Gunnison Sage-grouse Population Trend Analysis

Final Report of Statistical Analysis

Completed for

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Gunnison Sage-grouse Rangewide Steering Committee (2005) completed a rangewide conservation plan for the Gunnison sage-grouse (*Centrocercus minimus*) earlier this year that summarizes the history and current condition of Gunnison sage-grouse and their habitat. This conservation assessment includes an analysis of current threats and a quantitative population viability assessment based on estimated demographic parameters for the species. The assessment concludes with a statement of rangewide population objectives and a conservation strategy to meet those objectives. This statistical analysis is intended to provide additional insight into historic patterns of population change that must be included in a reasoned evaluation of whether this species warrants listing under the Endangered Species Act.

Lek counts conducted over the past 50+ years by Colorado Division of Wildlife and Utah Division of Wildlife Resources were obtained from biologists responsible for those data in each agency (Tony Apa, Mike Phillips and Dean Mitchell) in electronic form. Dr. Apa and Phillips discussed their concerns with me that the lek counts in 2005 appeared aberrant in many regions because of unusual weather conditions resulting in maximum counts more than doubling or tripling at many lek sites. Their impression is that late snows at low elevations led to birds which normally disperse to lower elevations prior to commencement of lek activities, remained at high elevation lek sites sufficiently long that they were double counted both at the high elevation leks as well as at lower elevation lek sites later in the breeding season. Potential approaches that I suggested to eliminate or minimize this potential bias were impossible to complete within the time-span available for this assessment. These data consist of estimated maximum male attendance at each lek determined from the highest count out of 4 approximately evenly spaced counts distributed in time across the entire period of lek activity (Tony Apa, personal communication).

Methods

Unbiased estimates of annual rates of change for males attending each lek were used as an index to rates of change in total number of grouse in the vicinity of each lek using a procedure successfully applied to greater sage-grouse for the assessment for that species completed in 2004 (Gunnison Sage-grouse Rangewide Steering Committee 2004). Annual rates of change were estimated for grouse populations in each area as follows:

$$AnnualFiniteRateofChange = \lambda_t = \frac{\sum_{i=1}^{L} n_{it+1}}{\sum_{i=1}^{L} n_{it}},$$

where n_{it} = number of males counted at lek i in year t,
and L = number of leks counted in both years of the interval t to $t+1$.

This approach calculates a weighted average rate of increase for the entire population sampled by the leks in each pair of years where the weights are equal to the size of each lek. The estimates are unbiased by sample size but increase in precision as the number of leks and sizes of leks increases.

Annual finite rates of change were then used to reconstruct relative population abundance in the past by setting the last population size (2005) as 100 ($N_{t=2005}=100\%$)and calculating the previous years relative population size as $N_{t-1} = N_t/\lambda_t$. Annual finite rates of change were converted to instantaneous annual rates of change ($r_t = ln\lambda_t$) for subsequent analysis of trend (μ)and variation (σ^2) in population size as indexed by lek counts.

Long term trend for the entire history of the population indices (1957-2005), for the older population data (1957-1995) and for the last 10 years (1995-2005) were calculated using the stochastic density-independent growth model of Dennis et al. (1991) by calculating average instantaneous rates of change (μ) and variance of rate of change (σ^2) for each data set (total population and each individual area). Probability of persistence for each population and minimum viable population size (MVP) were estimated under this stochastic density-independent growth model following the approach of Dennis et al. (1991) using the computer software STOCHMVP (© E. O. Garton 1997) as follows:

$$\text{Probability of Extinction} = \ 1, for \mu \leq 1.0 \ \text{or} \ \ \ e^{-2\mu x/\sigma^2}, for \mu \leq 1.0,$$
$$\text{where x=ln(N/N}_{extinct})$$

Long term trend for the entire history of the population indices (1957-2005) and for the last 10 years (1995-2005) were assessed using the stochastic density-dependent growth model of Dennis and Taper (1994) by estimating the likelihood of density-dependence, parameters of the density-dependent model (N_{max} = Maximum rate of increase, a= coefficient of density-dependence, and N_{eq} = equilibrium population size) for each data set (total population and each individual area) as follows: 1) Estimate N_{max} and a by regressing r_t on N_t. 2) Estimate N_{eq} from N_{max}/a . 3) Assess the likelihood of density-dependence using a parametric bootstrap to assess the significance of the T statistic testing the null hypothesis that $a = 0$ (Dennis and Taper 1994).

Results

Total population index reconstruction suggests that the region-wide population of Gunnison sage-grouse has varied between a low of 40% of the 2005 count in 1991 and 1993 to a high of 140% (in 1969) of that last count (Table 1). The lowest and highest count indices were all associated with a minimal number of leks making up the surveys (approximately a dozen leks) and probably reflect measurement error more than actual changes in population size as all of these unusual counts were immediately preceded and followed by more typical count indices. The rates of change associated with these counts

were unusually large in magnitude representing at least 50% change in numbers which, though possible, is fairly unlikely. The rate of change in 2004 ($r_t = 0.614$, Table 1) ranks third highest amongst 50 years of data and classifies as an outlier on that basis.

The long-term population trend estimated by the mean rate of change ($\mu=0.007$, Table 2) is notoriously sensitive to the first and last values in the series. This apparently aberrant estimate in 2005 clearly damages the value of the trend-line expressing the estimated pattern from a density-independent model of population growth (Fig. 1). In contrast, when this final count in 2005 is removed and the population size index is reconstructed from 1957 to 2004 (Table 3) the estimated trend line and mean rate of change ($\mu=-0.00621$, Table 4) appear much more descriptive of the observed trend in population numbers (Fig. 2). Note however that the mean rate of change reverses sign from very slightly positive using the 2005 index, implying an increasing population, to equally slightly negative ($\mu=-0.00621$, Table 4, implying a declining population) using the 2004 index as the reference value ($N_{2004} = 100$).

Minimum Viable Population (MVP) sizes estimated from a stochastic density-independent model of population growth produce highly variable values dependent on the inclusion of 2005 count (MVP=30% of 2005 count, Table 2) or its exclusion (5500% of 2004 count, Table 4).

A density-dependent model of population growth is far less sensitive to initial and final values in a time series and is very significantly superior statistically ($P<0.01$) to the density-independent model in either series (Tables 2 & 4). Visually these models appear superior to describe the population trend (Fig. 1&2) and estimate a mean population index within 2% of each other (67% of 1139=763 vs 122% of 638=778 total count).

