.3	1.5	21.5	31.5	43.4	30.0	30.8
N	26.9	0.0	18.8	38.3	39.2	36.0	37.3	23.1
O	0.0	4.9	14.4	17.0	35.4	34.8	34.7	36.9
P	-	5.7	18.6	23.3	28.1	35.2	19.0	20.9
Q	-	6.2	15.6	30.5	45.4	32.6	26.7	22.5
R	19.8	13.0	3.1	28.3	38.6	26.5	15.2	20.8
S	-	4.0	26.2	51.0	36.9	31.0	46.2	40.9
T	-	6.2	11.5	46.3	38.5	26.2	30.0	30.0
U	-	7.7	8.7	36.7	34.8	24.9	17.5	15.6
V	-	14.5	28.4	31.3	31.8	48.4	32.7	26.2
W	-	13.1	16.4	39.5	30.0	30.0	14.6	20.0
X	-	28.5	14.9	36.9	27.7	23.8	23.1	17.7
Y*	-	-	-	56.0	56.2	43.8	16.3	17.2
Z*	-	-	-	56.3	56.5	49.0	21.7	20.9
Mean±95% CI**	**15.5±4.2**	**8.4±2.8**	**15.1±1.0**	**34.0±0.9**	**37.7±2.5**	**29.3±3.9**	**26.1±3.8**	**24.6±2.8**

***** = Sites added in 2005; ****** = Confidence interval ± 95% confidence of containing true mean. ANF sites in **red**; Collins Pine in **green**; Bradford Watershed in **blue**; FIA in **purple**

Among-year differences of *percent plots no regeneration* were of much less magnitude than for *percent plots no impact* (Table 7). Of the four sites exhibiting an increase in *plots no regeneration* when deer density was decreasing (2003/2003-2006) the range was from 4-50%. As deer density increased 2006-2009, average increase in *percent plots no regeneration* (25.8%) was about half the increase in average density (45.6%) on the ten sites where *percent plots no regeneration* increased where deer density also increased.

Table 7. Mean percent plots with no regeneration 2002-2009.

Site	2002	2003	2004	2005	2006	2007	2008	2009
A	62.6	66.2	60.0	55.4	50.0	29.2	26.9	28.0
B	-	62.4	66.6	53.6	45.2	58.6	56.8	43.1
C	52.5	46.9	56.5	47.8	45.2	55.8	43.8	35.1
D	59.0	50.6	51.8	56.9	46.3	54.1	51.5	56.9
E	-	57.7	45.1	30.4	49.2	30.8	46.2	47.4
F	57.7	65.2	67.7	66.9	54.7	65.0	64.6	66.0
G	61.5	62.3	67.7	70.6	64.6	70.8	63.8	29.2
H	56.9	64.4	62.2	37.9	67.7	65.4	41.6	56.9
I	49.0	63.7	68.5	60.8	48.5	50.8	46.2	66.2
J	-	76.2	46.2	65.2	43.1	41.5	22.3	45.4
K	-	61.4	43.7	45.3	46.4	57.9	72.0	48.8
L	38.1	49.6	66.1	41.1	44.0	41.9	43.0	44.6
M	55.8	56.4	55.3	44.6	66.9	49.8	70.0	66.9
N	64.3	58.1	51.1	57.1	52.3	62.5	41.7	49.7
O	97.6	75.2	83.2	76.5	63.9	64.3	61.1	55.8
P	-	77.4	75.1	66.3	67.9	57.0	48.7	61.3
Q	-	84.6	81.2	66.5	54.6	66.7	71.7	77.4
R	47.9	64.6	55.4	50.7	51.3	69.1	68.8	49.2
S	-	72.4	49.2	44.8	53.8	64.4	50.8	57.5
T	-	83.0	85.4	53.7	52.3	67.7	64.6	69.2
U	-	70.7	48.4	56.4	41.0	64.4	70.3	62.3
V	-	43.7	55.7	45.5	42.4	40.1	45.1	56.7
W	-	60.8	65.4	52.0	50.8	56.9	56.9	58.5
X	-	26.9	32.7	45.4	55.4	53.1	60.7	63.8
Y*	-	-	-	38.3	37.7	53.9	47.4	60.1
Z*	-	-	-	40.5	38.9	44.0	55.4	60.3
**Mean± 95%CI ** **	**58.6±6.8**	**62.6±4.0**	**60.0±2.4**	**52.7±2.3**	**51.32±4.2**	**55.7±4.7**	**53.5±2.2**	**54.5±3.4**

***** = Sites added in 2005; ****** = Confidence interval ± 95% confidence of containing true mean. ANF sites in **red**; Collins Pine in **green**; Bradford Watershed in **blue**; FIA in **purple**

Percent plots no regeneration/no impact: *public vs. private sectors.* - For both *percent plots no regeneration* and *percent plots no impact*, responses to deer density were the same: as deer density decreased, impacts decreased, and as deer density increased, impacts increased (Fig. 14). However, because deer density on the Public Sector increased only slightly after 2006, while deer density increased significantly on the Private Sector, impacts on the Private Sector were greater. *Percent plots no impact* were significantly lower (P<0.01) on the Private Sector. *Percent plots no regeneration* were significantly higher (P=0.1) on the Private Sector, but only for 2009.

The differences in *percent plots no regeneration* (left graph, Fig. 14) between Public and Private Sectors were not nearly as pronounced as for *percent plots no impact* (right graph, Fig. 14), for Public and Private Sectors. This observation reinforces the impression discussed under ***percent plots no regeneration/no impact, entire project***

area on page 22 that differences of deer impact over time were of greater magnitude among *percent plots no impact* than among *percent plots no regeneration*.

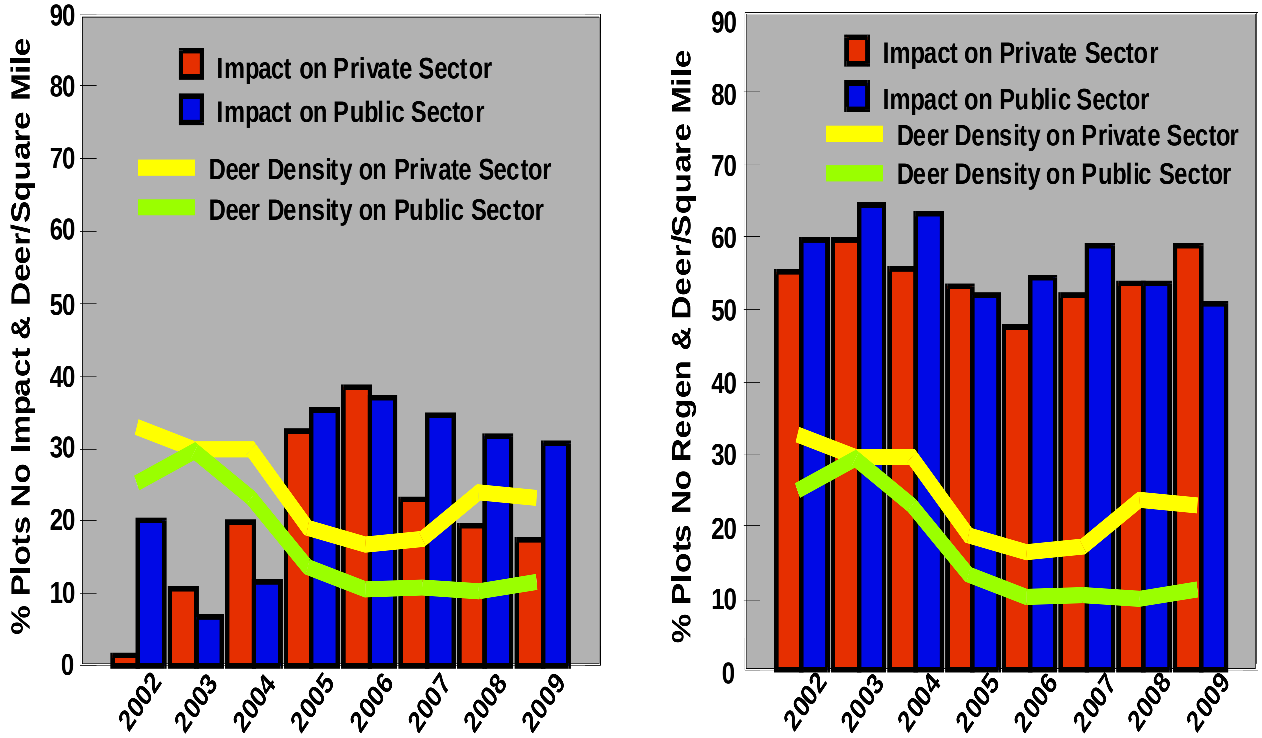


Figure 14. Deer density and impact by Public and Private Sectors: left graph = % plots with no impact; right graph = % plots with no regeneration.

Because differences in impact related to deer density were greater among years between Public and Private Sectors for *percent plots no impact*, the remaining discussion of deer impact at the coarse grain level for Public/Private Sector analysis is only for *percent plots no impact*.

The disparity in impact between Public and Private Sectors for the entire KQDC Project Area is similar when the KQDC Project Area is evaluated by North and South areas (DMAP Units 134 and 135)(Fig. 15). In both areas, deer density declined on Public and Private Sectors 2002-2006, then increased on the Private Sector 2007-2009 while remaining fairly unchanged on the Public Sector. The differences in density trajectories on Public and Private Sectors after 2006 were mirrored by differences in impact: where density increased, impact increased, and where density remained nearly stable, impact remained nearly stable. These results provide additional confirmation of the disproportionately higher impact reductions in DMAP licenses had on deer density on the Private Sector than in the Public Sector

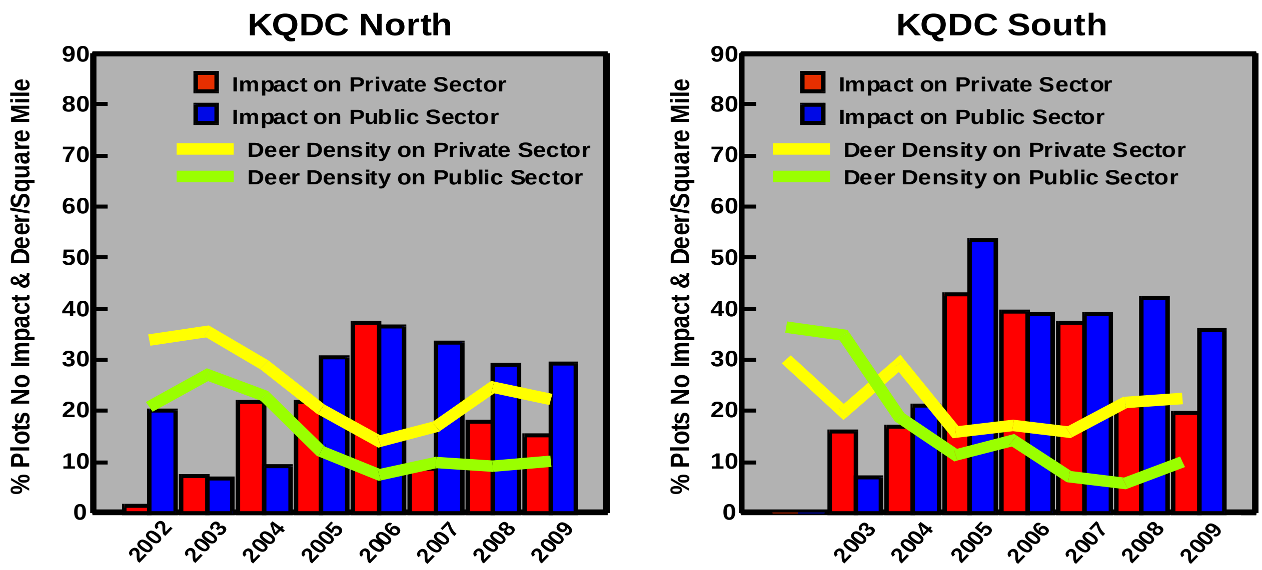


Figure 15. Deer density and impact by Public vs. Private Sectors: left graph = % plots with no impact for KQDC North; right graph = % plots with no impact for KQDC South.

