Description of KDFWR Elk Model Parameters

Introduction

Quantifying landscape-level population trends is one of the most challenging tasks that confronts wildlife managers. The ability to dependably identify population trends is especially important when issuing annual hunting permits for relatively small populations. Fortunately, past research provides various survey methodologies and population models that provide guidance when managing free-ranging wildlife populations.

KDFWR Elk Program staff have identified several key demographic metrics that are combined with site-specific variables (such as hunter access) to inform sound management decisions. It is important to note, however, that KDFWR staff do not view these metrics in a vacuum; rather, each piece of information is analyzed alongside the others as components of a whole. This approach entails additional complexity, but it provides a more comprehensive view of the elk population than might be otherwise obtained.

The following document describes the data currently collected by KDFWR Elk Program staff. Each section contains the rationale as to why the particular metric is important, followed by the general methods used to collect the data, and finally concluded with historical results over the course of the elk project. While no individual element provides a complete view of the Kentucky elk population, the combination of them all allows Elk Program staff to continue making sound management decisions in light of current data.

REPRODUCTION

Adult female reproduction and yearling female reproduction represent different components within the KDFWR elk model due to differential pregnancy rates between age classes. KDFWR collects two independent metrics for reproduction input into the model.

1. *Fetus collection:* KDFWR personnel collect fetuses from the cow elk hunt. This metric quantifies the breeding success rate during early gestation. Pregnancy rate is not a perfect proxy for successful reproduction due to potential termination of the pregnancy prior to birth, but it does provide information about reproductive trends over time (Table 1).
2. *Blood tests:* Development of a reliable blood test for pregnancy-specific protein B has allowed KDFWR to receive antemortem pregnancy data since 2012. These data have been collected as part of a cow elk research project and for cows captured for translocation to Missouri, Virginia, Wisconsin, interstate restoration and any other opportunistic captures. As with fetus collection, this pregnancy rate provides a quantifiable point of reference at a given period in gestation (Table 2). These samples have been collected throughout the elk zone and should provide a good representation of the general elk population.

Table 1. Pregnancy rate estimation from cow hunt fetus collections.

Year	Location	% Pregnant (Adult Only)	Average Conception Date
2002	Knott, Perry	100	9/25
2003	Knott, Perry	100	9/23
2004	Knott, Perry, Bell	72	9/27
2006	Knott, Perry, Floyd, Leslie, Bell	100	9/29
2007	Knott, Perry	71	

2008	Knott, Perry	81	
2010	Knott, Perry	100	9/24
2011			10/5
2012	Knott, Perry, Martin	93	9/26
2013	Knott, Perry	80	9/28
2014	Knott, Perry	89	10/7
2015	Knott, Perry	93	10/8
2016	Knott, Perry	83	10/6
2017	Knott, Perry	100	9/26
2018	None collected		
2019	Knott, Pike, Martin	80	9/29
2020	Knott, Pike, Martin	100	10/6

Table 2. BioPryn pregnancy test results.

Year	Age Class (n)	% Pregnant
2013	Yearling (9)	40
	Adult (14)	78
2014	Yearling (2)	50
	Adult (20)	75
2015	Yearling (3)	100
	Adult (6)	83
2016	Yearling (6)	17
	Adult (16)	88
2017	Yearling (1)	100
	Adult (8)	88
2018	Yearling (16)	38
	Adult (52)	85
2019	Yearling (13)	69
	Adult (56)	91
2020	Yearling (6)	17
	Adult (51)	88
2021	Yearling	50
	Adult (55)	76

SURVIVAL

Survival inputs are collected from a combination of past research and current observations.

1. *Past research:* Various studies have quantified annual survival and cause-specific mortality factors among discrete age and sex classes of Kentucky elk. These findings are used as a baseline for all modeling purposes (Table 3).
2. *Observations:* Past research results are compared with trend data from ARCs to ensure that these past results still seem valid in response to emerging information.

Table 3. Survival estimates from previous Kentucky elk studies.

Demographic Class	Survival rate	Period	Sample size	Reference
Adult female	.90	Annual	327	Larkin et al. 2003
Yearling female	.97	Annual	63	Larkin et al. 2003
Adult male	.92	Annual	81	Larkin et al. 2003
Yearling male	.90	Annual	66	Larkin et al. 2003
Calf	.76	Annual	27	Seward 2003
Calf	.92	Recruitment	143	Bowling 2009 (unpublished data)

Compendium of published survival rates for the Kentucky elk herd.