A novel approach to evaluating population viability based on the density-dependent model using a parametric bootstrap on minimum population size (N_{min}, Garton et al. in review) suggests a low probability ($<1\%$) that the population will reach a minimum population size of 5% of the 2005 or 2004 count (Table 2&4). Inclusion of the 2005 count does impact this measure substantially though as the probability of reaching 25% of the final count jumps from 5% with data through 2004 to 75% including the 2005 count (Table 2&4).

In summary, analysis of the long-term lek count index of population size (1957-2005) suggests that the population is stable, neither increasing nor decreasing, but variable in the rate of population change. Factors affecting the population apparently result in an inverse density-dependent pattern of population change that produces a low probability of declining to low abundances (i.e., below 25% of the long-term population abundance) in the future, if no future changes reduce the equilibrium population size below current levels or increase the variability in population rate of change.

1995-2005 Analysis

Analysis of recent counts (1995-2005) produces very similar results to analysis of the long-term data (Table 2&4, Fig. 1&2) with some exceptions. Smaller sample sizes decrease the significance of statistical tests for density-dependence (Table 2&4).

Density-independent models are not very descriptive of the population fluctuations and prove very sensitive to the 2005 count. Including 2005 yields a positive trend (4.9% increase per year, Table 2) while excluding it produces a negative trend (1.5% decrease per year, Table 4). Inclusion of the 2005 count converts a 0% probability of persistence under a stochastic, density-independent model to a 99.5% probability of persistence. MVP changes less from 18% of the 2005 count to 37% of the 2004 count (Table 2&4).

The density-dependent, stochastic growth models appear most descriptive of the pattern of population change (Fig. 1&2) and produce quite similar estimates of equilibrium population index (N_{eq} = 808 vs 772) based on time series either including or excluding the 2005 count. Probability of reaching a minimum population index as low as 25% of the current population index is less than 1% for either time series (Table 2&4).

In summary, analysis of the recent data (1995-2005) when a large number of leks were counted suggests the same patterns of population as described for the long-term data. The population is stable, neither increasing nor decreasing, but variable in the rate of population change. Estimates of the variance of rate of population change (σ^2) are only half to a quarter as large as estimated from the long-term data. This difference probably reflects the substantial increase in effort counting leks and resulting decrease in measurement error, rather than a decline in process variation in rate of change of the population. Factors affecting the population apparently result in an inverse density-dependent pattern of population change but the short time series reduces the significance of the statistical test for this effect. Combining reduced variability in rates of change with the estimated density-dependence still produces a low probability (<1%) of the population declining to low abundances (i.e., below 25% of the long-term population abundance) in the future. Again these predictions are dependent upon the assumption that the same variation and inverse density-dependence in population rates of change will continue in the future as observed during the past 10 years.

Individual Populations

Gunnison Basin

Leks counted in the Gunnison Basin constitute the largest component of the range-wide population survey and reflect similar patterns to the range-wide data. The long-term trend in population size as indicated by the index based on lek counts is slightly positive whether 2005 data are included or not (Table 5&6). The recent trend switches from positive to negative dependent upon inclusion or exclusion of the 2005 survey (Table 5&6). Apparently the population in Gunnison Basin is stable with the most descriptive pattern illustrated in Fig. 4 where 2005 data are excluded. Patterns of inverse density-dependence suggest that the population fluctuates about an equilibrium abundance approximately 15-20% above the 2003-2004 counts.

Glade Park/Pinyon Mesa

Estimating a trend from the population index based on leks counted in the Glade Park/Pinyon Mesa region suggests that this population has increased at a mean rate close to 10% per year since 1995 (Table 7). Given the high variation around the trend line (Fig. 5) and high probability of inverse density-dependence in the data (P=0.98, Table 7) the most descriptive model of population changes in this population is likely similar to the range-wide pattern, i.e. a stochastic density-dependent pattern of population growth. This model suggests that the underlying pattern is probably closer to a stable population trend with a high level of variation around the equilibrium population approximately 16% above the 2005 count (Table 7).

San Miguel Basin

The density-independent trend line for a population index calculated from lek counts in San Miguel Basin indicates a rapidly declining population (10% decline per year, Table 8, Fig. 6), however the sensitivity of this result to initial and final indices makes this trend less than certain. Counts were only recorded at 4 leks in 1995 early in the history of counts in San Miguel Basin while the surveys included more than 10 leks in 2005. If the first survey value is excluded then the trend line becomes virtually flat, indicating a stable population through time. The density-dependent model receives highly significant (P=0.95, Table 8) support relative to the density-independent model with the equilibrium population size index estimated approximately 30% above the 2005 index (Table 8). Given the small number of leks counted in 1995, I suspect that the

density-dependent model is probably closest to reality. This suggests a fairly stable trend from 1995 to 2005 with high variation year to year. Again the variation probably results partly from measurement error as well as underlying demographic variation in numbers, especially during the period prior to 2000 when fairly small numbers of leks were counted.

Crawford

Counts at 5 leks in the Crawford area have fluctuated between 25 and 55 but remained fairly flat from 1995 to 2005 (Fig. 7). This is a small population with a flat trend, some evidence for inverse density-dependence (P=0.77, Table 9) and an estimated equilibrium population size approximately 10% above the final value.

San Juan County, Utah

Counts at 3 main leks and one smaller lek in San Juan County, Utah, provide the source for a population index extending back to the early 1970s. The total number of birds counted has varied between approximately 30 and 100 birds over that period with the index of total numbers showing a 3-fold decline from 1976 to 2005 (Fig. 8). The long-term trend indicated by the mean rate of change over the entire period (-3.8% per year, Table 10) fails to portray the apparent pattern of a more rapid decline during the decade from 1976 to 1986, followed by more stable or possibly increasing numbers to the present (Fig. 8). Declining trends in both long-term and recent (1995-2005) periods (-2.6% per year, Table 10) probably are unduly influenced by individual years in which each time series began (1976 and 1995). In contrast to the range-wide and population-based analyses in Colorado, statistical support for inverse density-dependence is weaker in Utah (probability of density-dependence = 0.80 and 0.84 for long-term and recent data (Table 10) by the parametric bootstrap likelihood ratio test. Equilibrium population sizes are estimated to occur at a level 10-15% above the 2005 level (Table 10). Overall, analysis of counts in the last decade indicate that the population is approximately stable or declining slightly yet a parametric bootstrap evaluation of long-term prospects suggests that there is only a 5% likelihood that the population will fall as low as 15% of current numbers, assuming that current conditions do not deteriorate.

Statistical Analyses

All statistical analyses were completed using Statistical Analysis System, ver. 9.1 with preliminary data manipulation carried out in Microsoft Excel, ver. for

Windows 2000.

