The Effects of Special Mule Deer Buck Regulations on Mule Deer Populations and Harvest, 2018

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ABSTRACT

We evaluated the effects of restrictive buck season types on mule deer population and harvest characteristics across Montana. We used a mixed-effects, before-after-control-impact modeling framework, which allowed us to compare changes in the response variables as a function of changes in regulation, while allowing each hunting district (HD) to differ in its overall mean response values. We analyzed 5 harvest and hunter use response variables estimated annually through the telephone harvest survey, as well as 3 population response variables collected during annual aerial surveys. There were 4 treatments; HDs with no buck restrictions, HDs with a shortened season, HDs with unlimited buck permits, and HDs with limited buck permits. We fit 3 models to those treatments and looked for differences in the response variables relative to the treatments. We found that models that contained an effect for season restriction out-performed models with no effect for season restriction. Using buck restrictions to achieve specific buck:doe ratio objectives was effective if the objectives were not too high. Limited permit HDs had the greatest number of years with buck:doe ratios above 20:100, followed by HDs with shortened seasons, HDs with no restrictions, and then HDs with unlimited permits. HDs with limited permits, shortened seasons, unlimited permits, and no restrictions had the greatest to lowest declines in the total number of bucks and the number of bucks with 4 or more 4 points harvested per 100 mi^2, respectively. The proportion of bucks with 4 or more points was highest, and our model predicted an annual increase in this metric in HDs with limited permits. All other HDs showed an annual increase in the proportion of bucks with 4 or more points with shortened season and no restriction HDs having nearly identical increases while HDs with unlimited permits had the lowest annual increase in the proportion of 4 points in the harvest. HDs with limited permits had the highest buck:doe ratios observed on trend areas and that ratio was predicted to increase annually. Buck:doe ratios observed on trend areas in HDs with unlimited permits were higher than HDs with no restrictions and shortened seasons. Our model predicted that buck:doe ratios in HDs with shortened seasons and no restrictions showed an annual increase in the ratio while HDs with unlimited permits remained stable over time. Declines in hunter numbers and hunter days per 100 mi^2 were observed statewide, with the greatest to lowest declines in HDs with limited permits, HDs with unlimited permits, HDs with shortened seasons, and HDs with no restrictions, respectively. In all HDs with restrictions there was an increase in the number of fawns per 100 adults observed in the spring although, only the increase in HDs with shortened seasons was statistically significant. HDs with no restrictions showed a statistically significant annual decrease in the number of fawns:100 adults. The number of mule deer observed on trend areas were higher in HDs with limited and unlimited permits than HDs with shortened seasons and no restrictions for approximately 17 years after initiation of the season types. However, HDs with shortened seasons saw annual increases in the number of deer on trend areas, HDs with no restrictions remained unchanged over time and HDs with limited and unlimited permits saw annual decreases.

INTRODUCTION

In February of 1998 the Montana Fish, Wildlife and Parks (MFWP) Commission adopted a deer management policy to serve as a basis for establishment of deer hunting regulations. Because of this policy decision, MFWP developed a harvest management strategy that incorporated Adaptive Harvest Management (AHM) concepts into hunting regulations (MFWP 2001). MFWP divided the state into 5 Population Management Units (PMUs), the Northwest Montane, Mountain Foothill, Prairie/ Mountain Foothill, Southern Mountains and Prairie/Breaks Units. Regulations, categorized as liberal, standard, and restrictive, were established for each PMU and population and/or harvest objectives provided triggers that resulted in changes to regulations. Through a 1998 deer hunter survey, FWP determined that approximately 23% of deer hunters could be categorized as trophy hunters (MFWP 2001). Because of this documented demand for trophy deer hunting opportunity, MFWP set aside 16 hunting districts (HDs) where buck harvest opportunity was limited to decrease the harvest of antlered bucks, increase post season buck:doe ratios, and meet the demand to harvest an older-age-class buck in areas with good access. Objectives were established for each of these Special Management Districts (SMDs), for post-season buck:doe ratios, percentages of older-age-class bucks (>4 points on their antlers), and/or specified a percentage of bucks harvested with 4 or more points on either side (Table 1).