Differential responses of impact (*percent plots no impact*) to changes in deer density were similar between KQDC North and South areas when examined by Public and Private Sectors (Fig. 16). As deer density dropped then increased 2002-2009 on sites within the Private Sector (left graph, Fig. 16), deer impact inversely rose and fell. As deer density dropped, then remained low 2002-2009 on the Public Sector (right graph, Fig. 16), deer impact inversely rose and remained high. For the Public Sector (right graph, Fig. 16), deer density was slightly higher on KQDC North as was impact.

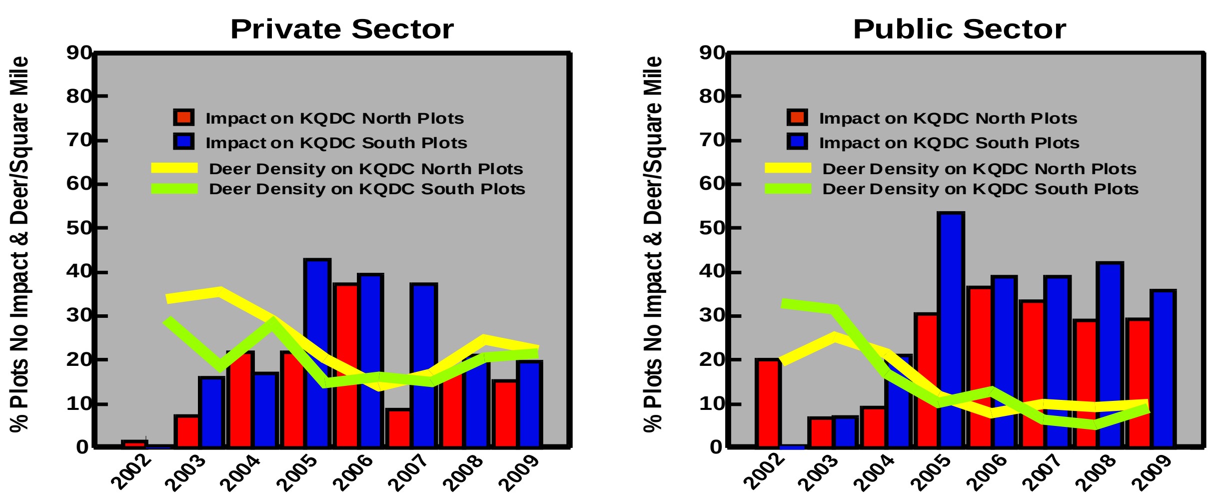


Figure 16. Deer density and impact by KQDC North vs. KQDC South: left graph = % plots with no impact for Private Sector; right graph = % plots with no impact for Public Sector.

Percent plots no regeneration/no impact: *ownerships.* - As with all other comparisons of deer density with impact, *percent plots no impact* responded more strongly to differences in deer density than *percent plots no regeneration* (Fig 17).

Percent plots no impact increased on all ownerships as reduction of deer density began in 2002 and continued through 2006. For this same period, *percent plots no regeneration* declined on all ownerships. However, after 2006, when numbers of available DMAP licenses plummeted, deer density began to climb, on all except the ANF portion of the Project Area. As deer density increased after 2006 on private ownerships, so did impact: *percent plots no impact* declined and *percent plots no regeneration increased*. As noted with other divisions of the KQDC Project Area, changes in indicators of impact were far greater for *percent plots no impact* than for *percent plots no regeneration*.

Because Unit 2F antlerless licenses remained constant 2006-2008 while DMAP license numbers were much reduced from 2003-2005, it is clear that reduction in DMAP licenses had a far greater impact on deer density and deer impact on the three private ownerships than on the ANF portion of the KQDC Project Area (Fig. 17). It is also clear that increasing DMAP license number to over 500 halted, or at least slowed the rate of, the increase in deer density. The low point in deer density on all ownerships occurred 2006-2007 which corresponded, with few exceptions, with the period of least impact evidenced by the two indicators.

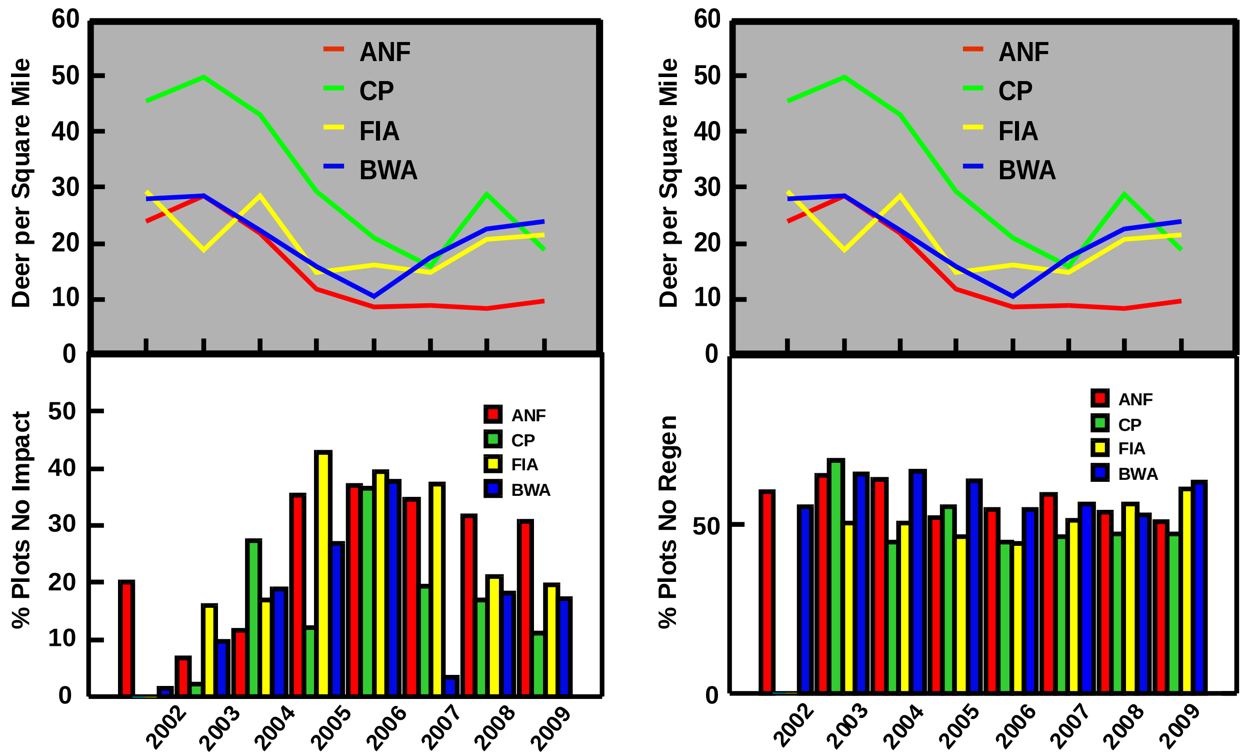


Figure 17. Deer density and impact by ownership: lower left graph = % plots with no impact; lower right graph = % plots with no regen. Top graphs display deer density.

Fine Grain Impact: Deer Impact on Indicator Species

Figures 18-23 display differences in level of deer impact on six indicator woody seedling species (American beech, striped maple, red maple, black cherry, eastern hemlock, and birch). Levels of intensity were light (0-49% stems browsed), moderate (more than 50% of stems browsed), heavy (more than 50% of stems browsed and plants browsed into tight balls of heavily browsed stems), and severe (hedged seedlings browsed to below 6 inches in height). Considerable variation in browsing intensity to changing deer density 2002-2009 existed among ownerships and among indicator species (Figs. 18-23).

Percent plots with different levels of deer impact averaged across properties and stacked as bar graphs provide an average percentage of plots stocked with each indicator species: the levels mutually exclusive and additive. For example, percent plots stocked with beech seedlings averaged across the entire KQDC Project Area in 2002 was 12% (upper left graph, Fig. 18). Beech was the most abundant indicator species on all ownerships except CP (where the most abundant indicator was red maple); and eastern hemlock was the least abundant. Comparing the Public Sector (ANF) with the Private Sector (BWA, CP, and FIA), American beech and striped maple were equally abundant on both Sectors, red maple and hemlock were higher on the Private Sector, and birches and black cherry were roughly twice as abundant on the Private Sector than on the Public Sector.

For all indicator species, average percent plots stocked increased from 2002-2009 for all ownerships (Figs. 18-23), indicating an increase in seedling stocking rates, likely reflecting the decrease in deer density by increased harvest through the antlerless programs (Unit 2F and DMAP). Order of abundance of indicator seedlings across the Project Area, beginning with the most abundant, was **(1)** American beech (~20-25% plots stocked), **(2)** striped maple (~10-12% plots stocked), **(3)** red maple (~5-10 percent plots stocked), **(4)** black cherry (~5-8 percent plots stocked), **(5)** birches (~2-8 percent plots stocked, and **(6)** eastern hemlock (~2-8 percent plots stocked). This relative ranking of stocking persisted throughout the period of the Demonstration Project.

