Pennsylvania

2022-23 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:

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

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;

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

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 Var($\hat{H}$) is estimated as;

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

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.

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HARVEST ESTIMATES, 2022-23

Overall Harvest Estimates

WMU	ANTLERED	ANTLERLESS	TOTAL
1A	9,000	13,800	22,800
1B	9,100	15,300	24,400
2A	8,700	11,000	19,700
2B	6,600	15,000	21,600
2C	10,000	16,600	26,600
2D	14,000	23,000	37,000
2E	6,700	10,600	17,300
2F	8,800	11,800	20,600
2G	6,400	5,100	11,500
2H	2,200	1,800	4,000
3A	5,700	5,600	11,300
3B	7,300	8,900	16,200
3C	8,000	12,000	20,000
3D	5,500	7,400	12,900
4A	3,800	11,100	14,900
4B	4,800	8,400	13,200
4C	6,900	8,200	15,100
4D	7,900	12,200	20,100
4E	8,000	12,400	20,400
5A	3,100	7,400	10,500
5B	10,900	16,300	27,200
5C	7,200	16,700	23,900
5D	2,500	6,700	9,200
UNK	1,090	1,470	2,560
TOTAL	**164,190**	**258,770**	**422,960**

Archery Harvest Estimates

(Includes harvests taken with archery methods, outside of the general firearms season)

WMU	ANTLERED	ANTLERLESS	TOTAL
1A	4,730	3,810	8,540
1B	3,970	2,950	6,920
2A	3,620	2,060	5,680
2B	4,830	6,750	11,580
2C	4,410	3,900	8,310
2D	6,690	4,450	11,140
2E	2,540	1,900	4,440
2F	3,250	1,930	5,180
2G	2,070	950	3,020
2H	770	280	1,050
3A	2,070	1,030	3,100
3B	3,050	1,830	4,880
3C	2,870	2,170	5,040
3D	2,260	2,030	4,290
4A	1,170	1,970	3,140
4B	2,070	2,100	4,170
4C	3,450	2,170	5,620
4D	3,020	2,840	5,860
4E	3,610	2,800	6,410
5A	1,390	2,460	3,850
5B	6,730	6,600	13,330
5C	5,020	8,040	13,060
5D	2,080	4,760	6,840
UNK	100	90	190
TOTAL	**75,770**	**69,870**	**145,640**

Regular Firearms Season Harvest Estimates

(Includes all harvests taken during the general firearms season, regardless of hunting implement)

WMU	ANTLERED	ANTLERLESS	TOTAL
1A	4,200	8,600	12,800
1B	5,100	11,100	16,200
2A	5,000	7,700	12,700
2B	1,700	7,400	9,100
2C	5,500	11,000	16,500
2D	7,200	15,900	23,100
2E	4,100	7,600	11,700
2F	5,500	8,400	13,900
2G	4,300	3,400	7,700
2H	1,400	1,200	2,600
3A	3,600	3,900	7,500
3B	4,200	6,000	10,200
3C	5,100	8,500	13,600
3D	3,200	4,600	7,800
4A	2,600	8,000	10,600
4B	2,700	5,500	8,200
4C	3,400	5,200	8,600
4D	4,800	8,100	12,900
4E	4,300	8,500	12,800
5A	1,700	4,400	6,100
5B	4,100	8,300	12,400
5C	2,100	7,900	10,000
5D	400	1,800	2,200
UNK	990	1,340	2,330
TOTAL	**87,190**	**164,340**	**251,530**

Muzzleloader Harvest Estimates

(Includes harvests taken with a muzzleloader, outside of the general firearms season)

WMU	ANTLERED	ANTLERLESS	TOTAL
1A	70	1,390	1,460
1B	30	1,250	1,280
2A	80	1,240	1,320
2B	70	850	920
2C	90	1,700	1,790
2D	110	2,650	2,760
2E	60	1,100	1,160
2F	50	1,470	1,520
2G	30	750	780
2H	30	320	350
3A	30	670	700
3B	50	1,070	1,120
3C	30	1,330	1,360
3D	40	770	810
4A	30	1,130	1,160
4B	30	800	830
4C	50	830	880
4D	80	1,260	1,340
4E	90	1,100	1,190
5A	10	540	550
5B	70	1,400	1,470
5C	80	760	840
5D	20	140	160
UNK	0	40	40
TOTAL	**1,230**	**24,560**	**25,790**