In addition, the AHM document identified HDs 400, 401, 403 and 406 as HDs with a shortened 3-week mule deer buck season. We categorized HDs 400, 401, 403, and 406 as Restrictive Season Hunting Districts (RSHDs) and analyzed data from these districts along with data from 25 additional HDs that had restrictions on the harvest of mule deer bucks (Table 2). Objectives for RSHDs differ from SMDs with buck restrictions established to raise buck:doe ratios to a level above 10 bucks per 100 does. The RSHD's buck:doe objectives, unlike objectives for SMDs, were not designed to produce larger and/or more mature bucks. HDs 400, 401, 403 and 406 were in the Prairie/ Breaks PMU while all the other RSHDs were in the Northwest Montane and Mountain Foothill PMUs.

All PMUs have a series of objectives and triggers, that when reached, suggest to managers when to move from restrictive to standard or to liberal season types. In the Northwest Montane and the Mountain Foothill PMUs there are additional triggers that suggest when to become more restrictive on buck harvest. These triggers have resulted in adjusted regulations designed to increase buck numbers in HDs that have very low buck numbers. In the Northwest Montane PMU managers may recommend that harvest of mule deer bucks be restricted by issuing unlimited mule deer buck permits if the post-season buck:doe ratio is less than 10 bucks:100 does for two consecutive years or if the harvest of bucks with 4 or more points was less than 25% of the total buck harvest. In the Mountain Foothill PMU managers may recommend that harvest of mule deer be restricted, by issuing unlimited mule deer buck permits, if the post-season buck:doe ratio is less than 10 bucks:100 does following 2 years of fawn recruitment greater than 40 fawns:100 adults.

Table 1. Original special management districts (SMDs) in the state of Montana with special regulations to limit mule deer buck harvest[1].

HD	Years of Restrictive Regulation	Restrictive Season Type	Objectives: Post-Season Bucks:100 Does	Objectives: Harvested Buck
202	1998-2016	Limited Buck Permits	40:100	30% ≥4 years old
210	1998-2016	Limited Buck Permits	40:100	30% ≥4 years old
261	1998-2016	Limited Buck Permits	40:100	30% ≥4 years old
270	1998-2016	Limited Buck Permits	40:100	30% ≥4 years old
291	1986-2016	Limited Buck Permits	40:100	30% ≥4 years old
300	1998-2016	Limited Buck Permits	25:100	30% ≥4 years old
312	1998-2016	Limited Buck Permits (portion of HD)	25:100	30% ≥4 years old
313	1994-2016	Short Season	15:100	35% ≥ 2.5 years old
320	2001-2015	Short Season	25:100	none
324	2000-2016	Limited Buck Permits	25:100	40% ≥4 years old
333	2001-2015	Short Season	25:100	none
441	1987-2016	2 weeks Gen A, last 3 weeks limited permits on private lands 50 Permits	25:100	60% ≥4 points
455	1992-2016	Limited Buck Permits valid for mule deer and whitetails.	20:100	50% ≥4 points
510	1998-2016	Unlimited Buck Permits	25:100	30% ≥ 4 years old
530	1987-2016	Limited Buck Permits	25:100	30% ≥ 4 years old
652	1996-2016	Limited Buck Permits	40:100	50% ≥ 4.5 years old & 30% ≥5.5 years old & ≥3.0 mule deer mi^2

[1] Areas with weapon restrictions are not considered SMDs and are not included in this table.

In 2011 an analysis of the effect of restrictive buck seasons on 7 harvest and hunter use metrics as well as 4 population response variables collected during aerial surveys was completed (Newell and Lukcas 2011). In 2017 the decision was made to update the existing harvest and survey databases and to reanalyze the effect of the restrictive buck seasons on the same harvest and hunter use metrics used in the original analysis along with four additional metrics, total number of mule deer bucks and number of mule deer bucks with 4 or more points harvested per 100 mi^2 of area and hunter numbers and hunter days per 100 mi^2.

