

Pennsylvania
2021-22 Deer Harvest Estimates



Introduction

The Pennsylvania Game Commission (PGC) uses a report card registration system for hunters to report the harvest of each white-tailed deer in combination with field-checked deer to estimate reporting rates by type of deer (antlered versus antlerless), and deer management unit (DMU). Reporting rates and report card counts are used to estimate harvest by DMU for antlered and antlerless deer. Traditionally, the PGC has field-checked harvested deer only during the regular rifle seasons when most deer are harvested and has used these reporting rates to estimate harvest in all other seasons (e.g., early and late archery and muzzleloader seasons). Harvests were calculated as:

$$H = \frac{N_{RC}}{r_{3\text{-year}}}; \quad (1)$$

where H is the calculated harvest, N_{RC} is the number of report cards, and r is the reporting rate based on a 3-year running average. Harvests are calculated for antlered and antlerless deer by deer management unit, but no measure of precision was determined.

A recent evaluation of this method validated the science behind the PGC's method of sampling harvested deer and estimating reporting rates (Rosenberry et al. 2004). Based on results of this evaluation, a new method of estimating deer harvests was implemented for the 2004-05 hunting seasons. The new method no longer calculates a harvest estimate based on a 3-year running average. Rather, it estimates an annual harvest based on year-specific data. In addition, the new method provides a harvest estimate (as compared to calculated) with appropriate measures of precision (e.g., variance, standard error, coefficient of variation). This additional information permits an evaluation of the reliability of deer harvest estimates that was not possible in the past.

Methods

Beginning in 2004-05, deer harvests are estimated using a mark-recapture technique that is similar to the method we use to estimate bear populations. As a result of their widespread use over a long time period, much work has been done on application of mark-recapture techniques under many different scenarios. When estimating deer harvests, a closed, two-sample Lincoln-Petersen estimator is used. Deer are considered marked when they are checked in the field by deer aging teams. The recapture occurs when marked deer are reported on report cards sent in by hunters.

Assumption of the Lincoln-Petersen estimator include:

1. The sampled population is closed.
2. All animals are equally likely to be captured in each sample
3. Data are recorded correctly.

Assumption 1. Closed Population. The sampled population is the annual deer harvest. Additions to this population occur throughout the hunting seasons; however, once deer aging activities are

completed, the marked sample will not change. Additions only occur as unmarked animals that continue to be reported throughout the deer hunting seasons. As a result, the closure assumption can be relaxed and the Lincoln-Petersen estimator remains valid for estimating the harvest once all report cards are tallied (Pollock et al. 1990).

Assumption 2. Equal catchability. This assumption is difficult to meet in most wildlife situations (Pollock et al. 1990, Thompson et al. 1998). For estimating deer harvests, the assumption that all animals are equally likely to be included in each sample refers to a harvested deer's chance being in both the marked sample and reported sample. Our marking procedures at processors and other specific locations do not provide an equal chance of being marked because some deer will not be taken to a processor. One method of relaxing this assumption is to use different methods for marking and reporting. In the case of deer harvest estimates, if the probabilities of a deer being marked and being reported are independent, Lincoln-Petersen estimates will be unbiased (Seber 1982). Available evidence indicates that our marked sample is representative of the harvest and therefore should not bias our results (Rosenberry et al. 2004).

One known problem with reporting rates is they differ by seasons (Rosenberry et al. 2004). As a result, early seasons such as archery and October muzzleloader and rifle season estimates would be biased high. This is an issue that warrants further investigation; however, the effect on the overall harvest estimate is minimal because most deer are harvested during the regular firearms season (Rosenberry et al. 2004).

Assumption 3. Data recorded correctly. This assumption is met through accurate recording and entering of data into databases. Validation programs are used to check data for accuracy.

Based on the assumptions of the Lincoln-Petersen estimator and the characteristics of our samples, the Lincoln-Petersen estimator is an appropriate method for estimating deer harvests.

Because reporting rates in Pennsylvania vary by year, antlered and antlerless deer, and DMU (Rosenberry et al. 2004), annual deer harvest estimates are calculated for antlered and antlerless deer in each WMU using Chapman's (1951) modified Lincoln-Petersen estimator;

$$\hat{H} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1; \quad (2)$$

where \hat{H} is the harvest estimate, n_1 is the number of deer marked by deer aging teams, n_2 is the number of deer reported via report cards by hunters, and m_2 is the number of deer marked by deer aging teams and reported via report cards by hunters. This estimator is recommended (Nichols and Dickman 1996) because it has less bias than the original Lincoln-Petersen estimator (Chapman 1951).

