A Deer Population Model for Microcomputers

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Abstract: A white-tailed deer *(Odocoileus virginianus)* population model is described which utilizes numbers and the age structure of animals taken in either sex harvests to predict population levels, future harvests and harvest levels required to manage properly the populations. The model predicted Kentucky's deer harvest within 5.1% from 1980 through 1984. Model design, harvest management decisions, and microcomputer utilities are discussed.

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Prior to 1979, white-tailed deer harvest decisions in Kentucky were based largely on buck harvest trends, percent of does in the harvest, and spotlight surveys. Almost inevitably, suggested changes in doe harvest regulations were met with requests that existing populations and optimum antlerless harvest quotas be determined. Given the lack of detail provided by routine survey data, changes in deer herd monitoring capabilities were in order.

Using the work of several authors (Anderson 1953, Land and Wood 1976, Shope 1978), a mathematical deer herd model was developed to provide county, regional, and statewide population predictions, recruitment rates, mortality data, and harvest predictions. The model was based on the number of deer harvested along with the sex and age of a sample of the harvested deer.

Methods

Kentucky's deer hunting regulations require that each successful hunter check his deer at 1 of about 500 check stations located throughout the state. Check stations are operated voluntarily by the owners of small businesses. Most are located at either country stores or gas stations. When a hunter brings the deer to a station, the deer tag is stamped to show that checking requirements were followed and completed. The hunter is required to fill out a portion of the deer tag listing the county of kill, date of harvest, and sex of the deer taken. Tags are collected at the end of the season and tabulated to determine the state's deer harvest.

From 1981 through the 1984 season, 19 biologists manned selected check stations and visited meat locker plants to determine the age and condition of the deer. The ages were determined by the wear and replacement method (Severinghaus 1949). Age and sex data from counties with similar harvest characteristics and from the same physiographic region were pooled to provide the basic age data used in calculating individual county population models. The age data were also pooled for the state to prepare a model of the whole herd.

The model was set up to operate on an electronic spreadsheet program called "Supercalc" distributed by the Sorcim Corporation. This program is available for use on microcomputers with 64 kilobytes of random access memory (RAM). The model Dpop4 can be made to operate on other spreadsheet programs such as "Visicalc" or "Multiplan." The only common feature needed is that the software should operate a framework of mathematical calculating cells created by the junction of columns and rows.

Table 1 displays the step-by-step procedure used in Dpop4. Cell A1 is titled "County," and the operator should place the name of the county or region to be modeled in cell B1. Column B contains input data that either must be known from other surveys or that must be derived from the model itself. Model steps are described in column A (cells A2-A54). Data regarding the age classes of bucks follow in descending order in B2 through B5. Starting with 0.5-year buck class (fawns), the classes are broken into years to the 3.5-year and older class. The total number in each class is opposite each description in cells B2 through B5. Female data follow the male data in cells B6 through B9. Total buck and doe harvests are requested in A10 and A11, respectively, and expressed numerically in B10 and B11, respectively.

Row 12 is for input of the total adult non-hunting mortality. Two years of population model data are required to calculate this parameter. If 2 years of data are not available then the model may be started with a value of 0.0001 in cell B12. Total adult non-hunting mortality is calculated by dividing the sum of the preseason year 1 adult male and female populations in the second year model by the postseason male and female populations of the first year's model and then taking the inverse of this value. The model does this in cell C57, and the results are displayed below. Similarly, the female non-hunting (NH) mortality is entered into row 13 after Dpop4 calculates it in cell C58. The formula here is the same except that it includes only females. The steps described above complete the input data items required to run the population model.

The mathematical steps in the model are listed and explained in Table 1. An actual example of Dpop4 models of Kentucky's deer herd for 1982 and 1983 are also given. The user should check the results with values given to ensure that no entry errors were made after entering the values and formulas.

Each calculation in the model relies either on the first 13 cells of input data or on calculations performed elsewhere in the model. The experienced user will soon find that formulas may be "short circuited" by entering direct values instead of calculated values. In cell B19, for example, the adult sex ratio is calculated from the

Table 1. Formulas and Results for Two Model Years Using DPOP4.