Since FWP routinely hears requests or interest from sportsmen's groups to increase buck numbers and age structure with season restrictions it is important to have the most current information available to provide a scientific basis for discussions as to the advantages and disadvantages of hunting seasons that restrict harvest on mule deer bucks.

Table 2. Hunting districts, other than the original special management districts (SMDs) with a restriction on the hunting of mule deer bucks[1], through 2016.

Hunting District[2]	Years of Restrictive Regulation	Restrictive Season Type	Objectives: Post-Season Bucks:100 Does	Objectives: Harvested Buck
109	2014-presemt	First 3 weeks any buck last two weeks limited permit only. Classified as Short Season	None	None
204	1999-2016	Unlimited Buck Permits (UBP) & Short Season	>10:100	None
212	2007-2016	UBP	>10:100	None
213	2007-2016	UBP	>10:100	None
214	2007-2016	UBP	>10:100	None
215	2012-2016	UBP	>10:100	None
217	2016	UBP	>10:100	None
240	1999-2016	UBP	>10:100	None
250[3]	1999-2009	UBP	>10:100	None
250	2010-2016	Limited Permits	>10:100	None
262	2014-2016	Limited Permits	>10:100	None
281	1998-2016	UBP	>10:100	None
292	2000-2016	UBP valid in 298	>10:100	None
298[4]	2008-2016	UBP valid in 292	>10:100	None
302	2010-2015	UBP	>10:100	None
318	2000-2016	UBP	>10:100	None
319	2003-2016	UBP	>10:100	None
329	2010-2016	UBP	>10:100	None
335	2000-2016	UBP	>10:100	None
339	2000-2016	UBP	>10:100	None
343	2000-2016	UBP	>10:100	None
380	2000-2016	UBP	>10:100	None
390	2004-2016	UBP (Portion HD)	>10:100	None
391	2000-2016	UBP	>10:100	None
392	2000-2016	UBP	>10:100	None
400	Prior to 1972-2016	Short Season	NA	None
401		Short Season	NA	None
403		Short Season	NA	None
406		Short Season	NA	None
640	2004-2011	Short Season	NA	None

[1]Areas with weapon restrictions are not considered SMDs and were not included in this analysis.
[2]HD 260 and 282 had buck restrictions but were not included in this analysis.
[3]In 2010 HD 250 changed buck regulation from unlimited to limited permits.
[4]Restrictive mule deer buck seasons included in analysis with HD 292.

The objectives of this analysis were as follows.

- Compare established population objectives to observed population parameters.
- Quantify differences between HDs with special mule deer buck regulations and HDs without special mule deer buck regulations.
- Compare current population and harvest parameters to those same parameters measured prior to the season structure change and to other HDs without restrictions.
- Evaluate the effect of limited buck seasons on mule deer population productivity by analyzing the effect of restrictive seasons on spring fawn:adult ratios and trends in total numbers.

STUDY AREA

In 2016 43 of 165 (26.1%) HDs or portions of HDs had some type of restriction on the harvest of mule deer bucks. Those 43 HDs encompassed approximately 20,212 square miles (sq. mi.) or 15.3% of the area of the state open to deer hunting (Fig. 1). We evaluated data from 45 HDs that had a special regulation on the harvest of mule deer bucks between 1986 and 2016: 14 with limited permits, 22 with unlimited permits, and 9 with a shortened season. HDs may have had multiple regulation types during the years included in this analysis and each HD was placed in one of the following regulation types for each year of the analysis.