Approximately unbiased variance of the harvest estimate $\text{Var}(\hat{H})$ is estimated as;

$$\text{Var}(\hat{H}) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2 (m_2 + 2)}; \quad (3)$$

from Seber (1970).

Results

By using mark-recapture estimators, more information is now available on precision of harvest estimates. Prior to 2003-04, calculated harvests were provided to the public with implied precision of a single deer (e.g., 517,529). In 2003-04, precision of calculated deer harvests was reported to the nearest ten deer (e.g., 464,890). In each case, implied precision of deer harvests overestimated the actual precision, but no methods of estimating precision were utilized. This is no longer the case and measures of precision are available for each harvest estimate. Consequently, more information can now be conveyed to the public regarding deer harvest estimates.

There are a number of options for presenting deer harvest results to the public. From a statistical viewpoint, the most appropriate presentation might include point estimates plus or minus standard errors or with confidence intervals. From a public relations standpoint, the most appropriate presentation may be point estimates. A concern with the statistical presentation is that all the numbers could be confusing to the general public and a concern with point estimates is the implied precision because point estimates are calculated to the single deer. An alternative, to both of these extreme cases, is to provide point estimates rounded to an appropriate number of figures. For example, if the precision of the harvest estimate is less than 1,000 based on the standard error, the harvest estimate would be rounded to the nearest 100. If the precision of the harvests estimate is greater than 1,000 based on the standard error, the harvest estimate would be rounded to the nearest 1,000. In the wildlife management literature, standard errors are commonly presented with point estimates as a measure of precision.

Season Harvests

Overall harvests are broken down into archery, regular firearms, and muzzleloader harvests, not because these numbers are used for deer management purposes, but because the public requests them. The overall removal of deer from a population during all hunting seasons is the parameter of greatest management interest. Whether a deer was harvested with a bow, muzzleloader, or rifle has limited value for management recommendations. Based on an evaluation of Pennsylvania's harvest estimates, attempting to calculate archery and muzzleloader harvests based on report cards and reporting rates results in biased numbers (Rosenberry et al. 2004), because hunters during the October seasons (archery, early muzzleloader, and October rifle) report deer harvests at a higher rate than hunters during the regular firearms season. This is a known problem with presenting archery and muzzleloader harvests, but it has minimal effect on

total harvests (Rosenberry et al. 2004) that are used for management purposes. Since season harvest estimates are expected by the public, we modified our method of calculating season harvests in 2007-08. Prior to 2007-08, we simply divided the overall harvest into season harvests using the proportion of report cards received during each type of season. For example, if 20% of the report cards were from archery season, then 20% of the harvest was identified as archery harvest. In 2007-08, we modified this slightly. First, we estimated the total deer harvests for all seasons. Second, we estimated the firearms season harvest using the animals we checked in the field, the number of those animals reported by hunters, and the number of report cards from the firearms season. We then subtracted the firearms season harvest from the overall harvest leaving only those deer killed during the archery and muzzleloader seasons. These remaining deer were divided into archery and muzzleloader harvests using the proportion of report cards similar to previous years. The primary difference between the current method and the previous method is that it should reduce bias in archery and muzzleloader harvests because the firearms harvest is estimated based on field data and not proportion of report cards.

Literature Cited

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HARVEST ESTIMATES, 2021-22

Overall Harvest Estimates

WMU	ANTLERED	ANTLERLESS	TOTAL
1A	6,000	13,200	19,200
1B	9,300	12,600	21,900
2A	6,800	10,600	17,400
2B	5,200	12,100	17,300
2C	9,300	15,400	24,700
2D	11,500	19,900	31,400
2E	5,900	9,500	15,400
2F	8,900	10,200	19,100
2G	6,200	4,800	11,000
2H	2,500	1,900	4,400
3A	5,400	5,400	10,800
3B	6,700	7,600	14,300
3C	7,600	9,400	17,000
3D	4,700	6,300	11,000
4A	4,900	10,300	15,200
4B	3,500	8,400	11,900
4C	5,700	6,400	12,100
4D	7,200	10,300	17,500
4E	7,900	11,800	19,700
5A	3,100	7,200	10,300
5B	7,800	17,100	24,900
5C	6,600	14,700	21,300
5D	2,600	6,300	8,900
UNK	20	90	110
TOTAL	145,320	231,490	376,810

Archery Harvest Estimates*(Includes harvests taken with archery methods, outside of the general firearms season)*