ANNUAL CHANGES

Overall Harvest Estimates

	Total Harvest Estimate				Percent Change	
WMU	2019-20	2020-21	2021-22	2022-23	Previous Year	Previous 3-Year Average
1A	19,600	27,000	19,200	22,800	19%	4%
1B	21,400	29,500	21,900	24,400	11%	1%
2A	16,800	19,900	17,400	19,700	13%	9%
2B	15,900	21,200	17,300	21,600	25%	19%
2C	23,469	24,100	24,700	26,600	8%	10%
2D	31,888	30,700	31,400	37,000	18%	18%
2E	15,873	17,800	15,400	17,300	12%	6%
2F	18,724	20,700	19,100	20,600	8%	6%
2G	14,205	14,300	11,000	11,500	5%	-13%
2H	3,500	4,500	4,400	4,000	-9%	-3%
3A	11,400	13,700	10,800	11,300	5%	-6%
3B	17,900	17,600	14,300	16,200	13%	-2%
3C	22,200	25,300	17,000	20,000	18%	-7%
3D	10,900	12,600	11,000	12,900	17%	12%
4A	13,924	16,000	15,200	14,900	-2%	-1%
4B	13,985	15,800	11,900	13,200	11%	-5%
4C	15,300	15,100	12,100	15,100	25%	7%
4D	19,655	21,400	17,500	20,100	15%	3%
4E	16,800	19,800	19,700	20,400	4%	9%
5A	8,400	9,600	10,300	10,500	2%	11%
5B	25,545	26,000	24,900	27,200	9%	7%
5C	22,027	23,600	21,300	23,900	12%	7%
5D	9,200	8,700	8,900	9,200	3%	3%
UNK	836	280	110	2,560		
TOTAL	**389,431**	**435,180**	**376,810**	**422,960**	**12%**	**6%**

Antlered Harvests

	Antlered Harvest Estimate				Percent Change	
WMU	2019-20	2020-21	2021-22	2022-23	Previous Year	Previous 3-Year Average
1A	6,400	9,000	6,000	9,000	50%	26%
1B	8,700	11,700	9,300	9,100	-2%	-8%
2A	6,900	8,100	6,800	8,700	28%	20%
2B	5,500	6,200	5,200	6,600	27%	17%
2C	9,400	8,400	9,300	10,000	8%	11%
2D	13,000	12,000	11,500	14,000	22%	15%
2E	6,400	6,500	5,900	6,700	14%	7%
2F	9,000	10,700	8,900	8,800	-1%	-8%
2G	8,100	7,500	6,200	6,400	3%	-12%
2H	2,400	2,900	2,500	2,200	-12%	-15%
3A	5,700	7,000	5,400	5,700	6%	-6%
3B	7,600	9,100	6,700	7,300	9%	-6%
3C	9,400	10,800	7,600	8,000	5%	-14%
3D	6,000	6,200	4,700	5,500	17%	-2%
4A	6,000	5,200	4,900	3,800	-22%	-29%
4B	5,700	5,000	3,500	4,800	37%	1%
4C	7,000	7,000	5,700	6,900	21%	5%
4D	8,700	9,100	7,200	7,900	10%	-5%
4E	7,300	8,600	7,900	8,000	1%	1%
5A	3,400	3,500	3,100	3,100	0%	-7%
5B	10,200	9,600	7,800	10,900	40%	18%
5C	7,600	8,400	6,600	7,200	9%	-4%
5D	2,500	2,200	2,600	2,500	-4%	3%
UNK	340	80	20	1,090		
TOTAL	**163,240**	**174,780**	**145,320**	**164,190**	**13%**	**2%**

Antlerless Harvests

	Antlerless Harvest Estimate				Percent Change	
WMU	2019-20	2020-21	2021-22	2022-23	Previous Year	Previous 3-Year Average
1A	13,200	18,000	13,200	13,800	5%	-7%
1B	12,700	17,800	12,600	15,300	21%	6%
2A	9,900	11,800	10,600	11,000	4%	2%
2B	10,400	15,000	12,100	15,000	24%	20%
2C	14,069	15,700	15,400	16,600	8%	10%
2D	18,888	18,700	19,900	23,000	16%	20%
2E	9,473	11,300	9,500	10,600	12%	5%
2F	9,724	10,000	10,200	11,800	16%	18%
2G	6,105	6,800	4,800	5,100	6%	-14%
2H	1,100	1,600	1,900	1,800	-5%	17%
3A	5,700	6,700	5,400	5,600	4%	-6%
3B	10,300	8,500	7,600	8,900	17%	1%
3C	12,800	14,500	9,400	12,000	28%	-2%
3D	4,900	6,400	6,300	7,400	17%	26%
4A	7,924	10,800	10,300	11,100	8%	15%
4B	8,285	10,800	8,400	8,400	0%	-8%
4C	8,300	8,100	6,400	8,200	28%	8%
4D	10,955	12,300	10,300	12,200	18%	9%
4E	9,500	11,200	11,800	12,400	5%	14%
5A	5,000	6,100	7,200	7,400	3%	21%
5B	15,345	16,400	17,100	16,300	-5%	0%
5C	14,427	15,200	14,700	16,700	14%	13%
5D	6,700	6,500	6,300	6,700	6%	3%
UNK	496	200	90	1,470		
TOTAL	**226,191**	**260,400**	**231,490**	**258,770**	**12%**	**8%**