1) Limited permit HDs were HDs where the number of permits for mule deer bucks could be adjusted annually. Hunters who held these permits could not hunt mule deer bucks in any other HD in the state, however they could hunt anywhere in the state where their general license was valid for antlerless mule deer or white-tailed deer. Permit numbers were lowered if objectives for bucks were not being met or raised if objectives for bucks were exceeded.
2) Unlimited permit HDs were HDs where anyone that applied in the special drawing would receive a permit, which allowed them to hunt in a specific HD or group of HDs for mule deer bucks. The hunter could not hunt a mule deer buck in any other HD, however they could hunt anywhere in the state where their general license was valid for antlerless mule deer or white-tailed deer.
3) Shortened season HDs were HDs that had a shortened season but were open to all general license holders for hunting. All these HDs had a 23-day season in 2016, however shortened seasons in previous years varied in length. The purpose of the shortened season is to eliminate hunting of mule deer bucks during the rut.
4) Other HDs were all the other HDs in the state that had no special restriction on mule deer buck hunting. Anyone holding a general deer license could harvest a buck in those HDs.
5) HDs 260 and 282 were censored form the analysis because they could not be categorized into any of the 4 season regulations above.

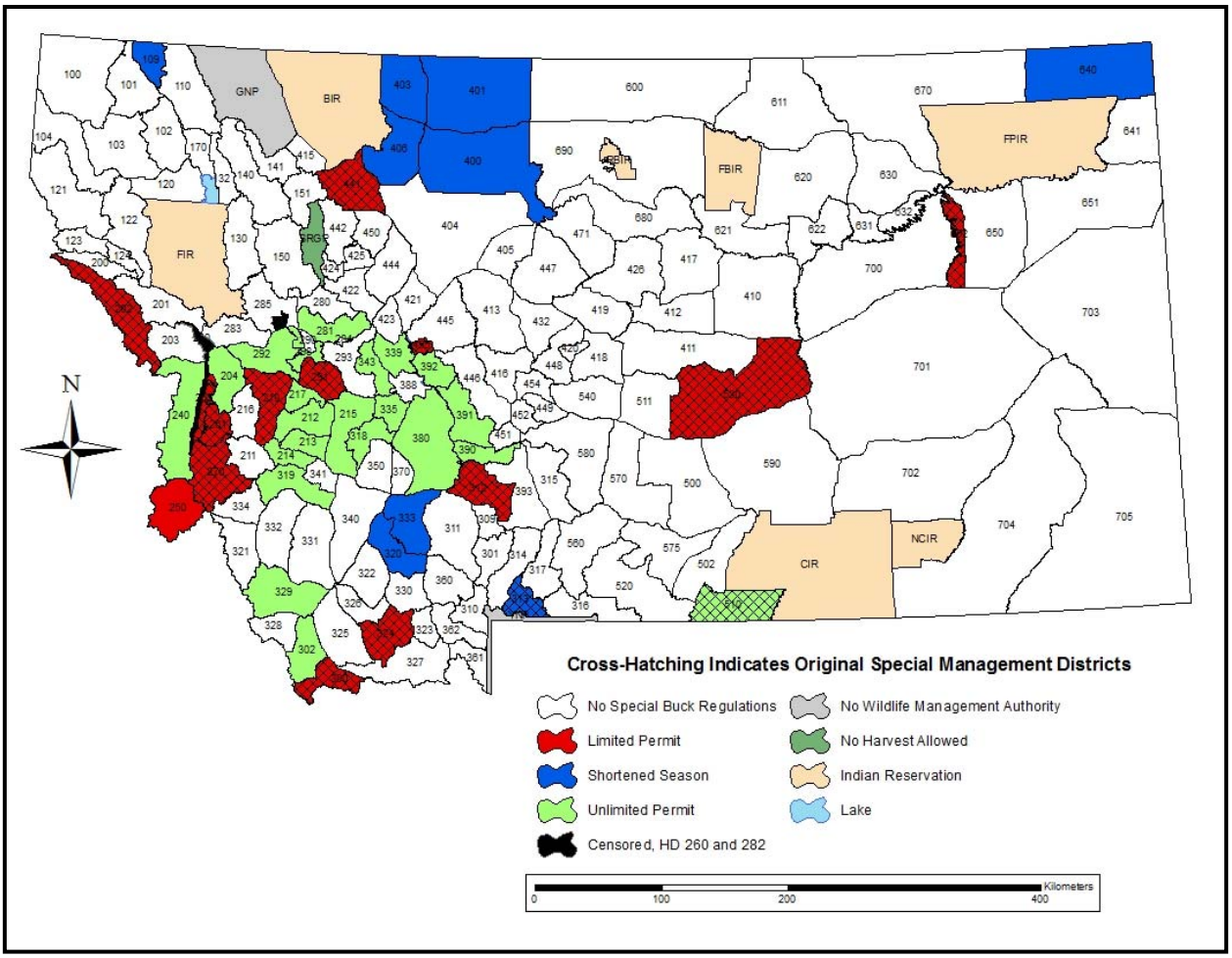


Figure 1. Hunting districts (HDs) that had a restrictive season on mule deer bucks between 1986 and 2016. HDs with cross-hatching indicate 16 original special management districts. HD size can change over time and the boundaries depicted here may be different than at the time they had a restrictive buck season.

METHODS

We analyzed data from the 16 original SMDs and 29 RSHDs (Table 3). There were two HDs (HD 260 and 282) that were not evaluated because the season structures for mule deer bucks were unique to those two HDs. HD 260 had no mule deer hunting, and in HD 282 hunters with a general deer license were also required to hold a 282-80 elk B-license or a 282-20 elk permit to hunt mule deer bucks during the rifle season. Several HDs were analyzed in different regulation categories if they changed regulations during the time-period. For this analysis we standardized the response variables for hunter numbers, hunter days, number of bucks and number of 4-point bucks harvested to number per 100 mi^2 allowing us to use data from HDs that changed in size.