WMU	ANTLERED	ANTLERLESS	TOTAL
1A	3,360	3,590	6,950
1B	4,550	2,250	6,800
2A	3,250	2,330	5,580
2B	3,950	5,300	9,250
2C	4,420	3,530	7,950
2D	5,800	4,010	9,810
2E	2,370	1,690	4,060
2F	3,270	1,350	4,620
2G	1,950	850	2,800
2H	770	280	1,050
3A	1,980	1,010	2,990
3B	2,640	1,430	4,070
3C	2,770	1,760	4,530
3D	1,980	1,500	3,480
4A	1,340	1,570	2,910
4B	1,670	2,070	3,740
4C	2,870	1,750	4,620
4D	2,780	2,300	5,080
4E	3,630	2,730	6,360
5A	1,380	2,200	3,580
5B	5,040	7,280	12,320
5C	4,730	6,890	11,620
5D	2,080	4,390	6,470
UNK	0	10	10
TOTAL	68,580	62,070	130,650

Regular Firearms Season Harvest Estimates*(Includes all harvests taken during the general firearms season, regardless of hunting implement)*

WMU	ANTLERED	ANTLERLESS	TOTAL
1A	2,600	8,300	10,900
1B	4,700	9,400	14,100
2A	3,500	7,000	10,500
2B	1,200	6,100	7,300
2C	4,800	10,600	15,400
2D	5,600	14,000	19,600
2E	3,500	6,900	10,400
2F	5,600	7,800	13,400
2G	4,200	3,300	7,500
2H	1,700	1,400	3,100
3A	3,400	3,800	7,200
3B	4,000	5,400	9,400
3C	4,800	6,800	11,600
3D	2,700	4,300	7,000
4A	3,500	7,800	11,300
4B	1,800	5,600	7,400
4C	2,800	4,100	6,900
4D	4,400	7,000	11,400
4E	4,200	8,100	12,300
5A	1,700	4,400	6,100
5B	2,700	8,500	11,200
5C	1,800	7,000	8,800
5D	500	1,700	2,200
UNK	20	80	100
TOTAL	75,720	149,380	225,100

Muzzleloader Harvest Estimates*(Includes harvests taken with a muzzleloader, outside of the general firearms season)*

WMU	ANTLERED	ANTLERLESS	TOTAL
1A	40	1,310	1,350
1B	50	950	1,000
2A	50	1,270	1,320
2B	50	700	750
2C	80	1,270	1,350
2D	100	1,890	1,990
2E	30	910	940
2F	30	1,050	1,080
2G	50	650	700
2H	30	220	250
3A	20	590	610
3B	60	770	830
3C	30	840	870
3D	20	500	520
4A	60	930	990
4B	30	730	760
4C	30	550	580
4D	20	1,000	1,020
4E	70	970	1,040
5A	20	600	620
5B	60	1,320	1,380
5C	70	810	880
5D	20	210	230
UNK	0	0	0
TOTAL	1,020	20,040	21,060

ANNUAL CHANGES

Overall Harvest Estimates

WMU	Total Harvest Estimate				Percent Change	
	2018-19	2019-20	2020-21	2021-22	Previous Year	Previous 3-Year Average
1A	18,200	19,600	27,000	19,200	-29%	-11%
1B	23,800	21,400	29,500	21,900	-26%	-12%
2A	16,900	16,800	19,900	17,400	-13%	-3%
2B	17,000	15,900	21,200	17,300	-18%	-4%
2C	21,387	23,469	24,100	24,700	2%	7%
2D	32,758	31,888	30,700	31,400	2%	-1%
2E	16,001	15,873	17,800	15,400	-13%	-7%
2F	15,673	18,724	20,700	19,100	-8%	4%
2G	13,702	14,205	14,300	11,000	-23%	-22%
2H	4,300	3,500	4,500	4,400	-2%	7%
3A	12,200	11,400	13,700	10,800	-21%	-13%
3B	15,400	17,900	17,600	14,300	-19%	-16%
3C	19,900	22,200	25,300	17,000	-33%	-24%
3D	10,900	10,900	12,600	11,000	-13%	-4%
4A	13,330	13,924	16,000	15,200	-5%	5%
4B	12,216	13,985	15,800	11,900	-25%	-15%
4C	13,000	15,300	15,100	12,100	-20%	-16%
4D	17,381	19,655	21,400	17,500	-18%	-10%
4E	16,300	16,800	19,800	19,700	-1%	12%
5A	7,700	8,400	9,600	10,300	7%	20%
5B	23,808	25,545	26,000	24,900	-4%	-1%
5C	24,015	22,027	23,600	21,300	-10%	-8%
5D	8,600	9,200	8,700	8,900	2%	1%
UNK	219	836	280	110		
TOTAL	374,690	389,431	435,180	376,810	-13%	-6%