Larkin, J.L., D.S. Maehr, J.J. Cox, D.C. Bolin, and M.W. Wichrowski. 2003. Demographic characteristics of a reintroduced elk population in Kentucky. Journal of Wildlife Management 67(3):467-476.

Larkin, J.L., D.S. Maehr, J.J. Cox, M.W. Wichrowski, and R.D. Crank. 2002. Factors affecting reproduction and population growth in a restored elk population. Wildlife Bilology 8:49-54.

Seward, N.W. 2003. Elk calf survival, mortality, and neonatal habitat use in eastern Kentucky. M.S. Thesis. University of Kentucky, Lexington, KY, USA

Bowling, W. E. 2009. Maternal antibody transfer and meningeal worm infection rate in Kentucky elk. M. S. Thesis. University of Kentucky, Lexington, KY, USA

HARVEST

Annual permit number recommendations from Elk Program staff reflect both biologically appropriate harvest levels and available hunting access. The harvest component of the elk model incorporates information from post-hunting season telecheck results (Table 4). Any discussion of the harvest component of the elk model, however, requires that two other facets be noted.

1. *Actual harvest rates vs. permit numbers:* Actual harvest rates almost always lag the number of permits provided, since some hunters do not harvest an animal. The actual harvest rate differs based on permit type (bull vs. cow) and weapon choice (firearm vs. archery). Historical harvest rates between permit types can be used to run the model, but the preferred method is to wait until post-season telecheck results are available (Table 5).
2. *Wounding loss:* Wounding loss does occur in the Kentucky elk population. Recent research has helped quantify this mortality factor, which is incorporated into the elk model's survival parameter.

Table 4. Overall permit allocation

Year	# Bull Permits	# Cow Permits	Either Sex Archery	Commission Permits	Landowner Permits	Youth Permits	Voucher	Late Season	ERP
2001	5	5		2					
2002	5	5		2					
2003	5	5		2					

2004	20	20		2					
2005	50	50		2					
2006	60	140		2	15				
2007	75	225		2	19	2			
2008	100	300		10	23	2		50	
2009	250	750		10	22	7		25	
2010	200	600		10	25	5		25	
2011*	200	600		10	25	5		25	
2012*	225	675		10	25	5		25	
2013*	250	750		10	26	10		29	
2014*	250	750		10	25	10		5	
2015*	250	650		10	37	10		5	
2016*	250	649		10	41	10		5	
2017*	250	450		20	42	10	3	5	1
2018*	250	450		10	57	10	2	4	9
2019*	150	244	175	7	45	25	3	4	6
2020*	150	244	175	7	44	25	1	4	0

* Years that separate archery season was held

Table 5. Elk Harvest by Sex/Age

	Female	**Visible Antler**	**No Visible Antler**
2011	335	204	11
2012	360	224	11
2013	436	233	9
2014	270	225	11
2015	295	235	7
2016	284	229	13
2017	150	179	6
2018	172	185	11
2019	100	135	7
2020	85	180	4

Table 6. Sex and weapon specific harvest rates based on actual permits sold.

Year	**Sex**	**Weapon Type**	**% Harvest Success**
2012	Bull	Archery	77
		Firearm	89
	Cow	Archery	36
		Firearm	78
2013	Bull	Archery	67

		Firearm	88
	Cow	Archery	47
		Firearm	78
2014	Bull	Archery	74
		Firearm	84
	Cow	Archery	35
		Firearm	80
2015	Bull	Archery	74
		Firearm	84
	Cow	Archery	32
		Firearm	68
2016	Bull	Archery	70
		Firearm	81
	Cow	Archery	35
		Firearm	68
2017	Bull	Archery	47
		Firearm	64
	Cow	Archery	23
		Firearm	46
2018	Bull	Archery	51
		Firearm	59
	Cow	Archery	31
		Firearm	54
2019	Bull	Firearm	37
	Cow	Firearm	42
	Either Sex	Archery	29
2020	Bull	Firearm	55
	Cow	Firearm	38
	Either Sex	Archery	36

Prior to 2011, elk permits were not specific to a certain weapon. Hunters could use whatever weapon type was legal for deer. For example, if a bull hunter was not successful during the two weeks of bull rifle, they could bow hunt the remainder of the season (the end of deer archery season) with archery equipment. Table 6a shows the percent of harvest based on weapon type for each year.