Table 3. Number of years of data in each hunting district (HD) for each response variable analyzed. Harvest information has 5 response variables; number hunters per 100 mi^2, number hunter days per 100 mi^2, total mule deer buck harvest per 100 mi^2, number of bucks harvested with 4 or more points per 100 mi^2 and proportion of bucks harvested with 4 or more points.

		Number of Years with Data While in Restrictive Season			
HD	HD Restriction	Buck:Doe Ratios	Fawn:Adult Ratios	Trend Counts	Harvest Information
109	Short Season	0	0	0	3
202	Limited	10	16	14	19
204	Unlimited	0	0	0	18
210	Limited	5	6	3	19
212	Unlimited	0	0	0	10
213	Unlimited	0	0	0	10
214	Unlimited	0	0	0	10
215	Unlimited	0	0	0	5
217	Unlimited	0	0	0	1
240	Unlimited	0	0	0	18
250[1]	Unlimited	2	2	0	11
250[1]	Limited	1	7	0	7
261	Limited	10	19	8	19
262	Limited	0	0	0	3
270	Limited	15	19	12	19
281	Unlimited	0	0	0	19
291	Limited	18	28	3	31
292MD[2]	Unlimited	11	15	9	17 for all of 292
292CF	Unlimited	6	6	6	17 for all of 292
298	Unlimited	0	0	0	9
300	Limited	18	19	12	19
302[3]	Unlimited	6	6	0	6
312	Limited	19	19	18	19
313	Short Season	16	20	19	23
318	Unlimited	0	0	0	17
319	Unlimited	12	14	11	14
320[4]	Short Season	14	15	8	15
324	Limited	17	17	12	17
329[3]	Unlimited	0	0	0	7
333	Short Season	0	0	0	15
335	Unlimited	0	0	0	17
339	Unlimited	13	17	16	17
343	Unlimited	0	0	0	17
380	Unlimited	14	17	15	17
390	Unlimited	0	0	0	13
391	Unlimited	13	16	12	17
392	Unlimited	0	0	0	17
400	Short Season	33	35	35	31

Table 3. (cont)

HD	Number of Years with Data While in Restrictive Season				
	HD Restriction	Buck:Doe Ratios	Fawn:Adult Ratios	Trend Counts	Harvest Information
401	Short Season	24	29	23	31
403	Short Season	36	38	34	31
406	Short Season	33	37	34	29
441	Limited	29	30	0	29
455	Limited	0	0	0	25
510	Unlimited	13	13	0	19
530	Limited	29	30	27	30
640[5]	Short Season	8	8	8	8
652	Limited	21	21	0	21
Total	Limited	192	231	109	277
Total	Unlimited	90	106	69	306
Total	Short Season	164	182	161	186
Grand	Total	446	519	339	769

[1]In 2010, HD 250 regulations changed to limited permits, information up until that time was analyzed with the unlimited permit type.