Antlered Harvests

WMU	Antlered Harvest Estimate				Percent Change	
	2018-19	2019-20	2020-21	2021-22	Previous Year	Previous 3-Year Average
1A	5,800	6,400	9,000	6,000	-33%	-15%
1B	8,000	8,700	11,700	9,300	-21%	-2%
2A	6,000	6,900	8,100	6,800	-16%	-3%
2B	5,000	5,500	6,200	5,200	-16%	-7%
2C	9,600	9,400	8,400	9,300	11%	2%
2D	11,800	13,000	12,000	11,500	-4%	-6%
2E	6,300	6,400	6,500	5,900	-9%	-8%
2F	7,700	9,000	10,700	8,900	-17%	-3%
2G	6,300	8,100	7,500	6,200	-17%	-15%
2H	2,500	2,400	2,900	2,500	-14%	-4%
3A	4,800	5,700	7,000	5,400	-23%	-7%
3B	7,000	7,600	9,100	6,700	-26%	-15%
3C	7,700	9,400	10,800	7,600	-30%	-18%
3D	5,200	6,000	6,200	4,700	-24%	-19%
4A	5,100	6,000	5,200	4,900	-6%	-10%
4B	5,300	5,700	5,000	3,500	-30%	-34%
4C	5,800	7,000	7,000	5,700	-19%	-14%
4D	8,300	8,700	9,100	7,200	-21%	-17%
4E	7,000	7,300	8,600	7,900	-8%	3%
5A	3,100	3,400	3,500	3,100	-11%	-7%
5B	9,200	10,200	9,600	7,800	-19%	-19%
5C	7,600	7,600	8,400	6,600	-21%	-16%
5D	2,600	2,500	2,200	2,600	18%	7%
UNK	50	340	80	20		
TOTAL	147,750	163,240	174,780	145,320	-17%	-10%

Antlerless Harvests

WMU	Antlerless Harvest Estimate				Percent Change	
	2018-19	2019-20	2020-21	2021-22	Previous Year	Previous 3-Year Average
1A	12,400	13,200	18,000	13,200	-27%	-9%
1B	15,800	12,700	17,800	12,600	-29%	-18%
2A	10,900	9,900	11,800	10,600	-10%	-2%
2B	12,000	10,400	15,000	12,100	-19%	-3%
2C	11,787	14,069	15,700	15,400	-2%	11%
2D	20,958	18,888	18,700	19,900	6%	2%
2E	9,701	9,473	11,300	9,500	-16%	-6%
2F	7,973	9,724	10,000	10,200	2%	10%
2G	7,402	6,105	6,800	4,800	-29%	-29%
2H	1,800	1,100	1,600	1,900	19%	27%
3A	7,400	5,700	6,700	5,400	-19%	-18%
3B	8,400	10,300	8,500	7,600	-11%	-16%
3C	12,200	12,800	14,500	9,400	-35%	-29%
3D	5,700	4,900	6,400	6,300	-2%	11%
4A	8,230	7,924	10,800	10,300	-5%	15%
4B	6,916	8,285	10,800	8,400	-22%	-3%
4C	7,200	8,300	8,100	6,400	-21%	-19%
4D	9,081	10,955	12,300	10,300	-16%	-4%
4E	9,300	9,500	11,200	11,800	5%	18%
5A	4,600	5,000	6,100	7,200	18%	38%
5B	14,608	15,345	16,400	17,100	4%	11%
5C	16,415	14,427	15,200	14,700	-3%	-4%
5D	6,000	6,700	6,500	6,300	-3%	-2%
UNK	169	496	200	90		
TOTAL	226,940	226,191	260,400	231,490	-11%	-3%

DATA USED TO ESTIMATE DEER HARVESTS

Antlered

WMU	No. Checked in Field	Checked & Reported	Total Reported	Published Harvest Estimates ¹
1A	146	52	2,149	6,000
1B	332	88	2,478	9,300
2A	190	59	2,150	6,800
2B	83	31	1,976	5,200
2C	342	116	3,182	9,300
2D	334	113	3,908	11,500
2E	269	96	2,125	5,900
2F	469	175	3,331	8,900
2G	318	122	2,374	6,200
2H	63	22	914	2,500
3A	349	119	1,865	5,400
3B	414	137	2,230	6,700
3C	370	120	2,468	7,600
3D	307	119	1,842	4,700
4A	180	54	1,491	4,900
4B	149	65	1,549	3,500
4C	360	156	2,484	5,700
4D	449	162	2,606	7,200
4E	407	122	2,379	7,900
5A	77	30	1,249	3,100
5B	251	96	2,999	7,800
5C	163	61	2,487	6,600
5D	52	23	1,193	2,600
UNK ²			7	20
TOTAL	6,074	2,138	51,436	145,320