Severity of deer impact may be assessed by relative proportions impact levels on seedlings: the greater the proportion of light-to-moderate impact (green and blue bars) to heavy-to-severe (gray and red bars) the lower the intensity of impact. For example, severity of impact on American beech for 2002-2004 was higher than for 2007-2009 on the entire Project Area (upper left graph, Fig. 18).

For all indicator species, severity of impact decreased on all indicator species on all ownerships 2002-2009 (entire period, when density 2009 much reduced from initial densities) and on all ownerships 2002-2006 (the period of sustained decline in deer density), again an indicator of the impact of reducing deer density on indicator species through the antlerless programs (Unit 2F and DMAP). As deer density began to climb—more on the Private Sector than on the ANF—severity of impact increased on two species (red maple and striped maple), but the increase was slight.

Impact levels (in decreasing order of severity) seemed higher on eastern hemlock, striped maple, and red maple which could be considered the preferred by deer indicators, and lighter on American beech, black cherry, and birches, which could be considered less preferred.

Abundance and severity of impact on several indicator species fluctuated in synchrony 2002-2009, suggesting intra-year variation in seed crop and germination. The huge spike in stocking and severity of impact on eastern Hemlock in 2007 suggested a major seed crop/germination in 2006 for this indicator species. The drop in abundance and increase in severity in 2005 on red maple and striped maple (preferred-by-deer species) on FIA, and BWA ownerships suggests a failure or low regeneration/germination in 2004 on those ownerships: the sharp decline in abundance of red maple on CP ownership in 2004 suggests the decline in seeding/germination occurred a year earlier on CP lands.

Impact on beech. – Beech was similarly abundant on all ownerships excepting Collins Pine, where it was somewhat lower in abundance than on other ownerships (Fig. 18). Collins Pine may have controlled beech throughout the project period to reduce the amount of interference by beech on other more preferred seedling species.

Deer impact on beech exhibited multiple levels of severity during early years of the KQDC project (2002-2004), but as deer density declined 2003-2006 higher severity levels of impact were predominantly low and sum of plots all levels of impact increased, reflecting reduced deer impact. Deer density stabilized on the ANF ownership 2006-2009 as did impact on beech. However, on the other three ownerships, as deer density increased 2006-2009 severity levels crept up on FIA and BWA ownerships. In the large absolute increases in deer density on BWA and CP ownerships percent plots with beech at combined level of impact climbed; with the slight absolute increase in deer density on the ANF ownership percent combined plots with beech decreased only slightly, as it did with the moderate increase in absolute deer density on the FIA ownership. As deer density increased 2008-2009 on FIA. BWA and ANF ownerships, beech abundance decreased: as deer density declined on CP, beech abundance increased.

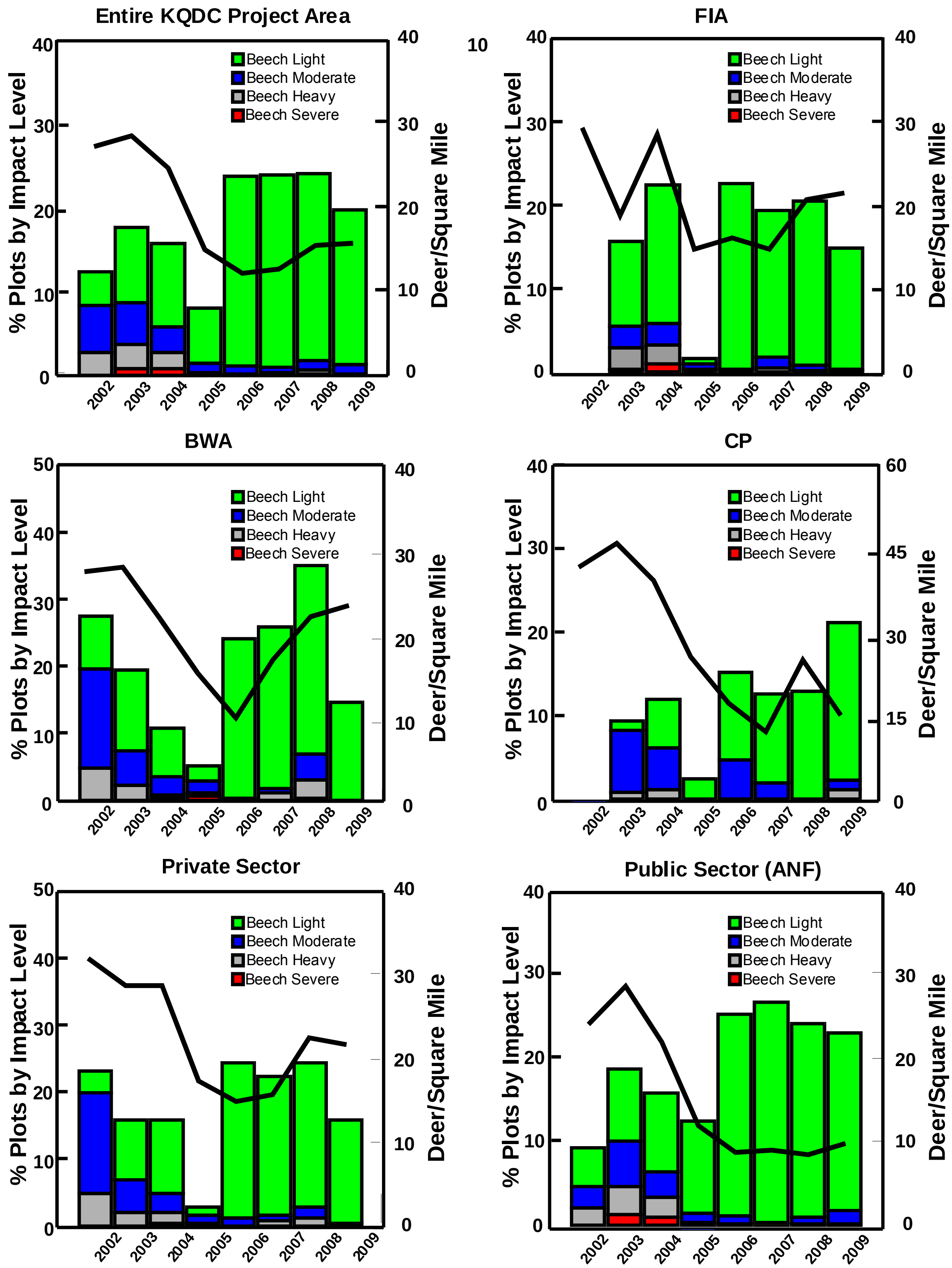


Figure 18. Impact levels on beech on ownerships and Public/Private Sectors 2002-2008.

Impact on striped maple. – As with beech, deer impact on striped maple exhibited multiple levels of severity during early years of the KQDC project (2002-2004) and higher levels of severity declined as deer density declined 2002-2007 for ANF, CP, and BWA ownerships (Fig. 19).

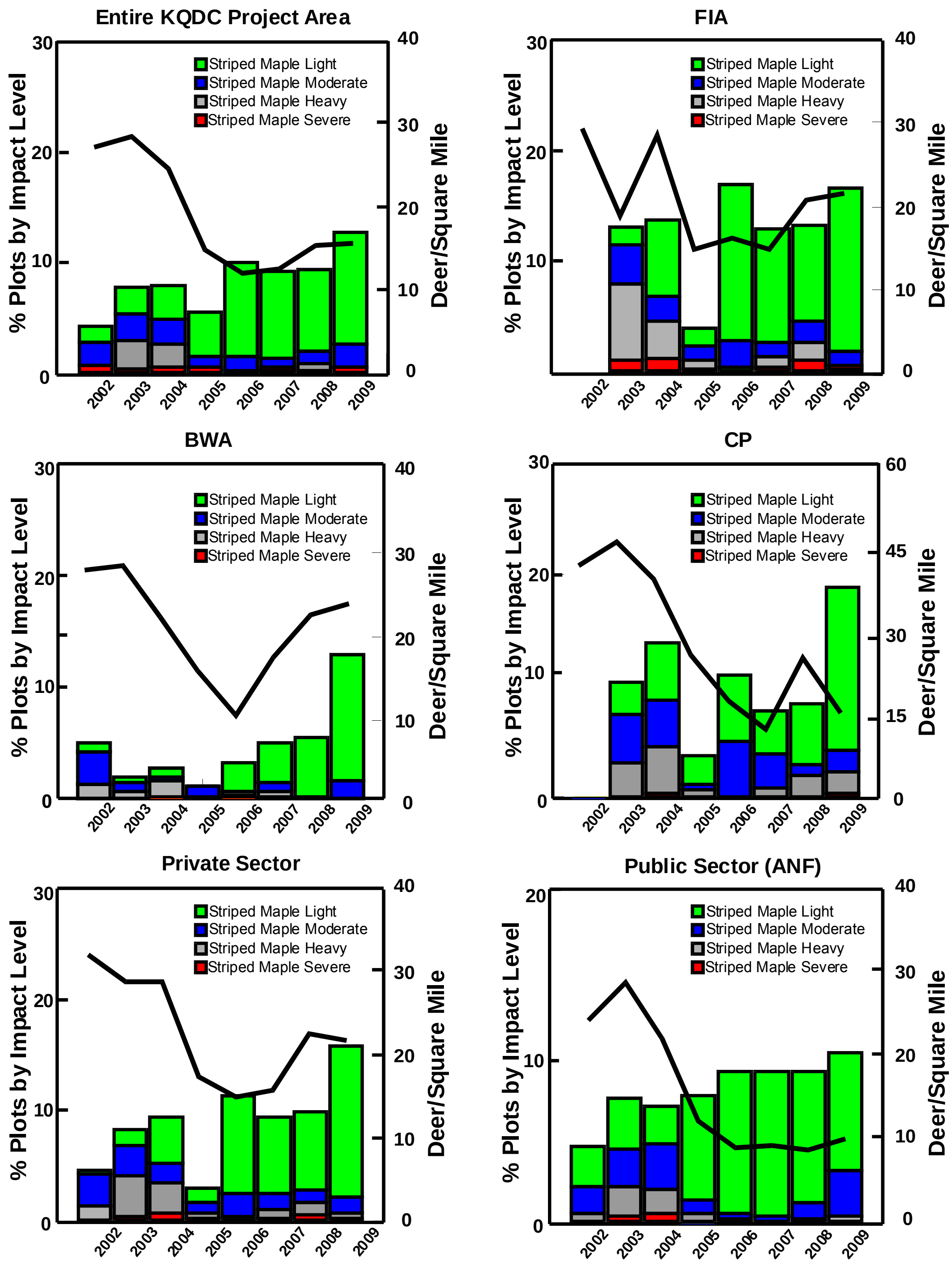


Figure 19. Impact levels on striped maple on ownerships and Public/Private Sectors 2002-2008.