Table 6a. Percent of harvest by weapon type.

Year	Archery	Firearm	Muzzleloader	Crossbow
2011	22	74	0	4
2012	23	71	1	5
2013	21	73	1	5
2014	25	68	1	6
2015	17	74	0	9
2016	21	71	0	8
2017	19	72	<1	9
2018	16	74	0	10
2019	10	74	0	16
2020	10	72	<1	17

Table 7. Average Age at Harvest from Collared Elk

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Male	4.5	4.25	4.8	5.6	6.7	5.2	5 (n=2)	4.8 (n=4)	4.5 (n=2)	4.0 (n=8)
Female	n/a	n/a	5.3	4.7	9.5	7.8	3 (n=1)	N=0	7.2 (n=3)	5.5 (n=2)

Table 8. Average Age at Harvest from Tooth Samples

	2014	2015	2016	2017	2018	2019	2020
Male	4.8 (n=36)	4.6 (n=93)	4.4 (n=109)	4.5 (n=89)	4.7 (n=109)	4.6 (n=66)	5.0 (n=71)
Female	4.8 (n=24)	4.8 (n=110)	3.8 (n=90)	4.4 (n=69)	4.9 (n=100)	4.2 (n=40)	3.9 (n=16)

Description of Current Population Analysis Methods

MARK-RESIGHT SURVEYS

Mark-resight surveys (MRS) have been described as the "golden standard" of population estimation techniques. This technique uses multiple sampling frames to compare the proportion of marked animals with unmarked animals. The utility of MRS are well recognized in the wildlife literature, but successful implementation requires significant numbers of marked animals on the landscape. Due to the high number of marked animals required, we have used this method exclusively in the Hazard Limited Entry Area.

Methods:

1. KDFWR personnel capture elk with either corral trapping or free darting and place visible marks (collars and eartags) on the subset of the population to be sampled. Since 2011, we have marked both antlered and adult antlerless components of the population.
2. Delineate a survey route that presents an equal opportunity of viewing both marked and unmarked portions of the population.
3. Conduct repeated surveys along the survey route and record the number of marked vs. unmarked animals. It is also important to ensure that all sections of the study area are surveyed within the same time frame to prevent double-counting individual animals. We have used multiple vehicles beginning at the same time from several different locations to ensure we do not double-count elk.
4. Following the completion of all sampling frames, use the Lincoln-Peterson Estimator to estimate population abundance of each demographic set across the study area (Table 9).

Caveats:

1. MRS methods are generally viewed as one of the most accurate population estimation techniques available.
2. Successful MRS projects require that extensive numbers of animals be marked (ideally, 30% of the total population of the demographic in question would be marked). However, marking efforts are extraordinarily time intensive and expensive, so this technique is not feasible across the entire elk restoration zone.

Table 9. Mark-Resight survey estimates from the Hazard Limited Entry Area.

Year	Demographic Group	Estimate
2012	Branch-antlered bulls	210
2013	Branch-antlered bulls	174
2015	Branch-antered bulls	189

AERIAL COUNTS

Aerial Counts (AC) are conducted from either helicopters or fixed wing aircraft to survey blocks of landscape inaccessible from the ground. AC also provide the benefit of covering large blocks of landscape in a much more timely fashion than can be accomplished from a ground-based count.

Methods:

1. ACs are usually scheduled for late winter. This seasonality usually coincides with congregation into larger herds and increased time in open habitat.
2. At least two KDFWR personnel are present for each AC session. Each person both observes and records data to ensure accuracy.
3. Upon locating elk, the pilot positions the aircraft in such a manner as to provide clear views to the observers. Multiple passes will be made until both observers are confident in their count (Table 10).
4. The AC continues until the designated area has been adequately covered.