A	B	C
1 YEAR	1983	1984
2 0.5 BUCKS	64	43
3 1.5 BUCKS	943	509
4 2.5 BUCKS	204	122
5 3.5+ BUCKS	84	52
6 0.5 DOES	48	38
7 1.5 DOES	53	37
8 2.5 DOES	41	32
9 3.5 DOES	24	20
10 BUCK HARVEST	15121	15982
11 DOE HARVEST	2725	2733
12 NON-HUNTING MORTALITY	0.028	0.058
13 FEMALE NON-HUNTING MORTALITY	0.081	0.106
14 PERCENT 1.5 BUCKS	B3/(B3+B4+B5)	SAME*
VALUE =	0.766	0.745
15 PERCENT 1.5 DOES	B7/(B7+B8+B9)	SAME
VALUE =	0.449	0.416
16 AM AARR	(B3−B5)/(B3+B4+B5)	SAME
VALUE =	0.698	0.669
17 MALE FAWN HARVEST	B10*(B2/(B2+B3+B4+B5))	SAME
VALUE =	747	947
18 ADULT MALE HARVEST	B10−B17	SAME
VALUE =	14373	15035
19 ADULT SEX RATIO	B14/B15	SAME
VALUE =	1.706	1.793
20 PRODUCTION RATE	(B2+B6)/(B7+B8+B9)	SAME
VALUE =	1.025 "short circuited"	1.005
21 SEG. PRODUCTION RATE	B20/2	SAME
VALUE =	0.512	0.503
22 ADULT DOE HARVEST	B11*((B7+B8+B9)/(B6+B7+B8+B9)	SAME
VALUE =	1937	1915
23 PRE Y1 AM POP	B18/B16	SAME
VALUE =	20598	22470
24 POST Y1 AM POP	B23−B18	SAME
VALUE =	6225	7436
25 PRE Y1 AD POP	B23*B19	SAME
VALUE =	35131	40281
26 PRE Y1 FF POP	B25*B21	SAME
VALUE =	18005	20241
27 PRE Y1 FEM POP	B25+B26	SAME
VALUE =	53135	60522
28 POST Y1 FEM POP	B27−B11	SAME
VALUE =	46327	51664
29 Y2 RECR	B28*B20	SAME
VALUE =	47485	51922
30 Y2 ANTLERLESS POP	B28+B29	SAME
VALUE =	93813	103586
31 PRE Y1 MF POP	B25*B21	SAME
VALUE =	18004	20241
32 POST Y1 MF POP	B31−B17	SAME
VALUE =	17257	19294
33 PRE Y2 AM POP	B24+B32	SAME
VALUE =	22824	25179
34 PROJ. MINIMUM POP	B33+B30	SAME
VALUE =	116638	128766

(TABLE 1. CONTINUED)

A	B	C
35 EX ANTLERED HARVEST	B33*B16	SAME
VALUE =	15927	16848
36 TOT NUMERIC MORT	B34*B12	SAME
VALUE =	3265	7468
37 STABLE HARVEST LEVEL	B29−B36	SAME
VALUE =	44220	44454
38 FEM NUMERIC MORT	B28*B13	SAME
VALUE =	3752	5476
39 FEMALE HARVEST RATE	B22/B25	SAME
VALUE =	0.055	0.048
40 REMAINDER Y2 FEMALES	B28−B38	SAME
VALUE =	42575	46187
41 LOCATION		
VALUE =	KENTUCKY 83	KENTUCKY 84
42 EX ADULT DOE HARVEST	B39*B40	SAME
VALUE =	2347	2169
43 EX FAWN HARVEST	B41*B20	SAME
VALUE =	2406	2207
44 TOTAL EXPECTED HARVEST	B35+B41+B42	SAME
VALUE =	20680	21251
45 EX MALE FAWN HARVEST	B42*(B2/(B2+B6))	SAME
VALUE =	1375	1171
46 EX FEMALE FAWN HARVEST	B42*(B6/(B2+B6)	SAME
VALUE =	1031	1035
47 EX TOT BUCK HARVEST	B35+B44	SAME
VALUE =	17302	18019
48 EX TOT DOE HARVEST	B41+B45	SAME
VALUE =	3378	3231
49 PRE Y1 AM POP	B23	SAME
VALUE =	20598	22471
50 PRE Y1 AD POP	B25	SAME
VALUE =	35131	40282
51 POST Y1 FEMALE POP	B28	SAME
VALUE =	46327	51664
52 PRE Y2 AM POP	B33	SAME
VALUE =	22824	25180
53 PROJ. MINIMUM POP	B34	SAME
VALUE =	116638	128766
54 EX ANTLERED HARVEST	B35	SAME
VALUE =	15927	16848
55 STABLE HARVEST LEVEL	B37	SAME
VALUE =	44220	44454
56 GROSS HARVEST LEVEL	B29	SAME
VALUE =	47485	51922
57 CALC TOT MORT	FROM PRIOR YEAR	1−((C48+C49)/(B50+B51))
VALUE =		0.093
58 CALC FEM MORT	FROM PRIOR YEAR	1−(C49/B50))
VALUE =		0.130

*The same formula as in column B but corrected to column C.

observed percentages of each sex in the 1.5-year age classes. In Table 1 it is calculated as 1.706. However, a different sex ratio may be entered in place of the calculated sex ratio, and the spreadsheet will then recalculate all values using the new entry. This is of value when the operator is outputting several models using data pooled from points distributed throughout a region. If a few points have values far different from the pooled average, the actual values may be substituted in place of the pooled average. The values also can easily be changed back to the original.