There was an increase in proportion of higher levels of impact (severe and heavy) on striped maple seedlings within all ownerships from 2007 to 2008, but the reverse occurred in 2009, when striped maple abundance increased as deer density increased. Striped ample abundance increased on all ownerships from 2008-2009.

Impact on red maple. – As with beech and striped maple, deer impact on red maple (Fig. 20) exhibited multiple levels of severity during early years of the KQDC project (2002-2004). Higher levels of severity declined as deer density declined 2002-2007. Unlike beech, and similar to striped maple, as deer density increased 2007-2009, levels of severity of impact on red maple increased across all ownerships, even on the ANF where deer density remained low and little changed 2006-2009. Red maple abundance increased on all ownerships from 2008-2009.

Severity levels were lowest on ANF ownership throughout the project period and increase in severity was least on ANF in 2009 when impact level increased on all ownerships. Red maple was the most abundant indicator species on the CP ownership, except in 2008 when the doubling of deer density was associated with a halving of red maple abundance. With the large decline in deer density on CP in 2009, abundance of red maple increased greatly: relative severity levels remained constant. Red maple was less abundant on the ANF and BWA ownerships than on FIA and CP, reflecting lower initial abundances and higher amounts of overstory canopy closure (see discussion on canopy closure, page 41), likely reflecting less timber harvest.

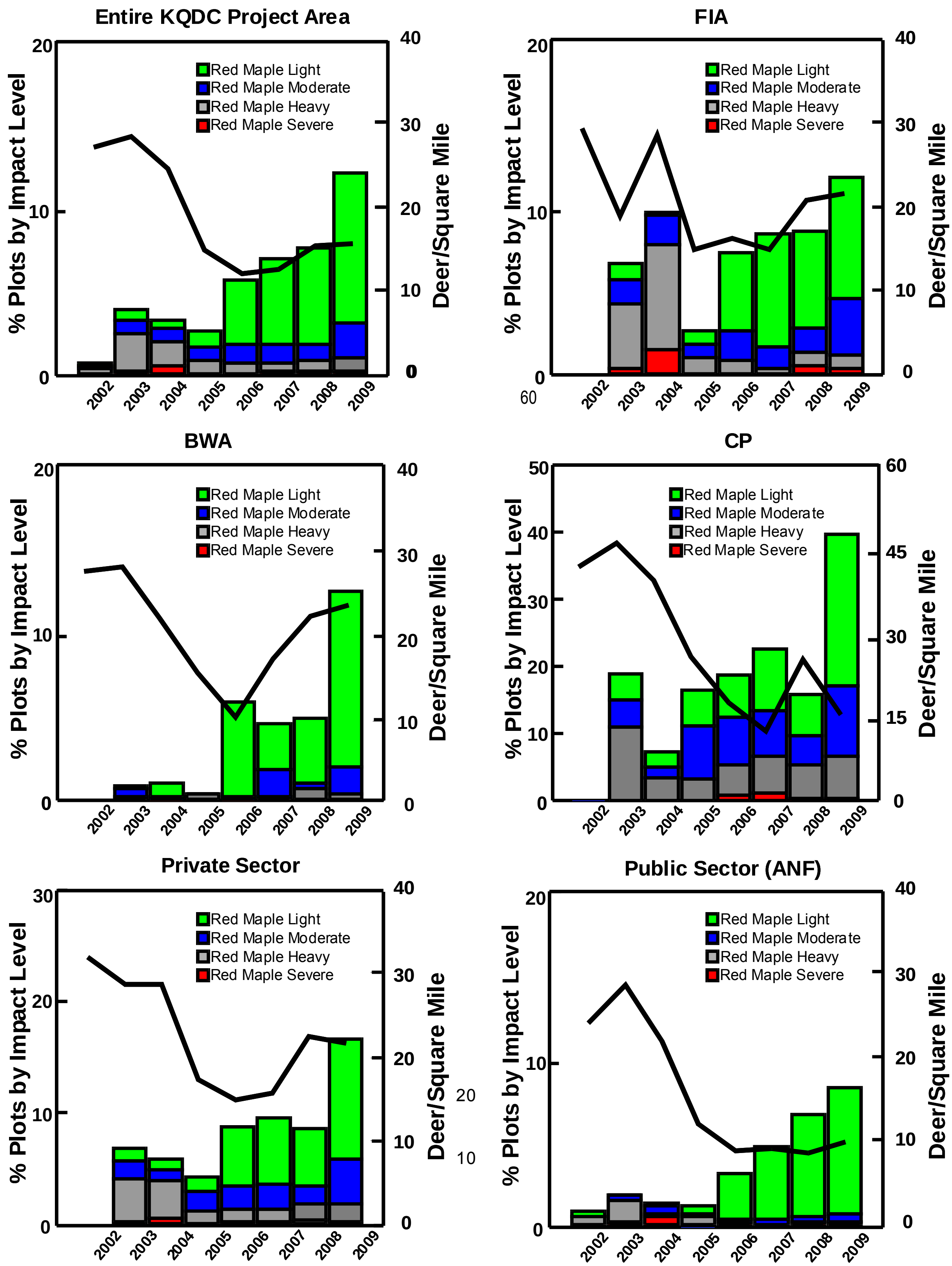


Figure 20. Impact levels on red maple on ownerships and Public/Private Sectors 2002-2008.

Impact on black cherry. – Overall impact on black cherry was little changed in 2009 from 2008, except on the Collins Pine ownership (Fig. 21), where it increased greatly after a large decline in deer density. Greater abundance of black cherry on CP sites may reflect control of interfering/competing species or increased canopy opening (highest on CP) with timber harvest, or both.

Impact levels on black cherry were predominantly light 2002-2009 on the ANF ownership, whereas on other ownerships impact at higher levels, in small proportion, was present at the beginning of the project. Impact levels on black cherry on Collins Pine sites were consistently higher in moderate-severe levels than on the other sites, possibly because deer density was higher. This observation (impact levels on indicator species higher on Collins Pine sites) holds for all indicator species, possibly because of higher deer densities on Collins Pine sites and a more even distribution of indicator species.

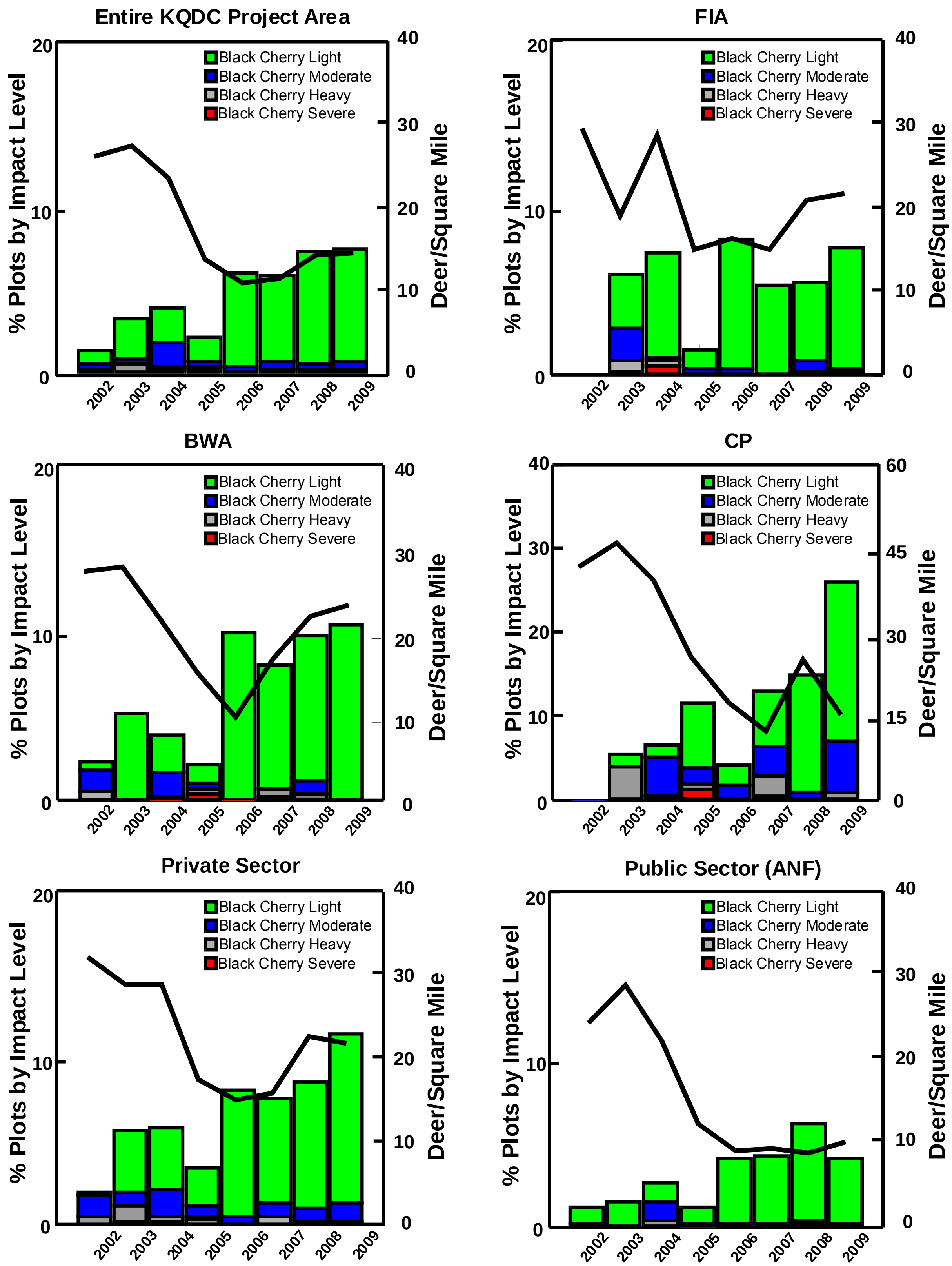


Figure 21. Impact levels on black cherry on ownerships and Public/Private Sectors 2002-2008.

<u>Impact on hemlock</u>. – Hemlock was most abundant on CP and BWA ownerships (Fig. 22) but was the least abundant indicator. Severity of impact on all ownerships lessened as deer density declined 2002-2007 but then increased 2008-2009 as deer density also increased. As noted above, the huge spike in hemlock abundance in 2007 most likely reflected a large seed crop/germination rate the previous year. The highest impact level on hemlock occurred in 2007 was severe (when hemlock was most abundant and more easily encountered by deer, attesting to deer preference for hemlock.