Literature Cited

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Table 1. Gunnison sage-grouse population reconstruction from range-wide lek counts with total population index, number of leks counted (Leks) and instantaneous annual rates of change (r_t).

Year	Total Index	Leks	r_t
1957	72	11	-0.010
1958	72	10	0.353
1959	102	14	-0.151
1960	88	11	-0.248
1961	68	5	0.579
1962	122	7	-0.794
1963	55	13	0.627
1964	103	12	-0.284
1965	78	13	-0.050
1966	74	13	-0.163
1967	63	12	0.338
1968	88	12	0.486
1969	143	12	-0.573
1970	81	15	0.105
1971	90	15	-0.397
1972	60	13	-0.267
1973	46	10	-0.207
1974	38	11	-1.167
1975	12	4	1.659
1976	61	17	0.089
1977	67	16	0.353
1978	96	19	-0.734
1979	46	18	0.151
1980	53	18	0.072
1981	57	17	-0.309
1982	42	17	0.344
1983	59	18	-0.183
1984	49	20	0.173
1985	59	21	-0.132
1986	52	15	0.099
1987	57	18	0.068
1988	61	21	-0.126
1989	54	14	0.117
1990	60	20	-0.386
1991	41	13	0.480
1992	66	22	-0.493
1993	41	16	0.043
1994	42	23	0.384
1995	62	37	0.011
1996	63	45	0.048
1997	66	45	0.170
1998	78	54	0.057
1999	83	52	-0.134
2000	72	56	0.088
2001	79	59	-0.187
2002	66	57	-0.197

2003	54	65	0.005
2004	54	62	0.614
2005	100	62	

Table 2. Density-independent and density-dependent model estimates for Gunnison
sage-grouse based on total population index from range-wide lek counts 1957-2005.

Period (Years)	1957-2005	1957-1995	1995-2005
Number of annual periods	48	38	10
Mu hat (mean instantaneous rate of change)	0.007	-0.004	0.048
Sigma squared (Variance of rate of change)	0.193	0.231	0.054
Sigma (Standard deviation of rate of change)	0.439	0.481	0.233
Finite Rate of Change (Lambda)	1.007	0.996	1.049
Mean rate of change per year (%)	0.674	-0.402	4.870

Density independent model predictions:

Probability of persistence for 100 years with N>5% of current (2005)numbers	0.992	0.000	0.995
Minimum viable population size for a 90% probability of persistence for 100 years above 5% of 2005 population index	30		18

Density dependent model predictions:

T-statistic testing density dependence	-3.890		-1.920
Likelihood of density dependence <=	0.990		0.940
Maximum rate of increase	0.651		0.904
Coefficient of density-dependence (per 1% increase in N)	-0.010		-0.013
Equilibrium population size as a percent of 2005 total population index	67%		71%

Probability of reaching a minimum population size (Nmin) in 100 years

Nmin (percentage of current population size)	Probability	Probability
50%	100%	99%
33%	99%	5%
25%	75%	<1%
15%	15%	<1%
10%	<1%	<1%

Table 3. Gunnison sage-grouse population reconstruction from range-wide lek counts with total population index, number of leks counted (Leks) and instantaneous annual rates of change (r_t).

Year	Total Index	Leks	r_t
1957	134	11	-0.010
1958	133	10	0.353
1959	189	14	-0.151
1960	162	11	-0.248
1961	126	5	0.579
1962	226	7	-0.794
1963	102	13	0.627
1964	191	12	-0.284
1965	144	13	-0.050
1966	137	13	-0.163
1967	116	12	0.338
1968	163	12	0.486
1969	265	12	-0.573
1970	149	15	0.105
1971	166	15	-0.397
1972	112	13	-0.267
1973	85	10	-0.207
1974	70	11	-1.167
1975	22	4	1.659
1976	114	17	0.089
1977	124	16	0.353
1978	177	19	-0.734
1979	85	18	0.151
1980	99	18	0.072
1981	106	17	-0.309
1982	78	17	0.344
1983	110	18	-0.183
1984	91	20	0.173
1985	109	21	-0.132
1986	95	15	0.099
1987	105	18	0.068
1988	113	21	-0.126
1989	99	14	0.117
1990	112	20	-0.386
1991	76	13	0.480
1992	123	22	-0.493
1993	75	16	0.043
1994	78	23	0.384
1995	115	37	0.011
1996	116	45	0.048
1997	122	45	0.170
1998	144	54	0.057
1999	153	52	-0.134
2000	134	56	0.088

2001	146	59	-0.187
2002	121	57	-0.197
2003	99	65	0.005
2004	100	62	

Table 4. Density-independent and density-dependent model estimates for Gunnison
 sage-grouse based on total population index from range-wide lek counts 1957-2004.

Period	1957 - 2004	1957-1995	1995 - 2004
Number of years	47	38	9
Mu hat = mean rate of change	-0.00621	-0.00403	-0.01541
Sigma squared =Variance (rate of change)	0.18902	0.231406	0.016498
Sigma = Standard deviation	0.434765	0.481046	0.128444
Finite Rate of Change (Lambda)	0.993808	0.995976	0.984704
Mean rate of change per year (%)	-0.6192	-0.40235	-1.52957

Density independent model predictions:

Probability of persistence for 100 years	0	0
(with N>5% of current numbers)		
Minimum Viable Population Size (P=0.9)	5500%	37%
(% of current numbers assuming u=0.001)		

Density dependent model predictions:

T-statistic testing density-dependence	-3.79	-0.908
Likelihood of density dependence <=	0.999	0.606
Maximum rate of increase	0.623	0.288
Coefficient of density-dependence	-0.00509	-0.00238
(per 1% increase in N)		
Equilibrium population size (% of current)	122%	121%

Probability of reaching a minimum population size (N_{min}) in 100 years

N_{min} (percentage of current population size)	Probability	Probability
50%	90%	<1%
33%	25%	<1%
25%	5%	<1%
15%	<1%	<1%
10%	<1%	<1%

Table 5. Density-independent and density-dependent model estimates for Gunnison
 Basin sage-grouse based on population index from lek counts 1976-2005.