Discussion

This model is primarily based on Lang and Wood's (1976) model that was used in Pennsylvania to predict harvests within 12% over 7 years. The key calculation is the adult male average annual reduction rate (AM-AARR). This variable reflects the average mortality of the adult male population (Lang and Wood 1976). The AM-AARR becomes more representative of the true mortality rate as the rate increases. At very low mortality rates the AM-AARR can even be negative (R. Downing pers. commun.). A better approximation might be obtained by substituting the yearling buck ratio (cell B14) for the AM-AARR.

Mortality rates calculated from the age structure tend to be most representative of true mortality when the rate is high and less representative when the rate is low because selection by the hunter favors younger animals until rates become high enough to begin correction for the bias (Anderson 1953). A high hunting mortality also improves model output because hunting will then make up a greater portion of the total mortality (Lang and Wood 1976).

Dpop4 is designed to be used when buck hunting pressure is limited by the number of days instead of the number hunters present, and doe hunting pressure is regulated by "doe days." In this situation the buck kill responds primarily to changes in population size, and the doe kill responds to changes in the numbers of hunter days.

DPOP4 will reflect naturally occurring changes in population size if hunting pressure is heavy and constant, but results tend to become confusing when major changes in hunting pressure occur. Two factors causing changes in hunting pressure are severe weather and changes in the laws establishing seasons that alter hunter participation. Another such factor in Kentucky is an increase in buck hunting pressure when doe hunting is initiated in a county. Such changes usually do not occur without the deer manager's knowledge, however.

The model loses much of its usefulness when hunting pressure is controlled directly by permits. This is especially true in instances when the number of permits fluctuates widely from one year to the next. In these cases the model predicts what would have occurred without changes in the hunting pressure, but the manager has changed the hunting pressure and resulting harvests so model results may be unreliable.

A fawn-per-doe ratio in the harvest is used in Dpop4 to estimate recruitment and is a feature that is subject to debate. Past studies have shown that the fawn segment of the herd may be subject to slightly more exploitation when the total level of exploitation is above 50% (Anderson 1953). Although fawn-to-doe harvest rates may not be an exact picture of the true herd, they do appear to be a viable index to recruitment. The use of fawn-to-doe ratios in the harvest to estimate recruitment has not been common in deer management since researchers began using age-specific reproduction rates (Severinghaus and Cheatum 1956).

A minor problem with Dpop4 is the use of the same recruitment rate to estimate fawn production in both the current year and the upcoming year. This can be corrected simply by entering either average or projected fawn-to-doe ratios or a recruitment rate based on antler beam diameter to calculate recruitment in subsequent years. In utero estimates of reproduction may also be substituted in the model for fawn-to-doe ratios when fawn mortality is known.

Mortality rates in Dpop4 are calculated by finding the proportional loss of animals between 2 model years. The post season Y1 female population (row 51 in Table 1) was 46,327 in 1983, yet the pre-season Y1 adult doe population (row 50 in Table 1) in the 1984 model was 40,282. The proportional loss, 0.870, is the survival rate, and the inverse, 0.130, is the calculated female mortality rate (row 58 in Table 1). This calculation has been shown to have a positive correlation with the posthunt modeled population (Shope 1978).

The calculation of a stable harvest level by Dpop4 is somewhat different from that calculated by Lang and Wood (1976) in that the mortality, as calculated by Shope's formula, is subtracted from the recruitment (row 37 in Table 1). Accordingly, the deer manager can tell if the upcoming harvest will be too many or too few deer by comparing the stable harvest level with the total expected harvest in the upcoming year. Harvests above the stable harvest rate will cause declines in the population, and harvests below the stable harvest rate will cause the population to increase.

The female harvest rate calculation in Table 1 is essential in making harvest management decisions. The female harvest rate is the percent of the preseason female population taken in the legal harvest. Use of the calculated female harvest rate in Dpop4 is an improvement over using the percent does in the total harvest (Hayne 1978) to make management decisions. The percent of does in the harvest does not take into account differences in mortality or natality rates and leaves this problem for the manager to decipher from the harvest data.