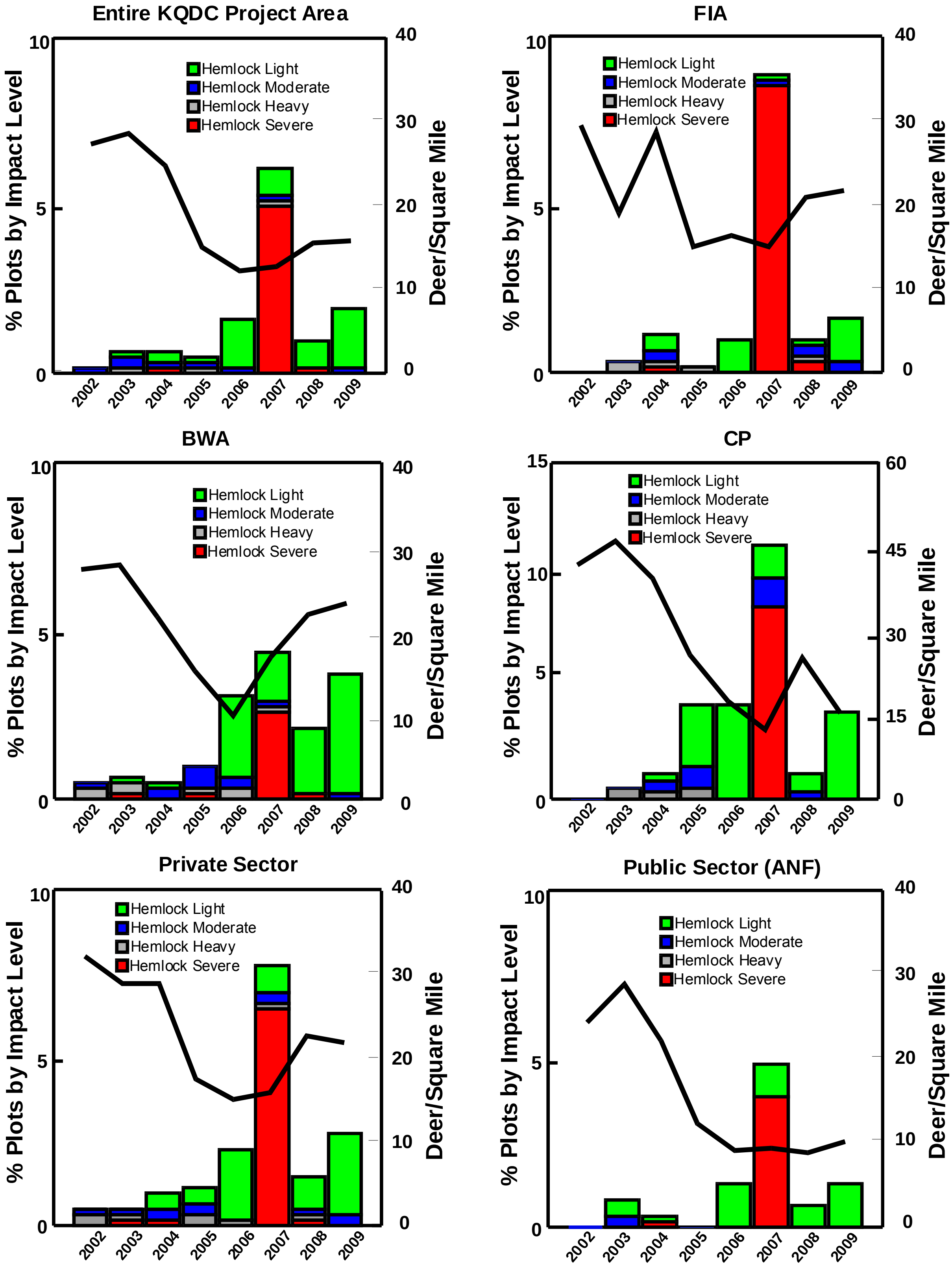


Figure 22. Impact levels on eastern hemlock on ownerships and Public/Private Sectors 2002-2009.

Impact on birch species. – Birch was more abundant on CP and FIA ownerships (Fig. 23), which also had a higher percentage of plots with open overstory: birches are relatively shade-intolerant and seedlings germinate and grow better when the overstory is opened above them and the soil is disturbed by activities such a logging. Preponderance of impact level on birch was light, indicating that birch is relatively low in preference as deer forage. The large drop in birch abundance 2006-2007 on FIA, BWA and ANF ownerships more likely reflected a low seed crop and/or poor germination in 2006 than a sudden increase in intensity of deer browsing, especially as percent plots with severe-heavy impact levels was low.

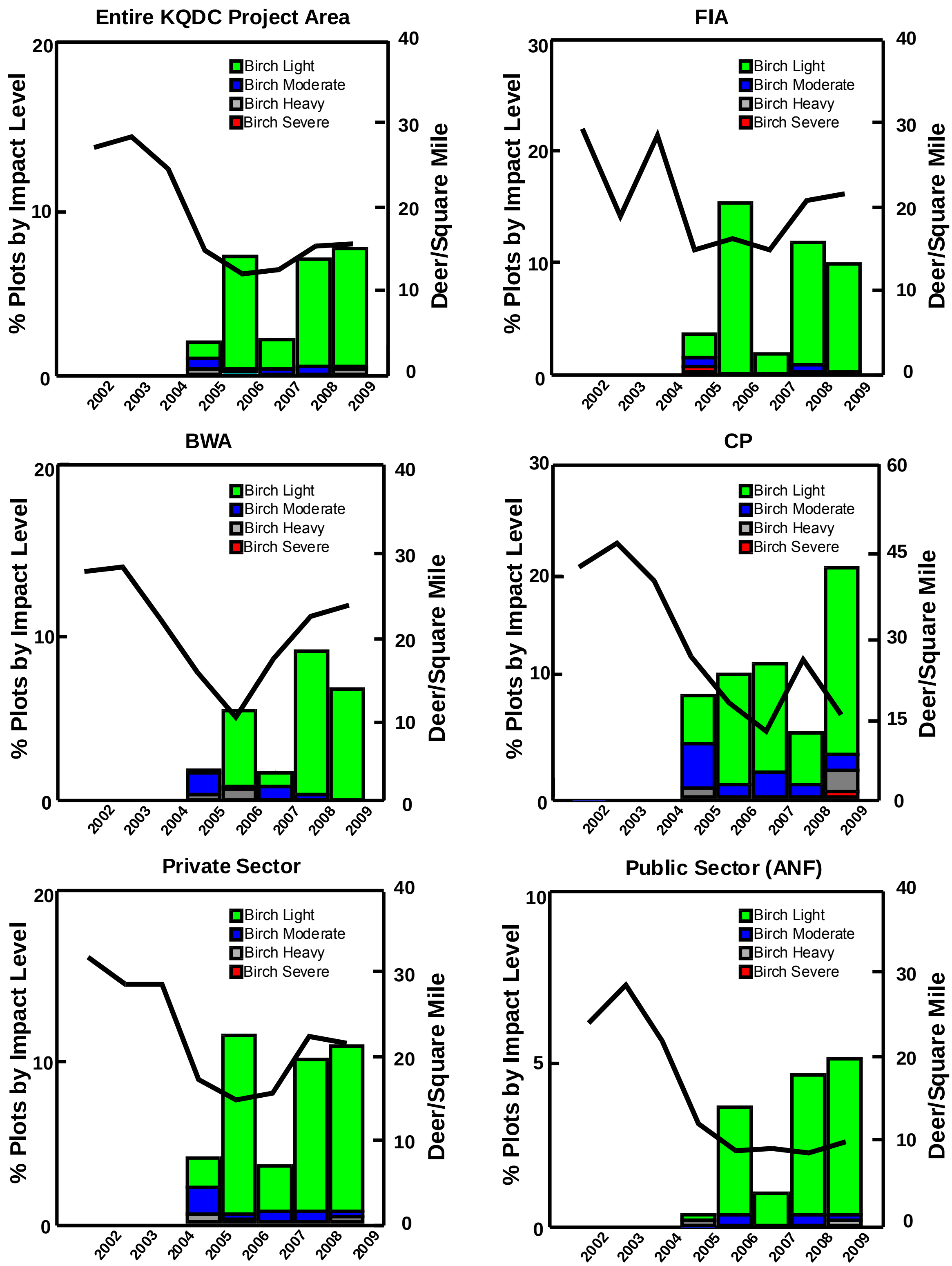


Figure 23. Impact levels on birch on ownerships and Public/Private Sectors 2002-2008.

Severity of impact on hemlock and red maple seedlings (preferred by deer) was higher on the Private Sector in 2009, where deer density was higher, but impact levels on another preferred indicator, striped maple, were not different between Public and Private Sectors. Impact levels of non-preferred indicators (birch, black cherry, beech) were not different between Private and Public Sectors, but the less shade-tolerant birch and black cherry were more abundant on the Private Sector, where overstory opening was greater.

In summary, deer density increased only marginally in 2009 across the Project Area and impact at coarse and fine grain levels exhibited similarly small increases overall. Continuance of deer density above goal levels 2007-2009 on the Private Sector was followed by slight increases in impact at coarse and fine grain levels on the Private Sector.

For all indicator species, severity levels of impact were lowest on the ANF, where deer density was lowest. Change in severity level of impact on all indicator species 2008-2009 was least on the ANF ownership.

Deer density and coarse and fine grain impact levels progressively and continuously declined on all ownerships 2002-2006, reflecting the impact of antlerless and DMAP licenses to depress deer density and impact. However, reductions in DMAP and antlerless licenses after 2006 resulted in increases in deer density and increases in impact on all ownerships except the ANF.

Collins Pine sites had the highest deer abundance (except in 2009) and highest abundance of all indicator species, excepting beech. Moderate impact was generally higher for all indicators on CP, but combined proportions of light and moderate impact on indicator species for CP were similar to proportions on other ownerships. Assuming no consistent bias of observers collecting data on Collins Pine sites for reporting lower impact levels, management practices favoring control of interfering species (beech and striped maple), higher timber harvest levels, and higher proportion of unfenced harvest areas were associated with deer impact on CP ownership similar to other ownerships with lower deer density. Among the four ownerships, CP sites had a significantly higher proportion of plots under open canopy (see section below on Open/Closed canopy, page 41). The relatively higher density of deer required on sites with more forage to produce impact levels observed at lower deer densities on sites with less forage is a phenomenon hypothesized in the mid-1980s by David Marquis.