[2]HD 292 had two trend areas that were surveyed, thus the abbreviations following the HD designation.

[3]HD 302 and 329 regulations changed to unlimited permits in 2010. HD 302 regulations changed back to an any buck on the general license in 2016.

[4]HDs 320 and 333 regulations changed from a shortened season to a full 5-week season in 2015.

[5]HD 640 regulations changed from a shortened season to a full 5-week season in 2012.

We were not aware of any HD boundary changes that affected survey areas flown for mule deer. However, in some cases biologists had reduced trend areas in size, making total counts pre and post change incomparable, and we censored those data.

In several cases, HDs had restrictions on mule deer buck harvests for a short amount of time at some point in the past. For example, most of the 200 and 300 HDs in Table 3 had a requirement to validate a hunter's general deer license prior to the time they could hunt in those HDs for the period 1997-1999. In HD 312, hunters were restricted to shooting a 2-point mule deer buck the last two weeks of the season for the period 1989-1998 along with requiring validation for the period 1997-1999. Although these earlier restrictions may have affected population and harvest parameters for those individual HDs, we chose to combine those years with the group of HDs with no restrictions.

We analyzed the impact of restricting mule deer buck harvest on each response variable in a before-after-control-impact framework. This allowed pre- and post- comparisons for the response variables of interest within the SMD and RSHD districts, as well as comparison of the SMDs and RSHDs to other HDs. The primary predictor variable of

interest in all analyses was the season type, e.g., limited permits, unlimited permits, or shortened seasons.

The number of years that response variables were collected and analyzed for each RSHD, SMD and other HDs varied (Tables 3 & 4). Overall, we analyzed harvest data going back to 1986 and survey data going back as far as 1971-72 when data were available. Some HDs had surveys that were flown in both the post-season survey period, December-January, and the spring survey period, March-May. Post-season surveys measured buck:doe ratios, fawn:doe ratios, and occasionally trend in total population; while spring recruitment surveys measured fawn:adult ratios and trend in populations on specific trend areas. Although deer age data are collected in many HDs and in some cases are used in the objectives for a HD, we did not evaluate these data because of the difficulty in gathering enough age information to make meaningful comparisons.

Statistical Methods

We used mixed-effects general linear models to examine the relationship between deer populations, harvest, hunter numbers and types of regulations at the HD level. The mixed-effects framework allowed us to partition variation within and among HDs in a repeated measures framework (Neter et al. 1996). We used these models to examine a wide range of aspects of deer populations and hunting by looking at 8 response variables:

1) number of bucks harvested per 100 mi^2
2) number of bucks harvested per 100 mi^2 with 4 or more antler points
3) proportion of buck harvest with 4 or more antler points
4) number of bucks per 100 does
5) number of hunters per 100 mi^2
6) number of hunter days per 100 mi^2
7) spring fawns per 100 adults
8) number of deer counted on trend areas

We standardized the number of bucks harvested, number of deer with 4 or more antler points harvested, number of hunters, and number of hunter days by unit area (per 100 mi^2). By standardizing these response variables, we were able to eliminate the influence that HD size might have on response variables and it allowed us to use some HDs that had changed in size and were censored in the first analysis.