Period	1976-2005	1976-1994	1995-2005
Sample size	29	19	10
Mu hat = mean rate of change	0.023767	0.010806	0.048393
Sigma squared =Variance (rate of change)	0.081338	0.096478	0.059067
Sigma = Standard deviation	0.285198	0.310609	0.243037
Finite Rate of Change (Lambda)	1.024052	1.010865	1.049583
Mean rate of change per year (%)	2.41	1.09	4.96

Density independent model predictions:

	1976-2005	1995-2005
Probability of persistence for 100 years	0.898	0.994
(with N>5% of current numbers)		
Minimum Viable Population Size (P=0.9)	102%	20%
(% of current numbers assuming u=0.001)		

Density dependent model predictions:

	1976-2005	1995-2005
T-statistic testing density-dependence	-3.57	-2.19
Likelihood of density dependence <=	0.99	0.91
Maximum rate of increase	0.759	1.229
Coefficient of density-dependence	-0.0133	-0.0185
(per 1% increase in N)		
Equilibrium population size (% of current)	116	66

Table 6. Density-independent and density-dependent model estimates for Gunnison
 Basin sage-grouse based on population index from lek counts 1976-2004.

Period	1976-2004	1976-1994	1995-2004
Sample size	28	19	9
Mu hat = mean rate of change	0.00125	0.010806	-0.01892
Sigma squared =Variance (rate of change)	0.069102	0.096478	0.01547
Sigma = Standard deviation	0.262873	0.310609	0.124377
Finite Rate of Change (Lambda)	1.001251	1.010865	0.981254
Mean rate of change per year (%)	0.13	1.09	-1.87

Density independent model predictions:

Probability of persistence for 100 years	0.76		0.99
(with N>5% of current numbers)			
Minimum Viable Population Size (P=0.9)	313%		20%
(% of current numbers assuming u=0.001)			

Density dependent model predictions:

T-statistic testing density-dependence	-2.39		-1.11
Likelihood of density dependence <=	0.98		0.70
Maximum rate of increase	0.233766		0.417728
Intraspecific competition coefficient	-0.00202		-0.0035
(per 1% increase in N)			
Equilibrium population size (% of current)	116		119

Table 7. Density-independent and density-dependent model estimates for Gunnison sage-grouse in Glade Park/Pinyon Mesa based on population index from lek counts 1995-2005.

Period	1995-2005
Sample size	10
Mu hat = mean rate of change	0.088
Sigma squared =Variance (rate of change)	0.0463
Sigma = Standard deviation	0.215
Finite Rate of Change (Lambda)	1.091
Mean rate of change per year (%)	9.15

Density independent model predictions:

Probability of persistence for 100 years	1.00
(with N>5% of current numbers)	
Minimum Viable Population Size (P=0.9)	9%
(% of current numbers assuming u=0.001)	

Density dependent model predictions:

T-statistic testing density-dependence	-2.39
Likelihood of density dependence <=	0.98
Maximum rate of increase	0.234
Coefficient of density-dependence	-0.00202
(per 1% increase in N)	
Equilibrium population size (% of current)	116

Table 8. Density-independent and density-dependent model estimates for Gunnison sage-grouse in San Miguel Basin based on population index from lek counts 1995-2005.

Period	1995-2005
Sample size	10
Mu hat = mean rate of change	-0.103
Sigma squared =Variance (rate of change)	0.2006
Sigma = Standard deviation	0.448
Finite Rate of Change (Lambda)	0.902
Mean rate of change per year (%)	-9.81

Density independent model predictions:

Probability of persistence for 100 years	0
(with N>5% of current numbers)	
Minimum Viable Population Size (P=0.9)	6000%
(% of current numbers assuming u=0.001)	

Density dependent model predictions:

T-statistic testing density-dependence	-3.09
Likelihood of density dependence <=	0.95
Maximum rate of increase	0.666
Coefficient of density-dependence	-0.00515
(per 1% increase in N)	
Equilibrium population size (% of current)	129

Table 9. Density-independent and density-dependent model estimates for Gunnison
sage-grouse in Crawford based on population index from lek counts 1995-2005.

Period	1995-2005
Sample size	10
Mu hat = mean rate of change	-0.001
Sigma squared =Variance (rate of change)	0.1311
Sigma = Standard deviation	0.362
Finite Rate of Change (Lambda)	0.999
Mean rate of change per year (%)	-0.08

Density independent model predictions:

Probability of persistence for 100 years	0
(with N>5% of current numbers)	
Minimum Viable Population Size (P=0.9)	1550%
(% of current numbers assuming u=0.001)	

Density dependent model predictions:

T-statistic testing density-dependence	-1.69
Likelihood of density dependence <=	0.77
Maximum rate of increase	0.584
Coefficient of density-dependence	-0.00526
(per 1% increase in N)	
Equilibrium population size (% of current)	111

Table 10. Density-independent and density-dependent model estimates for Gunnison sage-grouse in San Juan County, Utah based on population index from lek counts 1976-2005.

Period	1976-2005	1976-1994	1995-2005
Sample size	29	19	10
Mu hat = mean rate of change	-0.03847	0.010806	-0.0265
Sigma squared =Variance (rate of change)	0.069417	0.096478	0.04687
Sigma = Standard deviation	0.263471	0.310609	0.2165
Finite Rate of Change (Lambda)	0.962257	1.010865	0.994
Mean rate of change per year (%)	-3.77	1.09	-2.61

Density independent model predictions:

Probability of persistence for 100 years	0		0
(with N>5% of current numbers)			
Minimum Viable Population Size (P=0.9)	320%		20%
(% of current numbers assuming u=0.001)			

Density dependent model predictions:

T-statistic testing density-dependence	-1.87		-1.56
Likelihood of density dependence <=	0.80		0.84
Maximum rate of increase	0.134382		0.411473
Intraspecific competition coefficient	-0.00119		-0.00378
(per 1% increase in N)			
Equilibrium population size (% of current)	113		109
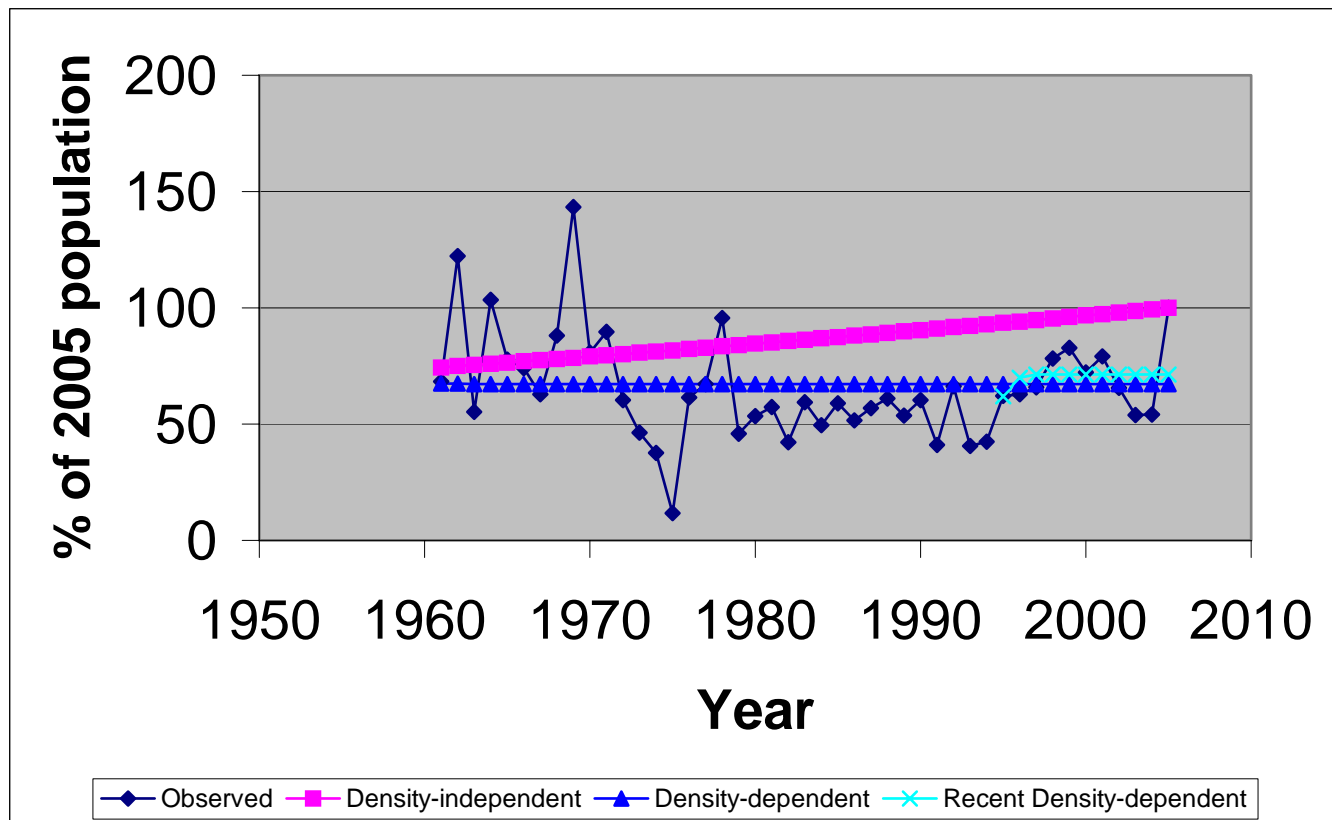
Figure 1. Observed population size index for range-wide Gunnison sage-grouse
population expressed as percent of 2005 lek count with predictions of density-
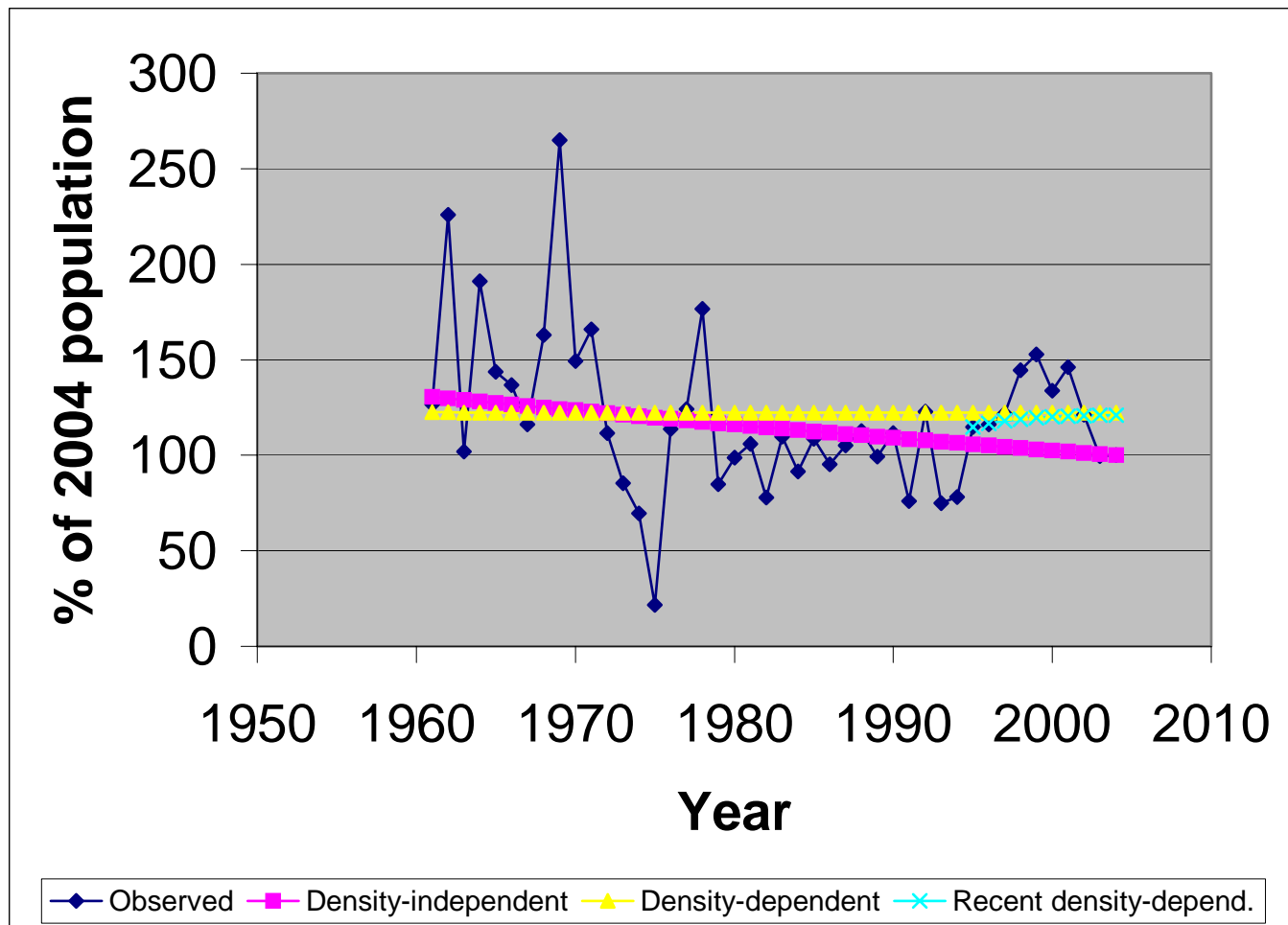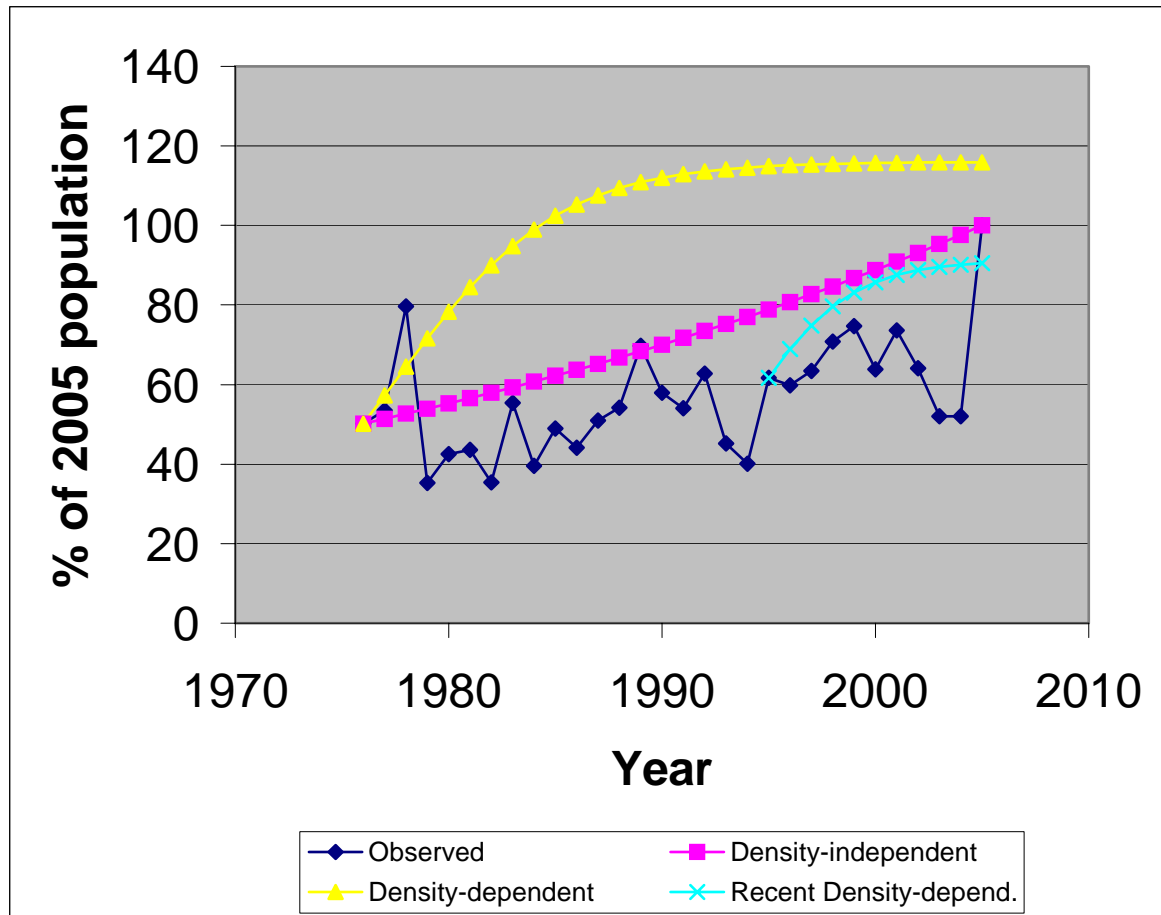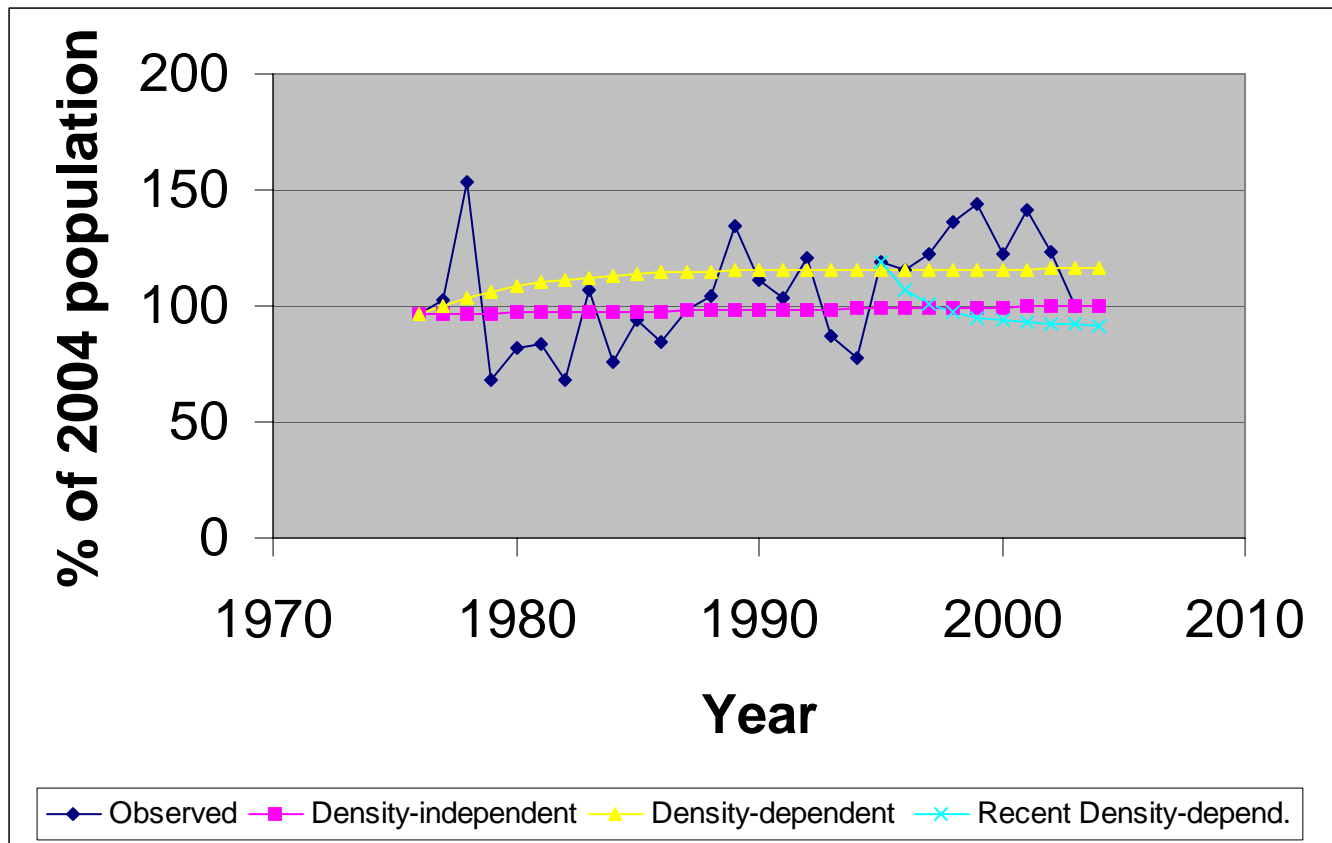independent, density-dependent and recent density-dependent (1995-2005)
models.