Caveats:

1. At best, ACs provide a minimum count of visible elk. There is no way to account for elk that are in the timber or otherwise unavailable for sighting.
2. ACs are somewhat weather dependent. Success is generally highest on days with increased snow cover and cloudy weather. However, there are usually limited numbers of days each year that fit these criteria.
3. The Commonwealth has very limited numbers of pilots and aircraft. KDFWR sometimes cannot conduct ACs when desired due to a lack of available pilots.
4. ACs are expensive. Fees for Commonwealth of Kentucky aircraft is $130/hour for helicopters and $550/hour for fixed wing aircraft.
5. Aerial surveys are necessarily hazardous due to low flight altitudes, low airspeed, and mountainous terrain. A recent review concluded that the majority of on-duty North American wildlife biologist deaths involve aircraft.

Table10. Elk minimum count numbers observed from aerial counts.

Year	Area	Elk Minimum Count
2009	Begley	221
	Blue Diamond	146
2010	Begley	423
	Blue Diamond	337
	Knott	763
	Martin/Pike	242

2011	Begley	184
	Knott	468
	Pike	357
2013	Begley	223
	Knott	288
2014	Knott	315

ANNUAL RATIO COUNTS

Annual Ratio Counts (ARC) are conducted each fall to quantify bull:cow ratios and calf:cow ratios (Table 11). These numbers are used in two contexts. First, they constitute important trend data that can illuminate changes in local herd compositions. Secondly, these data are compared to the expected output from the KDFWR elk population model as a form of ground-truthing.

Methods:

1. KDFWR personnel visit sites with good vehicle access and observable elk populations each fall. Visits are timed to coincide with the beginning of herd congregation in anticipation of the rut, and prior to the beginning of elk season.
2. KDFWR personnel survey as much habitat as possible and record the overall numbers of branch-anterlered bulls, spikes, calves, and antlerless elk.
3. Counts are repeated on consecutive days until a reasonably complete count is finalized.
4. At the end of the season, results from each location are tabulated for an overall ARC.

Caveats:

1. ARC numbers provide a snapshot in time of elk available for ground counts. There is no way to account for elk in locations that are inaccessible to vehicles, or for elk that are utilizing habitats that prevent sighting.

Table11. Elk annual ratio counts.

Year	Branch bull/cow	Calf/cow
1998	.35	.6
2001	.21	.59
2002	.23	.55
2007	.35	.61
2008	.47	.59
2009	.48	.46
2010	.48	.49
2011	.87	.56
2012	.32	.57
2013	.37	.47
2014	.32	.64
2015	.63	.6
2016	.93	.51

2017	.56	.48
2018	.34	.39
2019	.54	.52
2020	.88	.56

Other Topics of Interest

Table 12. Number of Non-Hunting Mortalities per Year Over Sex/Age Classes

	F Adult	F Yearling	F Calf	M Adult	M Yearling	M Calf
2011	14	4	5	29	8	2
2012	17	9	3	48	9	5
2013	28	7	3	39	16	5
2014	17	9	8	37	13	4
2015	21	5	1	25	13	2
2016	20	4	2	23	9	2
2017	16	4	4	27	11	2
2018	19	6	6	17	10	3
2019	11	7	2	13	9	0
2020	13	4	2	8	6	1

Table 13. Average Age for Non Hunting Mortalities

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Male	5	4	5	2.5	3.2	3	2.5	2.3	3.5	3.2
Female			3	3.8	2	2	3.2	2.1	4.2	5.8

POACHING

Some level of poaching undoubtedly occurs in the Kentucky elk population. Anecdotes of illegal harvest and malicious shootings are quite prevalent. While these claims are frequently repeated, they are largely unsubstantiated by physical evidence. If extensive illegal kills were occurring, some evidence (dead animals on the landscape, tips to KDFWR Law Enforcement Division, etc.) would undoubtedly exist. This evidence is largely lacking at this time. The overall poaching rate is almost certainly higher than the instances substantiated by KDFWR (Table 14), but there is currently no reason to believe that it occurs at a level that threatens the persistence of the herd.