Besides standardizing some of the response variables, this analysis differed slightly from Newell and Lukacs (2011) in two ways: 1), this analysis has two random effects, HD and year rather than HD only as in the first analysis. We added year as a random rather than a fixed effect because we recognized that some years may provide differing results in large geographic areas because of environmental conditions and 2) we included restriction year as a fixed effect in the models. This allowed us to see the effect of the length of time a restriction had been in place on the response variables. As in Newell and Lukacs (2011) there were 4 treatments; HDs with no buck restrictions, HDs with a shortened season, HDs with unlimited buck permits and HDs with limited buck permits. We fit 3 models to those treatments and looked for differences in the response variables relative to the

Table 4. Number of years population response variables were available from trend areas located in hunting districts (HDs) without buck restrictions.

Trend Area[1]	Bucks: 100Does	Fawns:100 Adults	Pop. Trend	Trend Area	Bucks: 100Does	Fawns:100 Adults	Pop. Trend
103	0	9	9	502	32	34	33
121	0	5	5	510	8	0	0
202	2	1	1	511	34	30	28
210	7	1	1	520	26	34	34
261	9	2	1	530	6	7	0
270	9	1	1	560	23	30	24
281	3	0	0	570CCR	29	31	21
291	4	1	0	570YBR	29	31	20
292MD	16	3	3	580BCR	22	26	26
292CF	16	3	3	580GR	34	35	27
300	9	16	16	575	39	37	37
302	21	0	0	590	30	31	0
312	26	27	27	600	6	6	6
313	5	7	7	611	7	6	6
319	26	27	22	620	6	5	5
320	12	8	8	621	6	5	5
324	11	6	6	630-632	5	5	5
325	4	4	4	640	12	20	9
326	18	25	25	650	5	0	3
331	6	6	4	651BM	3	3	0
339	3	4	3	651CU	18	17	13
340	38	39	24	652	3	0	0
341	39	41	33	670	8	7	7
360	0	23	21	680	6	6	6
380	7	6	4	690	6	6	6
391	8	4	4	700DC	20	20	20
393	39	32	28	700HAX	23	33	33
404	32	1	33	700SB	23	33	33
405	13	14	15	701CC	22	28	28
410	8	8	7	701SC	19	37	37
413	2	7	7	702SC	16	35	34
418	0	7	7	702TR	3	3	0
419	8	8	8	703BL	17	19	19
422	6	6	6	704-705	19	16	17
424	4	5	1	704OC	13	29	30
425	4	5	5	704OL	18	17	18
426	9	9	9	705BC	7	12	12
441	8	0	0	705BR	14	25	25
442	24	18	17	705HC	16	20	20
500	31	31	20	705TC	14	19	19

[1]HDs with multiple survey areas have letter abbreviations following the HD number.

treatments. The first model included random effects for year and HD and a fixed effect for restriction year (the number of years in the restriction type). This model represented no effect of buck hunting restrictions. The second model contained a fixed effect for type of hunting restriction, and random effects for year and HD for each regulation type. In addition, this model included a fixed effect for restriction year. This model represented an effect in the response variable as a function of restriction type that was consistent through time. The third model contained fixed effects for type of hunting restriction and restriction year, random effects for year and HD, and an interaction term for season effect and restriction year. This model represented an effect of the restriction type on the response variable that varied through time as a function of the restriction type. We fitted models in the statistics program R (R Development Core Team 2011) using the lme4 package (Bates et al. 2004).

We used Akaike information criterion (AIC) to select among the 3 models for each response variable. The model with the lowest AIC value was most supported by the data. We also examined parameter estimates and their variances to determine the quality of the model fit. It should be noted that in this analysis we changed the estimator to a maximum likelihood estimator as compared to the restricted maximum likelihood estimator used by Newell and Lukacs (2011). This represents an improvement in terms of the validity of AIC comparisons among models, given the assumptions and equations implicit in AIC comparisons.

RESULTS

In limited permit HDs with an objective of 40 bucks:100 does, post-season, the objective was met or exceeded 40.0% of the time or in 32 of 80 HD-years (Table 5). HD 652 accounted for most of the years that this objective was met and when it was eliminated from calculations, the objective was met in only 11 of 47 HD-years or 23.4% of the time. In limited permit HDs with an objective of 25 bucks:100 does post-season the objective was met or exceeded in 72 of 102 HD-years or 70.6% of the time. Over all HD-years with limited permits the post season buck:doe ratio was above 30:100, 49.5% of the time; above 20:100, 80.2% of the time; and above 10:100, 98.4% of the time (Fig. 2). In most cases the lowest buck:doe ratios were observed in the years immediately following the change to a more restrictive buck season.