¹ - Published harvest estimates are estimated using a Mark-Recapture estimator and are rounded to the nearest 100 or 1,000 depending on precision of the estimate.

² - UNK calculated as total unknown reported divided by statewide reporting rate, rounded to 10s

Antlerless

WMU	No. Checked in Field	Checked & Reported	Total Reported	Published Harvest Estimates¹
1A	470	129	3,653	13,200
1B	1,141	291	3,220	12,600
2A	570	143	2,670	10,600
2B	399	103	3,144	12,100
2C	1,033	318	4,755	15,400
2D	1,198	376	6,259	19,900
2E	538	174	3,080	9,500
2F	903	263	2,990	10,200
2G	374	119	1,522	4,800
2H	110	43	765	1,900
3A	453	145	1,749	5,400
3B	810	248	2,348	7,600
3C	777	253	3,057	9,400
3D	635	207	2,072	6,300
4A	539	152	2,908	10,300
4B	593	167	2,388	8,400
4C	753	288	2,462	6,400
4D	904	301	3,434	10,300
4E	1,210	368	3,588	11,800
5A	252	75	2,170	7,200
5B	1,050	295	4,815	17,100
5C	639	211	4,857	14,700
5D	225	96	2,692	6,300
UNK²			30	90
TOTAL	15,576	4,765	70,628	231,490

¹ - Published harvest estimates are estimated using a Mark-Recapture estimator and are rounded to the nearest 100 or 1,000 depending on precision of the estimate.

² - UNK calculated as total unknown reported divided by statewide reporting rate, rounded to 10s

NOTE: CWD DMAP permits not included in 'Total Reported'.

COMMENTS

- Reporting rates remain low. Antlered 35% (Range: 27% to 44%), Antlerless 31% (Range: 25% to 43%)
- Majority of deer were reported online. 70% of deer harvest reports were online, 22% were on report cards, and 8% were by phone.
- Harvest estimates are based on more than 21,000 deer checked by Game Commission personnel and more than 122,000 harvest reports submitted by successful hunters.
- Harvest estimates are calculated using a common wildlife management technique called ‘mark-recapture’. Data used to estimate harvests includes 2 data sets; 1) data collected in the field by Game Commission deer aging teams and 2) reports from successful hunters.
- For a full explanation of harvest estimating procedures, including example calculations, see pages 55 to 59 in the [deer management plan](#). The plan is available on the PGC’s website, www.pgc.pa.gov, click on “Popular Hunting Pages” at bottom of home page, then “White-tailed deer”, then under “Deer Management”.

Antlered Harvests

- Antlered harvest decreased an average of 15% from the 2020-21 season.
- Age structure of this year’s harvest was 38% 1.5 year old bucks and 62% 2.5 year old and older bucks.
- Comparisons between the current year’s harvest and historic antlered harvests often do not consider hunter numbers. In 1986, there were 1,000,000 deer hunters in Pennsylvania. Today, there are around 650,000 deer hunters. When corrected by the number of hunters, success rates are higher today than in the past, even with antler-point restrictions.
 - Historic Antlered Deer Hunter Success Rates versus Recent

1987-88	16% of deer hunters harvested an antlered deer
1997-98	19% of deer hunters harvested an antlered deer
2007-08	15% of deer hunters harvested an antlered deer
2017-18	23% of deer hunters harvested an antlered deer
2018-19	22% of deer hunters harvested an antlered deer
2019-20	25% of deer hunters harvested an antlered deer
2020-21	26% of deer hunters harvested an antlered deer
2021-22 ¹	22% of deer hunters harvested an antlered deer

¹ Current year deer hunter numbers are not available until later this year, so are based on previous year.

Antlerless Harvests

- Age structure of this year’s harvest was 69% adult females, 16% button bucks, and 15% doe fawns, consistent with long-term averages.
- Antlerless hunter success rates remained around 25% (approximately a quarter of all antlerless licenses were used to harvest an antlerless deer). This is on average with harvest success for recent years.