DATA USED TO ESTIMATE DEER HARVESTS

Antlered

WMU	No. Checked in Field	Checked & Reported	Total Reported	Reporting Rate	Published Harvest Estimates[1]
1A	196	50	2,337	0.26	9,000
1B	351	105	2,746	0.30	9,100
2A	222	62	2,461	0.28	8,700
2B	93	29	2,104	0.31	6,600
2C	355	120	3,410	0.34	10,000
2D	349	103	4,133	0.30	14,000
2E	253	82	2,193	0.32	6,700
2F	439	163	3,280	0.37	8,800
2G	312	109	2,243	0.35	6,400
2H	67	23	765	0.34	2,200
3A	356	113	1,818	0.32	5,700
3B	379	124	2,408	0.33	7,300
3C	511	177	2,773	0.35	8,000
3D	317	121	2,100	0.38	5,500
4A	153	60	1,508	0.39	3,800
4B	186	66	1,715	0.35	4,800
4C	353	141	2,767	0.40	6,900
4D	404	140	2,736	0.35	7,900
4E	312	95	2,450	0.30	8,000
5A	60	28	1,488	0.47	3,100
5B	275	83	3,315	0.30	10,900
5C	258	94	2,640	0.36	7,200
5D	89	45	1,290	0.51	2,500
UNK[2]			371		1,090
TOTAL	**6,290**	**2,133**	**55,051**	**0.34**	**164,190**

[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	Reporting Rate	Published Harvest Estimates[1]
1A	677	205	4,191	0.30	13,800
1B	1,151	305	4,065	0.26	15,300
2A	704	213	3,341	0.30	11,000
2B	485	117	3,703	0.24	15,000
2C	930	287	5,123	0.31	16,600
2D	1,279	393	7,088	0.31	23,000
2E	578	194	3,581	0.34	10,600
2F	841	259	3,638	0.31	11,800
2G	398	130	1,684	0.33	5,100
2H	72	21	536	0.29	1,800
3A	540	173	1,816	0.32	5,600
3B	770	242	2,814	0.31	8,900
3C	859	248	3,485	0.29	12,000
3D	646	238	2,739	0.37	7,400
4A	486	120	2,768	0.25	11,100
4B	571	175	2,594	0.31	8,400
4C	812	301	3,052	0.37	8,200
4D	847	247	3,563	0.29	12,200
4E	1,123	352	3,903	0.31	12,400
5A	195	65	2,486	0.33	7,400
5B	1,031	352	5,587	0.34	16,300
5C	755	246	5,444	0.33	16,700
5D	285	127	2,995	0.45	6,700
UNK[2]			499		1,470
TOTAL	**16,035**	**5,010**	**80,695**	**0.31**	**258,770**

[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: DMAP and CWD DMAP permits not included in 'Total Reported'.

COMMENTS

- Reporting rates remain low. Antlered 34% (Range: 26% to 51%), Antlerless 31% (Range: 24% to 45%).
- Majority of deer were reported online. 72% of deer harvest reports were online, 20% were on report cards, and 8% were by phone.
- Harvest estimates are based on more than 22,000 deer checked by Game Commission personnel and more than 135,000 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 increased an average of 13% from the 2021-22 season.
- Age structure of this year's harvest was 33% 1.5-year-old bucks and 67% 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
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	22% of deer hunters harvested an antlered deer
2022-23[1]	26% 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 67% adult females, 17% button bucks, and 16% doe fawns, consistent with long-term averages.
- Antlerless hunter success rates remained around 27% (approximately a quarter of all antlerless licenses were used to harvest an antlerless deer). This is on average with harvest success for recent years.