Overall Deer Impact. - Based on the diagram (Fig. 4, Appendix 1) and associated interpretation of impact levels, deer impact for 2009 is characterized as "light-moderate" for the ANF, and "moderate" for other ownerships, reflecting a slight increase in impact levels for all ownerships.

There were still more than 50% plots with no advance regeneration of any species in 2009 on all ownerships, as in 2005-2007. Additionally, percent plots no impact decreased, and severity levels of impact on all indicator species increased slightly from

2008. Impact levels likely are due to the interacting influences of deer impact, low levels of tree harvest existing outside of fenced areas, and to interference from ferns and grasses. Without harvests to open the forest overstory, there is less stimulation for development of abundant and diverse advance regeneration of seedlings outside of fenced areas. High deer impact in the past favored predominance of ferns and grasses in the understory (ferns and grasses are little eaten by deer: removal of competing tree seedlings by deer allowed ferns and grasses to spread and interfere with development of tree seedlings). The window of lower deer density and impact that occurred 2005-2006 appears to be closing, rendering it less likely that cooperating landowners within the Project Area will be able to take down existing fences and to build fewer fences around some but not all new timber harvest sites.

Open vs. Closed Canopy

Overstory canopy was significantly ($P<0.08$) more open on the CP ownership than the others, more open ($P<0.08$) on the FIA ownership than on ANF and BWA, and more open ($P=0.02$) on BWA than ANF (Fig. 24) for 2009.

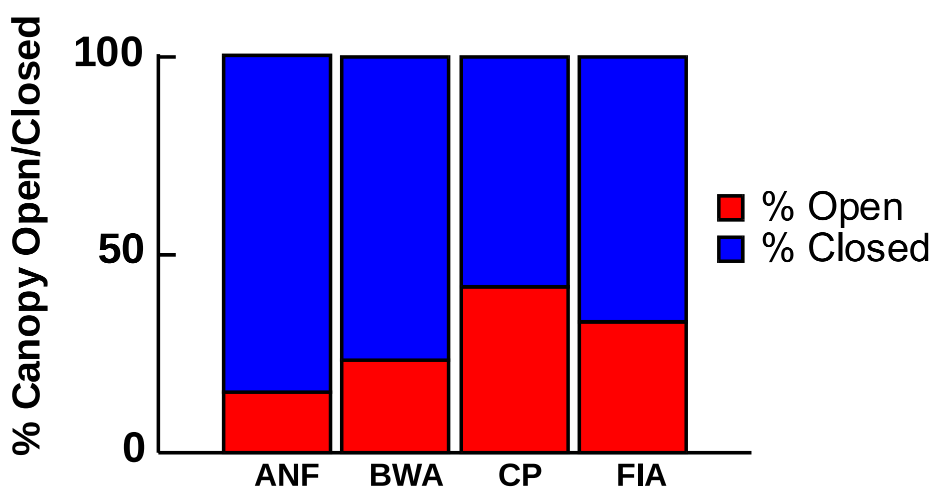


Figure 24. Open vs. Closed Canopy Among Ownerships

As noted above, CP ownership had the highest deer density, but similar impact levels for CP compared with other ownerships. However, the significantly higher canopy opening may have produced more forage on CP forestlands, reducing the impact of deer density that was higher than on other ownerships with a smaller percentage of open canopy (and ostensibly less forage). As is obvious from Fig. 24, percent open canopy is lower ($P<0.01$) on the Public Sector (ANF) than the Private Sector.

Appendix 1 – Deer Density and Impact Protocols

Data for estimating overwinter deer density and deer impact on indicator plant species were collected from plots spaced 100' apart on five transects 5,280' long spaced 1,000' apart. Twenty-six grids of five transect lines were randomly located within the Project Area (Fig. 1).

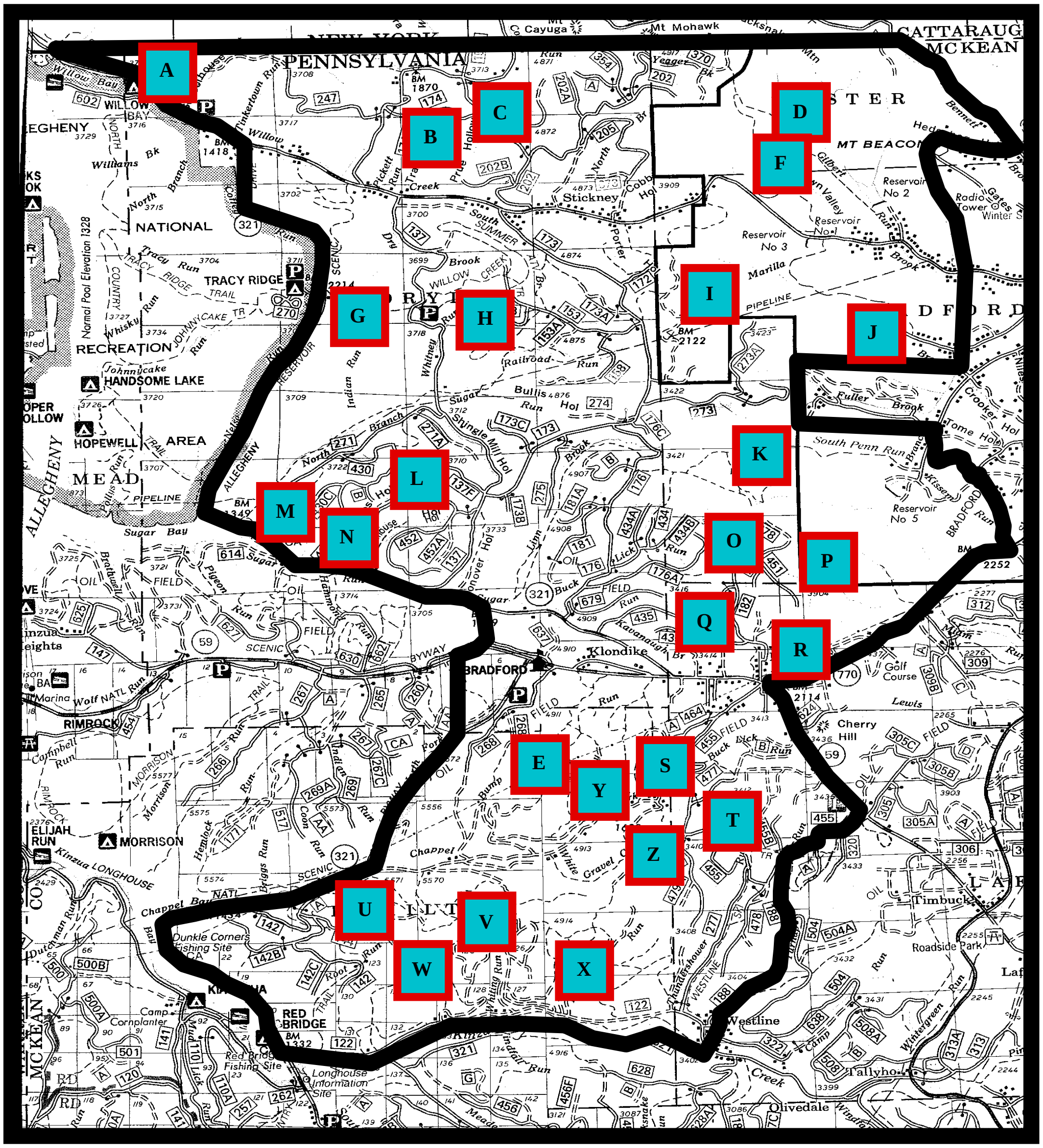


Figure1. Location of 26 sites where deer density and impact estimates were collected in 2008.

Typical grid of five transect lines 5,280' long spaced 1,000' apart characterized by site "U" (Fig.2).

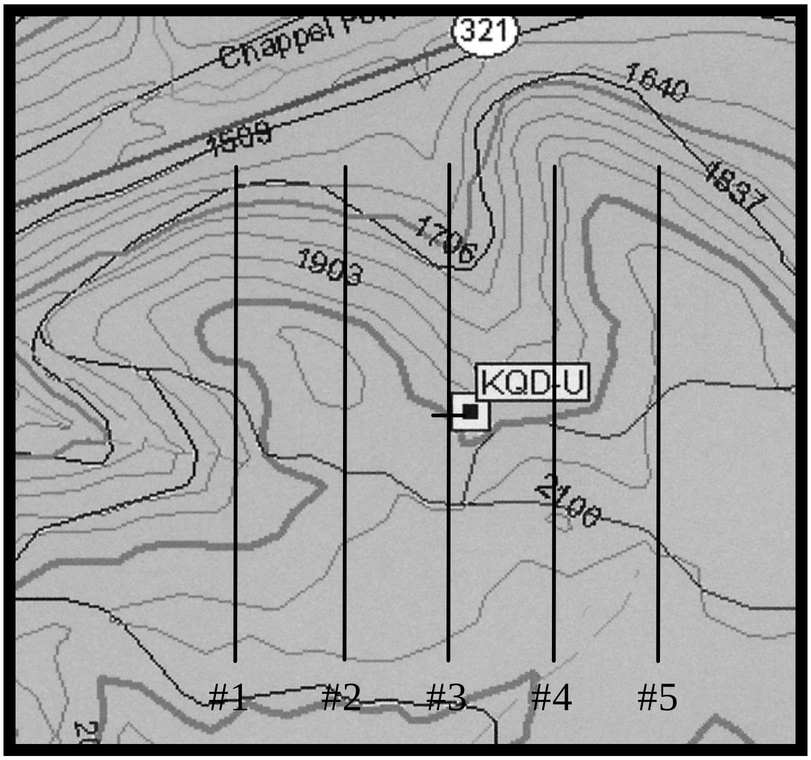


Figure 2. Typical deer density and impact grid.

The middle transect line (line #3) runs through the center point of each randomly located grid. Deer density data (counts of deer pellet groups) were collected on every plot; impact data (five impact levels on five indicator plant species) were collected on every other plot.

Density and impact data were collected by volunteers after the snow melted (to reveal presence of pellet groups) and prior to green-up of ground vegetation (after which pellet groups are covered by ground vegetation such as ferns and club mosses)(generally April 1 – May 10).

The five transect lines at each of the 24 locations were each treated as replicates: for estimates of deer density and impact there were thus five replicate samples. Each replicate sample of 24 transect lines was derived by randomly assigning the numbers 1-5 to each transect line at each location. The first replicate sample was comprised of all transect lines randomly selected as # 1, the second replicate sample was comprised of all transect lines randomly selected as #2 and so on.

Format for recording density and impact data is displayed in Table 1 below.