Figure 2. Observed population size index for range-wide Gunnison sage-grouse
population expressed as percent of 2004 lek count with predictions of density-
independent, density-dependent and recent density-dependent (1995-2004)
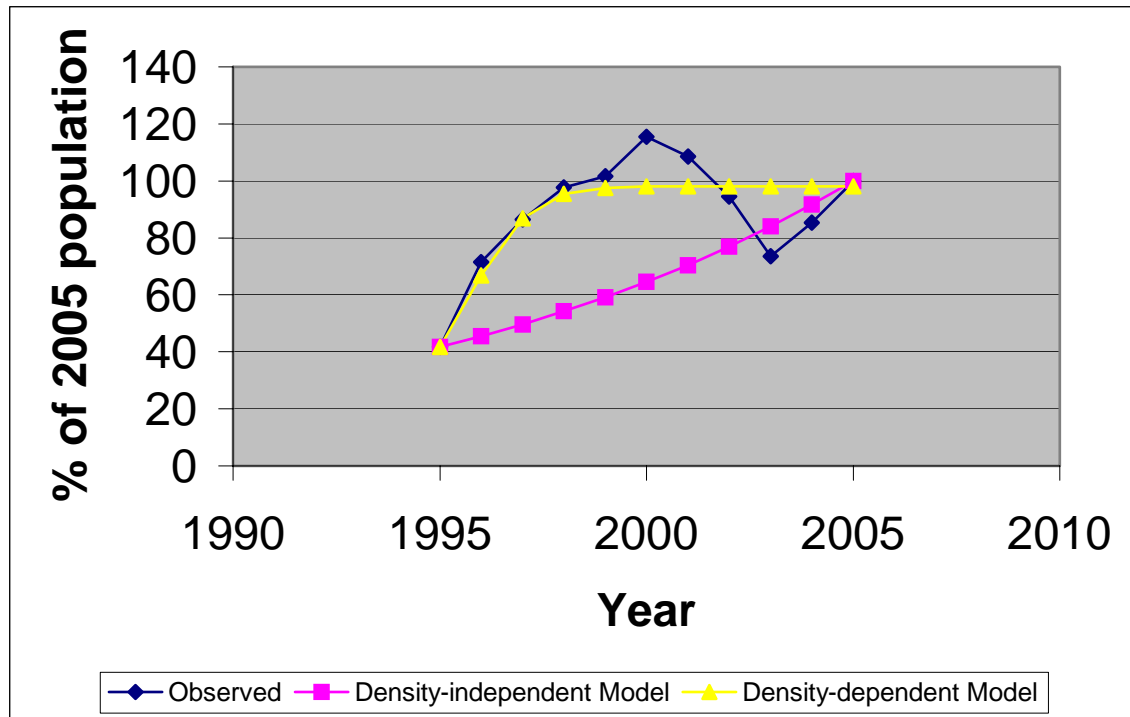models.