Table 14. Number of probable elk poaching cases reported to KDFWR

Year	**# Reported Probable Poaching Instances**
1998	2
1999	1
2000	1

2001	8
2002	4
2003	3
2004	11
2005	7
2006	13
2007	12
2008	20
2009	13
2010	7
2011	8
2012	4
2013	8
2014	11
2015	4
2016	16
2017	2
2018	4
2019	3
2020	1

MENINGEAL WORM INFECTION

Meningeal worm *(Parelaphostrongylus tenuis)* is a naturally occurring parasite that can cause severe neurologic debilitation in elk populations. Some concern about the potential impacts of this parasite on long-term persistence of the Kentucky elk population existed prior to initial restoration efforts. However, numerous Kentucky research projects have demonstrated that *P. tenuis* infection – while detrimental to individual animals – is not operating at a level that threatens overall herd survival. In fact, evidence suggests that many adult females that are exposed to the parasite can maintain reproductive efficiency in spite of the infection (Table 15). However, due to the gross similarities between clinical symptoms of *P. tenuis* infection and chronic wasting disease (CWD), neurologic elk are euthanized and samples are submitted for CWD testing (Table 16).

Table 15. Percentages of Kentucky elk calves exhibiting maternal transfer of *P. tenuis* antibodies

Year	% calves exhibiting *P. tenuis* antibodies at birth
2004	53
2005	55
2006	55

Table 16. Number of elk euthanized for probable meningeal worm infection.

Year	# Elk Euthanized for Probable *P. tenuis* Infection
1998	0

1999	6
2000	3
2001	14
2002	17
2003	40
2004	45
2005	50
2006	22
2007	34
2008	40
2009	20
2010	43
2011	26
2012	39
2013	41
2014	43
2015	40
2016	43
2017	24
2018	39
2019	28
2020	12

DAMAGE

Negative human-elk interactions across the Kentucky elk zone most often result from elk damage to small landholders. Reported damage most often included personal gardens, yards and ornamental plantings, and pasture fencing (Table 17). Though relatively rare, some instances of crop damage (row crops and forage crops) have occurred in past years. Damage issues are dealt with on a case-by-case basis by Elk Program staff and/or Regional Program staff. Past responses have included technical guidance for the landowner, temporary loans of exclusion fencing, relocation of problem animals, development of special nuisance units to focus hunting pressure in problem areas (Table 18), and lethal control of individual animals (Table 19). Kentucky Revised Statute (KRS) 150.170 also allows landowners to use lethal control without a permit to remove animals causing damage. Although it is rarely used as a damage control tool, it is an option that landowners can utilize (Table 20).

Table 17. Number of annual elk damage complaints (Stoney Fork area excluded).

Year	# of Complaints
2002	12
2003	20
2004	10
2005	23
2006	15
2007	13
2008	22
2009	20

2010	14
2011	11
2012	16
2013	15
2014	15
2015	4
2016	8
2017	7
2018	5
2019	3
2020	1

Table 18. Results from the Stoney Fork elk depredation pilot program.

Year	# of Permits Issued	Harvest Percentage	# Visits Made
2011	36	42	42
2012	25	32	40
2013	28	25	29

Table 19. Elk Depredation Permits Issued and Elk Harvest with Depredation Permits by Year

Year	# of Permits Issued	# of Elk Killed	Percent Used
2014	1	1	100
2015	0	0	0
2016	4	1	25
2017	0	0	0

Table 20. Number of elk killed by landowners under KRS 150.70.

Year	Number of Elk killed
2015	1
2017	1
2018	1
2019	0
2020	0

ROAD KILLS

Prior to elk restoration in Kentucky, some concern existed about the potential for elk-vehicle collisions. While valid, this concern has not been manifested. Some elk-vehicle collisions are reported in the elk zone each year, but the overall occurrence of elk road kills are substantially lower than observed for white-tailed deer (Table 20). Evidence suggests that elk-vehicle collisions tend to concentrate in specific areas, as elk herds often utilize somewhat specific travel corridors. This tendency for elk to cross the highway in predictable locations likely decreases the incidence of elk road kills, since local traffic is able to account for potential elk presence in the roadway. In some locations with repeated instances of elk road kills KDFWR staff has conducted hazing and/or translocation efforts within the highway corridor to mitigate this issue.

Table 20. Annual reported elk-vehicle collisions.

Year	# of Road Killed Elk
1998	3
1999	5
2000	11
2001	14
2002	9
2003	10
2004	12
2005	17
2006	23
2007	19
2008	25
2009	28
2010	11
2011	15
2012	25
2013	25
2014	27
2015	21
2016	20
2017	11
2018	8
2019	2
2020	11