Dpop4 appears to do as well as Lang and Wood's (1976) model; however, DPOP4 has not been in use as long as the Lang and Wood model. Dpop4 predicted harvests within 5.1% of statewide harvests (Table 2) and predicted most counties within 15% (Table 3). However, in 14% of the cases, the prediction ranged between 17 and 23%, and doe harvests were overestimated by 10.1%. The reason for these occasional errors is suspected to come from 2 possible sources. As already pointed out, major changes in hunting pressure can invalidate the predictions due to changes in the adult male average annual reduction rate (row 16 in Table 1). Small sample

Table 2. Open County Deer Harvest and Population Predictions from DPOP4.

Year	Minimum Population	Expected Harvest	Actual Harvest	% Difference
1980	81,910	9,296	9,702	4.4
1981	105,484	14,399	14,960	3.9
1982	127,519	18,561	17,969	3.2
1983	118,464	19,480	18,732	3.8
1984	131,554	24,246	23,012	5.1
1985	134,350	25,967		

Table 3. Performance of DPOP4 in Predicting Harvests in 1984 in Kentucky.

County	Predicted Harvest			Actual Harvests			% Difference		
	Bucks	Does	Total	Bucks	Does	Total	Bucks	Does	Total
Carlisle	189	74	263	163	50	213	16.0	48.0	23.5
Bracken	255	108	363	236	94	330	8.1	14.9	10.0
Christian	817	244	1,061	780	231	1,011	4.7	5.6	4.9
Hancock	211	56	267	245	78	323	−13.9	−28.2	−17.3
Hopkins	685	183	868	670	166	836	2.2	10.2	3.8
Livingston	326	85	411	380	77	457	−14.2	10.4	−10.1
Owen	723	436	1,159	795	413	1,208	−9.1	5.6	−4.1
Scott	293	157	450	343	151	494	−14.6	4.0	8.9
Shelby	273	148	421	300	107	407	−9.0	38.3	3.4
Washington	238	107	345	257	119	376	−7.4	−10.0	−8.2
Webster	322	113	435	364	71	435	−11.5	59.1	0
Adair	91	0	91	107	0	107	−14.9	0	−14.9
Campbell	59	13	72	71	8	79	−16.9	62.5	−8.9
Graves	315	23	338	315	22	337	0	4.5	0.3
TOTAL	4,797	1,747	6,544	5,026	1,587	6,613	−4.6	10.1	−1.0

sizes or low harvests may also have biased model predictions. Most of the county doe harvests in Kentucky are <100 animals, and percentage figures may be inflated accordingly.

Determination of the proper sample size is a problem when modeling relies upon age structures. The sample size will vary with mortality rates, fawn-to-doe ratios or any of the numerous other features calculated by the model. The answer to this problem may be very difficult to determine.

Conclusions

Dpop4 can be a valuable tool for the deer manager by: 1) giving the public confidence in the ability of a deer manager; 2) allowing the manager to predict harvests; 3) showing visibly and instantaneously the effect of changes in vital statistics of the population; 4) showing the effects of doe day hunting and predicting doe hunting effects in regions without doe seasons; and 5) offering a management alternative when doe permit hunting is not needed or desired. Although it is a minimum population model, Dpop4 can represent what is occurring in the population. It also uses information that is easily gathered by the deer manager. The spreadsheet format is easy to use and understand and most input data are routinely gathered by many state fish and wildlife agencies. The model can be duplicated on any spreadsheet by typing in the formulas and input values in Table 1 while checking for accurately calculated results.

Literature Cited

Anderson, J. 1953. Analysis of a Danish doe-deer population. Danish Rev. of Game Biol. 2:127–155.

Hayne, D. W. and J. V. Guynn. 1976. Percentage does in total kill as a harvest strategy. Proc. Joint NE-SE Deer Study Group Meet., Blackstone, Va. 1:117–123.

Lang, L. M. and G. W. Wood. 1976. Manipulation of the Pennsylvania Deer Herd. Wildl. Soc. Bul. 4:159–166.

Severinghaus, C. W. 1949. Tooth development and wear as criteria of age in white-tailed deer. J. Wildl. Manage. 13:195–216.

——— and E. L. Cheatum. 1956. Life and times of the white-tailed deer. Pages 57–186 *in* W. P. Taylor, ed. The deer of North America. The Stackpole Co., Harrisburg, Pa. 668pp.

Shope, W. K. 1978. Estimating deer populations using CIR procedures and age structure data and harvest management decision making from CIR estimates. Trans. Annu. Northeast Deer Study Group. 14:28–35.