Figure 3. Observed population size index for range-wide Gunnison Basin population of Gunnison sage-grouse expressed as percent of 2005 lek count with predictions of density-independent, density-dependent and recent density-dependent (1995-2005) models.

Table 4. Observed population size index for Gunnison Basin sage-grouse population
expressed as percent of 2004 lek count with predictions of density-independent,
density-dependent and recent density-dependent (1995-2004) models.

Figure 5. Observed population size index for Gunnison sage-grouse population in Glade
Park/Pinyon Mesa expressed as percent of 2005 lek count with predictions of
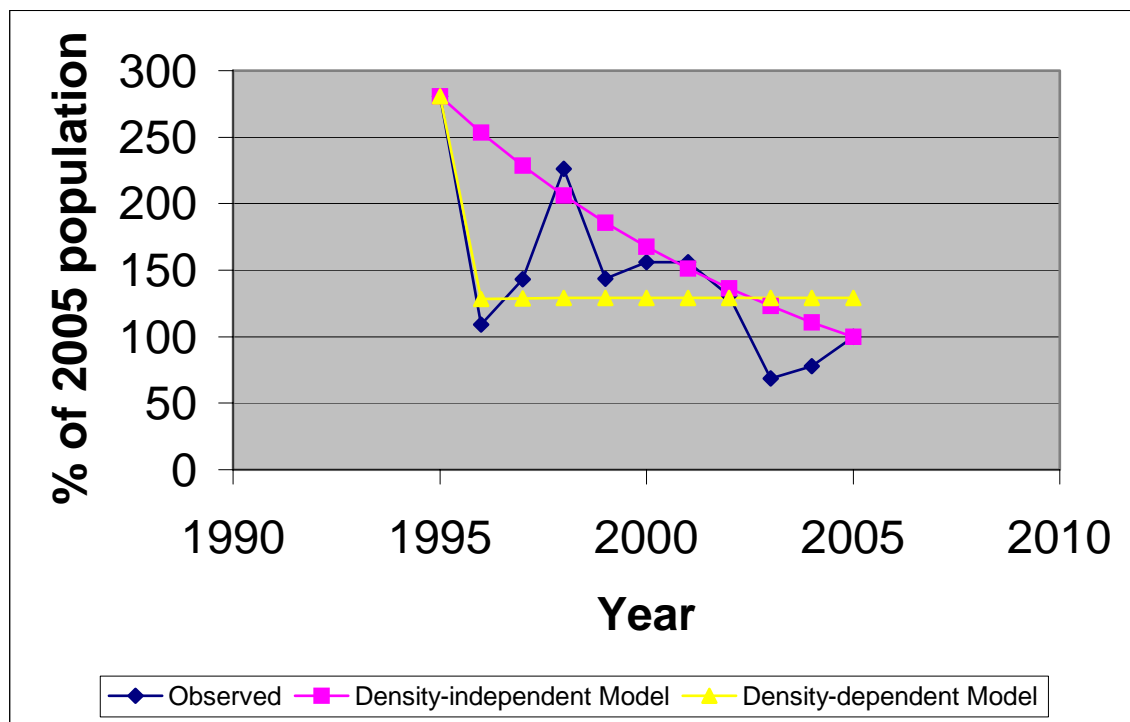density-independent and recent density-dependent (1995-2005) models.