Table 1. KQDC Deer Density and Impact Data Sheet 2009

Site ______ Date ________________ Observer(s) ________________________________ Weather ___________________________

Pellet Group Route ____ Date _________ Observer _________ Weather _________

Transect Line	1	2	3	4	5
Number Plots					
Number Pellet Groups					
Number Dead Deer					

Deer Impact (record impact data at every other pellet group plot).

Transect Line				1			2			3			4			5		
Number Plots																		
Plots Without Regeneration																		
Plots With Regen, No Impact																		
Canopy closure (open or closed)				O	C		O	C		O	C		O	C		O	C	
Beech	0	L	M															
		H	S															
Striped	0	L	M															
Maple		H	S															
Red	0	L	M															
Maple		H	S															
Black	0	L	M															
Cherry		H	S															
Birches	0	L	M															
		H	S															
Hemlock	0	L	M															
		H	S															

Protocol for Collecting Pellet Group and Impact Data

Pellet Groups

1) Pellet groups are counted within 4 foot radius plots located at 100 foot intervals along transect lines one mile long. The first plot taken is 100 feet from the starting point from the beginning of each transect line, and the last plot is ~ 100 feet from the end of the line. At the end of each transect take a 90° bearing and travel 1,000 feet to the starting point of the next transect. There should be 52 plots per line (exceptions: plots inside fenced enclosures, or that fall in bodies of water aren't counted). Distances may be measured by pacing or hip chain. Keep track of plots for each transect line by tallying each plot by "dot tally" (see instructions below).

2) There must be at least 10 pellets in a group before it is counted, at least half of the pellets must be within the 4 foot radius plot, and pellets must be on top of leaves. Record number of pellet groups by "dot tally" (see instructions for "dot tallies" below).

3) If fenced enclosures or ponds/lakes are encountered along the transect line, either climb over the fence/wade through the water and continue along the transect line, or take a sighting on the other side of the fence/water, walk around, and resume the line. Do not count pellet groups inside the fence/water. Deduct number of plots that would have fallen inside the fence/water from the total of plots possible (52 for pellet group counts, 26 for impact counts) taken for each line. Try to keep the transect line as close to 5280 feet as possible. Observers using hand-held GPS units can plot way points from one side of the fence to the other and walk around rather than climb over the fence – just be sure to note length of transect line not walked inside the fence to be sure you only travel along 5,280 feet of transect line (including length inside fence).

4) Write the total number of plots and pellet groups for each transect line (top of form other side of page).

5). Record number of dead deer observed along transect line.

Deer Impact

1) Record deer damage to seedlings within the 4 foot radius plot by each of five species (striped maple, beech, red maple, black cherry, hemlock). Record data for seedlings $\geq$ 2 inches tall.

2) Impact will be recorded at every other pellet group plot. If no regeneration exists on plot, tally in "plots without regeneration" box. If regeneration exists, but is not browsed, tally in "plots with regen, no browsing" box. If seedlings are browsed, record impact for each of 5 indicator species (beech, striped maple, black cherry, red maple, hemlock). Use the Impact Diagram (Fig. 3 below) to characterize impact. Record impact in one of 5 categories: **0** – no impact; **light (L)** – 0 to 50% of seedling stems are browsed; **moderate (M)** - more than 50% of stems are browsed but plant is not hedged; **heavy**

(H) - more than 50% of stems are browsed and the plant is hedged (plant is browsed to a small ball of twigs); **severe (S)** - more than 50% of stems are browsed, the plant is hedged, and is less than 6 inches tall. There may be more than one seedling (including groups of seedlings as stump sprouts) for any species within a plot. Use your best judgment to characterize browsing across seedlings for each species within each plot, i. e. if most are heavily browsed, record damage as heavy for the species for that plot. Record data with "dot tally" described below.

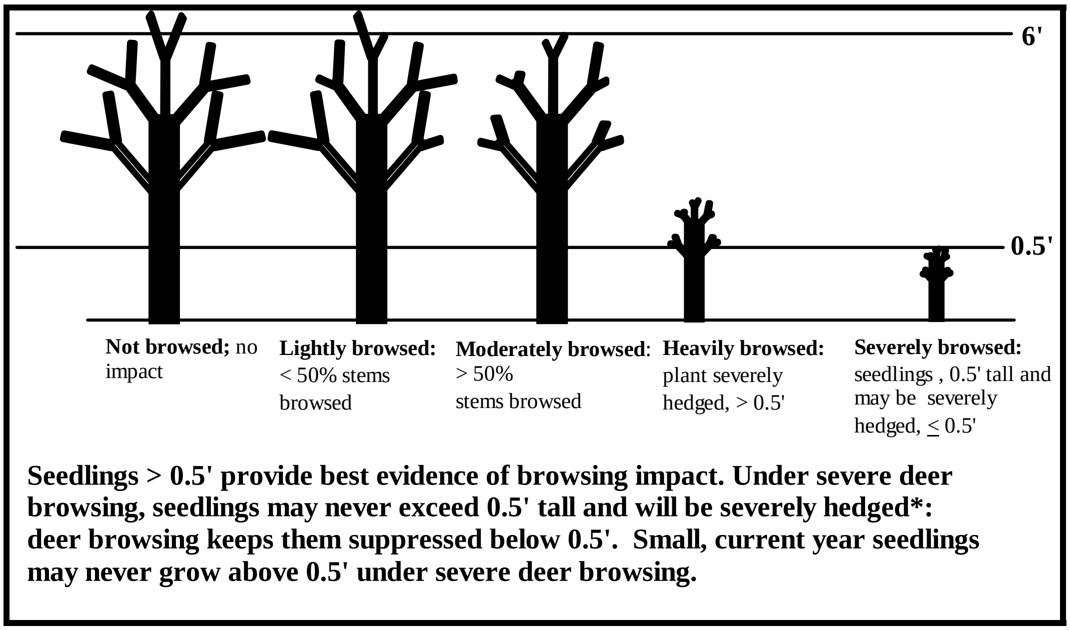


Figure 3. Deer impact diagram.

3) Record all data as a dot tally for all data entries for each transect line.

Recording dot tally data – **density plots and impact plots**: Keep track of number of density and impact plots *for each transect line* by dots and lines:

The first plot is recorded as a single dot (**.**);

The second plot is recorded by adding a second dot (**..**);

The third plot is recorded by adding a third dot: (**.:**);

The fourth plot is recorded by adding a fourth dot (**::**);

The fifth plot is recorded by connecting two of the dots (⁚_⁚);

The sixth plot is recorded by connecting another two dots (∟⁚);

The seventh plot is recorded by connecting another two dots (⊏);

The eighth plot is recorded by connecting another two dots (□);

The ninth plot is recorded by connecting another two dots (⧅);

The tenth plot is recorded by connecting the last two dots (⊠);

The next plot starts the sequence of dots and lines over: e.g., the 11th plot will be a dot next to a completed box of 4 dots and 6 lines.

Recording dot tally data – **pellet groups**: each pellet group observed within individual transect lines is recorded by a dot or a line. There often is more than one pellet group recorded per plot. Start over with the first dot for the first pellet group on succeeding transects: tally data separately for each transect.

The first pellet group is recorded as a single dot (**.**);

The second pellet group is recorded by adding a second dot (**..**);

The third pellet group is recorded by adding a third dot: (**.:**);

The fourth pellet group is recorded by adding a fourth dot (**::**);

The fifth pellet group is recorded by connecting two of the dots (⎵);

The sixth pellet group is recorded by connecting another two dots (∟);

The seventh pellet group is recorded by connecting another two dots (⊏);

The eighth pellet group is recorded by connecting another two dots (□);

The ninth pellet group is recorded by connecting another two dots (⧅);

The tenth pellet group is recorded by connecting the last two dots (⊠);

If there are more than ten pellet groups within individual plots/transects, the next group is recorded as a dot and succeeding groups are recorded as above – a second "box" of dots is constructed.

Recording dot tally data – **impact**: for each transect record: 1) plots with no regeneration; 2) plots with no impact to existing regeneration of any species, not just indicator species; 3) plots with impact level for each indicator seedling species in the respective impact level box (five boxes). There is only one impact level recorded per plot per indicator seedling species. If there are no indicator plants within individual plots, simply move to the next plot and record data for that plot, if indicator seedlings are present. For each transect, start over with the first dot for plots with no regeneration, for plots with no impact, and for plots with impacts on indicator seedlings.

For recording no regeneration/no impact, record dots and lines only for plots where there is no regeneration or no impact. Tally data separately for each transect line.

No regeneration/no impact at first plot is recorded as a single dot (**.**);

No regeneration/no impact at next plot is recorded by adding a second dot (..);

No regeneration/no impact at next plot is recorded by adding a third dot: (.:);

No regeneration/no impact at next plot is recorded by adding a fourth dot (::);

No regeneration/no impact at next plot is recorded by connecting two dots (⌴);

No regeneration/no impact at next plot is recorded by connecting two other dots (∟);

No regeneration/no impact at next plot is recorded by connecting two other dots (⊏);

No regeneration/no impact at next plot is recorded by connecting two other dots (□);

No regeneration/no impact at next plot is recorded by connecting two other dots (⧅);

No regeneration/no impact at next plot is recorded by connecting last two dots (⊠);

The next plot (within individual transects) starts the sequence of dots and lines over: e.g., the no regeneration/no impact plot will be recorded as a dot next to a completed box of 4 dots and 6 lines.

For recording impact levels on indicator seedlings, record dots and lines only for plots where there the indicator species is present. Tally data separately for each transect.

Impact level at first plot with impact at specific level is recorded as a single dot (.);

Impact level at next plot with impact at specific level recorded by adding a second dot (..);

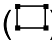
Impact level at next plot with impact at specific level is recorded by adding a third dot: (.:);

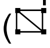
Impact level at next plot with impact at specific level is recorded by adding a fourth dot (::);

Impact level at next plot with impact at specific level is recorded by connecting two of the dots (⌴);

Impact level at next plot with impact at specific level is recorded by connecting another two dots (∟);

Impact level at next plot with impact at specific level is recorded by connecting another two dots (⊏);

Impact level at next plot with impact at specific level is recorded by connecting another two dots ();

Impact level at next plot with impact at specific level is recorded by connecting another two dots ();

Impact level at next plot with impact at specific level is recorded by connecting the last two dots ();

Impact level at next plot with impact at specific level starts the sequence of dots and lines over: e.g., the impact level within individual plots will be recorded as a dot next to a completed box of 4 dots and 6 lines.

Percent Overstory Canopy Closure

The Density/Impact Data Sheet for 2008-2009 was modified to include spaces for recording canopy closure information (see Table 1. KQDC Deer Density and Impact Data Sheet 2008 above, change highlighted in red font).