Figure 6. Observed population size index for Gunnison sage-grouse population in San
Miguel Basin expressed as percent of 2005 lek count with predictions of density-
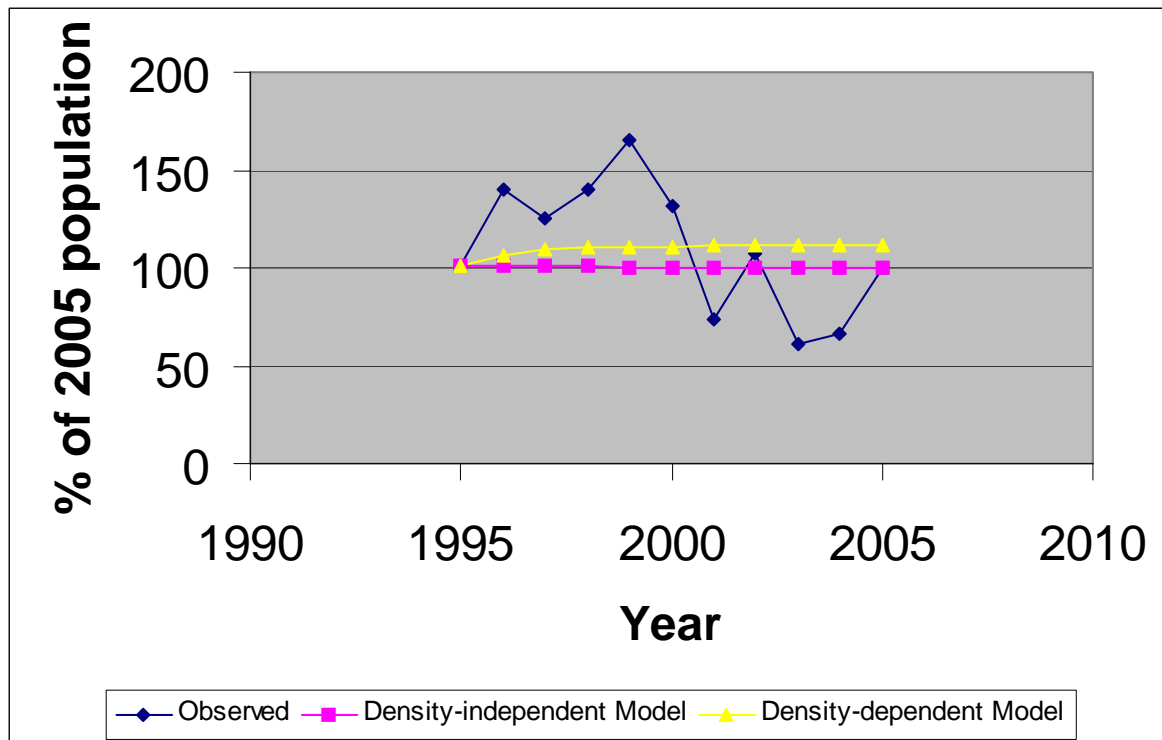independent and recent density-dependent (1995-2005) models.

Figure 7. Observed population size index for Gunnison sage-grouse population in
   Crawford expressed as percent of 2005 lek count with predictions of density-
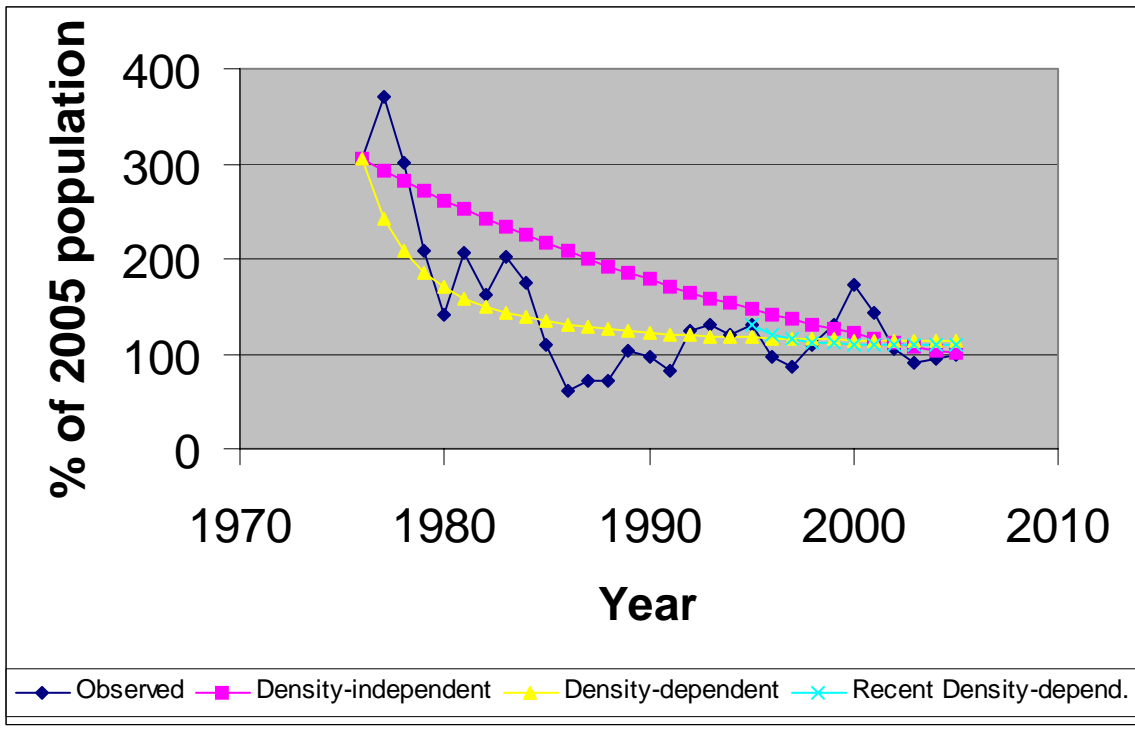   independent and recent density-dependent (1995-2005) models.

Figure 8. Observed population size index for Gunnison sage-grouse population in San Juan County, Utah expressed as percent of 2005 lek count with predictions of density-independent, density-dependent and recent density-dependent (1995-2005) models.