Protocol for determining whether canopy is open or closed. “Open” or “closed” status was recorded at each impact plot by dot tally as described below. Data tallied separately for each transect.

Open:

- ***Recent clearcut*** - If the plot falls in a recent clearcut and seedlings/shrubs haven’t grow up tall and thick enough to shade out the ground when leaves are on, record in the **Open** box

- ***Maturing stand that is thinned*** - If the plot falls in a maturing stand (trees in sawlog category – diameters over 10 inches) and the stand is thinned or shelterwood cut and the overstory is sufficiently opened to stimulate regeneration of seedlings (canopy of overstory trees are not touching other tree canopies on at least two sides) when leaves are out, record in the **Open** box

- ***Old growth stand with open canopy*** - If an you are lucky enough to be assessing impact in an old-growth stand, record in the **Open** box if plot falls in a spot where there tree canopies of overstory trees touch on 2 or fewer sides and if there is no intermediate canopy of dense sapling or pole trees that would suppress regeneration when leaves are on. Record in the **Closed** box if overstory trees touch on 3 or more sides and/or if there is dense shade provided by an intermediate canopy by sapling or pole trees.

Closed:

- ***Older clearcut, seedlings over 6 feet tall*** - If the plot falls in an older clearcut with seedlings over 6 feet tall and the ground below is likely completely shaded out when leaves are on, record in the **Closed** box

- ***Sapling/Pole stand*** - If the plot falls in a dense, unthinned sapling/pole stand (individual trees less than 10 inches in diameter, densely packed) with little sunlight reaching the ground when leaves are on, record in the **Closed** box
- ***Maturing stand not thinned*** - If the plot falls in a maturing stand (trees in sawlog category – diameters over 10 inches diameter) and the stand is not thinned or shelterwood cut so that little light will reach the forest floor when leaves are out, record in the **Closed** box

Open/Closed data are recorded with the “dot tally” method.

Record data as open or closed in first plot as a single dot (**.**);

Record data as open or closed in next plot by adding a second dot (**..**);

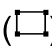
Record data as open or closed in next plot by adding a third dot: (**.:**);

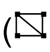
Record data as open or closed in next plot by adding a fourth dot (**::**);

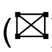
Record data as open or closed in next plot by connecting two dots ();

Record data as open or closed in next plot by connecting two other dots ();

Record data as open or closed in next plot by connecting two other dots ();

Record data as open or closed in next plot by connecting two other dots ();

Record data as open or closed in next plot by connecting two other dots ();

Record data as open or closed in next plot by connecting two other dots ();

The next plot starts the sequence of dots and lines over: e.g., the open/closed plot will be recorded as a dot next to a completed box of 4 dots and 6 lines.

Analysis and Interpretation of Deer Density and Impact

Separate estimates of deer density, impact, and canopy closure were calculated for each transect line. Percent of plots without regeneration was calculated by dividing number of plots without regeneration by total number of regeneration plots. Percent of plots without impact was calculated by dividing number of plots without impact by total number of regeneration plots. Percent of plots with open or closed canopy was calculated by dividing number of plots with open or closed canopy by total number of regeneration plots.

Precision

Sample variance (s^2) was calculated by the standard formula:

$$s^2 = \sum_{1..i}(y_i - \hat{y})^2/n(n-1)$$

where y_i = density and impact estimate from each transect line, $\hat{y}$ = average of all estimates, and n = number of estimates (24).

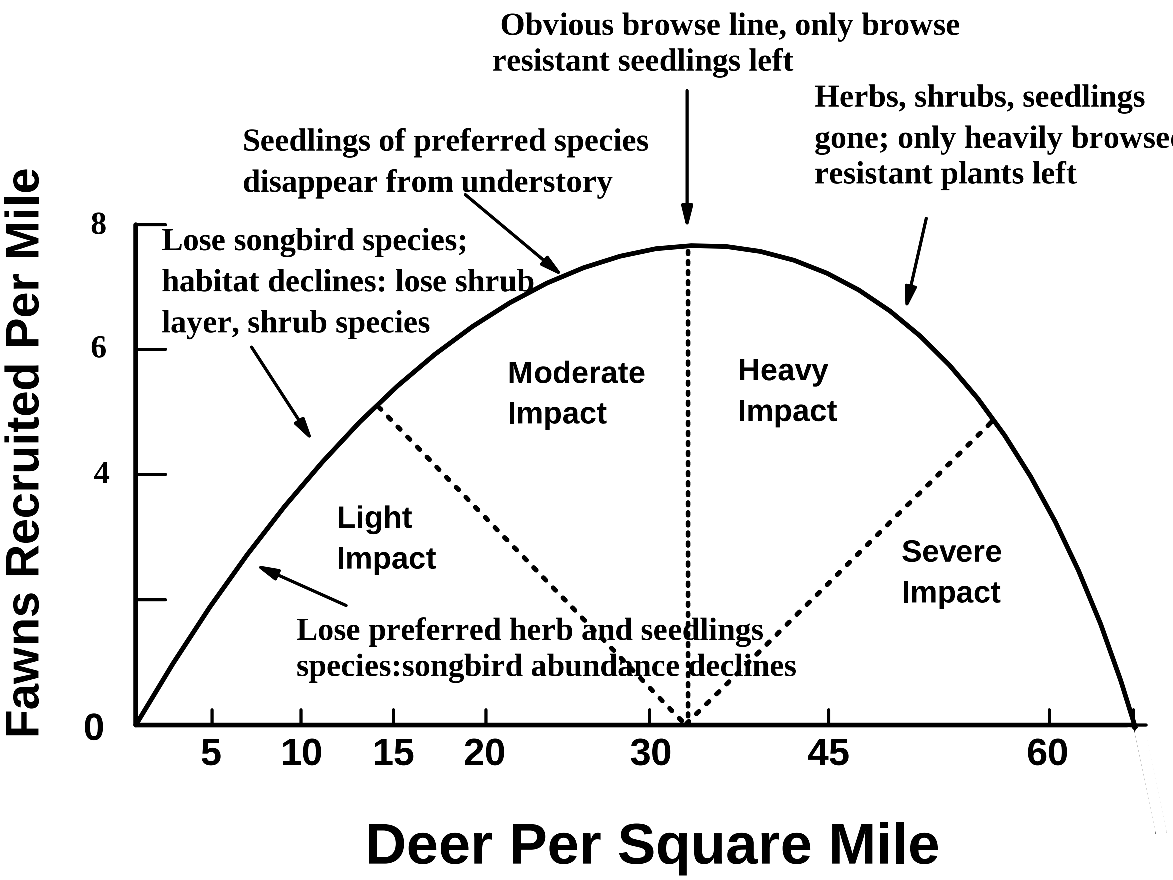
Precision of the density and impact estimates was estimated by constructing a confidence interval about the mean value of the estimates. The formula for the confidence interval was taken from Li (1964:212):

$$C.I. = \hat{y} \pm \tau_{\alpha/2} \sqrt{s^2/n},$$

Where $\hat{y}$ = average of transect estimates, $\tau_{\alpha/2}$ = t value for selected significance level/2 (2-tailed test), s^2 = sample variance, n = number of estimates. Selected significance level was 95%. Deer density and impact estimates are reported as the average density from the from five replicates ± the 95% confidence interval.

Interpretation of Impact Estimates

Interpretation of deer impact data is achieved by integrating impact levels on preferred, less-preferred, and non-preferred seedlings with percent plots with no impact to regeneration (see Fig. 4 below).



Light impact: Impact level is light to moderate for preferred and less-preferred species, and none to light for non-preferred species. Plots with no impact to regeneration are > 50%, plots with no regeneration are < 20%.

Moderate impact: Impact level is moderate to heavy for preferred species, and light to moderate for less-preferred and non-preferred species. Plots with no impact to regeneration are 20-50%, plots with no regeneration are >20% and < 60%.

Heavy impact: Impact level is heavy to severe for preferred species, and moderate to heavy for less-preferred and non-preferred species. Plots with no impact to regeneration are 10-20%, plots with no regeneration are >60% but less than 90%.

Severe impact: Imact level for all indicator seedlings, is heavy to severe. There is less than 10% of plots with no impact to regeneration and >90% plots with no regeneration.

Figure 4. Diagram for interpreting deer impact data.

Protocol for Deriving Estimates of Deer Density

Separate estimates of deer density were constructed for 5 replicates across the Project Area. A random number generator was used to assign a replicate number for each of the 5 transects at each of the 26 locations. All transect lines (26) assigned number one were used to generate an estimate of deer density for the entire Project Area. This process was repeated for each of the remaining 4 transect numbers, resulting in 5 randomly selected estimates of deer density for the Project Area. Deer density on each replicate was calculated by the formula:

$$\text{Deer density} = \frac{\text{number of pellet groups counted}}{\text{Pellet group deposit rate x days x area of transects in square miles}}$$

It was assumed that because of the small plot size observers would miss few, if any, pellet groups: daily defecation rate (pellet group deposit rate = 25 per day) determined by Sawyer et al. (1990) was used. Days is length of time in days from leaf-off (generally between October 25 and November 10, every year the date of leaf-off is noted for use in calculations the following spring) to the day the transects were run in spring. Area of transect in square miles was calculated as plot area (50.4 square feet) times number of plots divided by area of square mile (5,280' X 5,280').

Precision

Sample variance (s^2) was calculated by the standard formula:

$$s^2 = \sum_{1..i}(y_i - \hat{y})^2/n$$

where y_i = density estimate from each replicate of 24 transect lines, $\hat{y}$ = average of all replicates, and n = number of replicates (5).

Precision of the pellet group count technique was estimated by constructing a confidence interval about the mean value of pellet group counts.

$$\text{C.I.} = \hat{y} \pm \tau_{\alpha/2} \sqrt{s^2/n},$$

Where $\hat{y}$ = average of all replicates, $\tau_{\alpha/2}$ = t value for selected significance level/2 (2-tailed test), s^2 = sample variance, n = number of replicates. Selected significance level was 95%. Deer density estimates are reported as the average density from the 5 random samples ± the 95% confidence interval. Thus for 2004, estimated deer density of 24.7 deer per square mile has a 95% confidence interval of plus or minus 3.3 deer per square mile (true density lies between 28.0 deer per square mile and 21.4 deer per square mile).

Significance of Differences Among Years: Deer Density and Impact Data

Deer density and impact data are entered into a spreadsheet. Deer density is analyzed as discrete variables. Impact data are analyzed as proportional data. Mean values of parameters are calculated. Analysis of variance is used to test for differences with comparisons for more than 2 variables; τ-test is used for comparisons with only 2 variables.