Two of the HDs with a shortened season had a post-season buck:doe ratio objective of 25:100, one had an objective of 15:100 and the rest had no specific objective for buck:doe ratios. For all the shortened season HDs the objective for buck:doe ratios were met in 17 of 30 HD-years (56.7%). The buck:doe objective in the HD with an objective of 15 bucks:100 does was met 75.0% of the time while the buck:doe objective in the HD with an objective of 25 bucks:100 does was met 35.7% of the time. In HDs with a shortened season the buck:doe ratio was above 30:100 17.7% of the time, above 20:100 44.5% of the time, and above 10:100 82.9% of the time (Fig. 2).

Table 5. Number of years that HDs met objectives for buck:doe ratios.

HD	HD Restriction	Bucks:100 does Obj.	No. Years Obj. Met	No. Years Obj. Not Met	No. Years Unknown
109[1]	Short Season	NA	NA	NA	NA
202	Limited	40:100	5	5	6
210	Limited	40:100	0	5	10
261	Limited	40:100	2	8	9
270	Limited	40:100	4	11	4
291	Limited	40:100	0	18	10
300	Limited	25:100	5	13	1
312	Limited	25:100	15	4	0
313	Short Season	15:100	12	4	4
320	Short Season	25:100	5	9	1
324	Limited	25:100	10	7	
333	Short Season	25:100	NA	NA	NA
441	Limited	25:100	26	3	1
455	Limited	20:100	NA	NA	NA
510	Unlimited	25:100	1	12	6
530	Limited	25:100	26	3	1
652	Limited	40:100	21	1	0
109[1]	Short Season	NA	NA	NA	NA
204	Unlimited	>10:100	NA	NA	NA
212	Unlimited	>10:100	NA	NA	NA
213	Unlimited	>10:100	NA	NA	NA
214	Unlimited	>10:100	NA	NA	NA
215	Unlimited	>10:100	NA	NA	NA
217	Unlimited	>10:100	NA	NA	NA
240	Unlimited	>10:100	NA	NA	NA
250[2]	Unlimited	>10:100	NA	NA	NA
250[2]	Limited	>10:100	1	2	6
262	Limited	Included with 261 in Table 4			
281	Unlimited	>10:100	NA	NA	NA
292MD[3]	Unlimited	>10:100	8	3	4
292CF[3]	Unlimited	>10:100	5	1	11
298[3]	Unlimited	Survey data combined with HD 292.			
302	Unlimited	>10:100	6	0	0
318	Unlimited	>10:100	NA	NA	NA
319	Unlimited	>10:100	9	3	2
329	Unlimited	>10:100	NA	NA	NA
335	Unlimited	>10:100	NA	NA	NA
339	Unlimited	>10:100	12	1	4
343	Unlimited	>10:100	NA	NA	NA
380	Unlimited	>10:100	9	5	3
390	Unlimited	>10:100	NA	NA	NA
391	Unlimited	>10:100	12	1	3
392	Unlimited	>10:100	NA	NA	NA

Table 5 (cont.)

HD	HD Restriction	Bucks:100 does Obj.	No. Years Obj. Met	No. Years Obj. Not Met	No. Years Unknown
400	Short Season	NA	NA	NA	NA
401	Short Season	NA	NA	NA	NA
403	Short Season	NA	NA	NA	NA
406	Short Season	NA	NA	NA	NA
640	Short Season	NA	NA	NA	NA

[1]First three weeks of season any buck, last two weeks limited buck permits.
[2]In 2010 HD 250 changed to limited permits, harvest information up until that time analyzed with the unlimited permit type.
[3]Combined survey information for HDs 292 and 298 for the period 2008-2016. HD 292 had multiple survey areas.

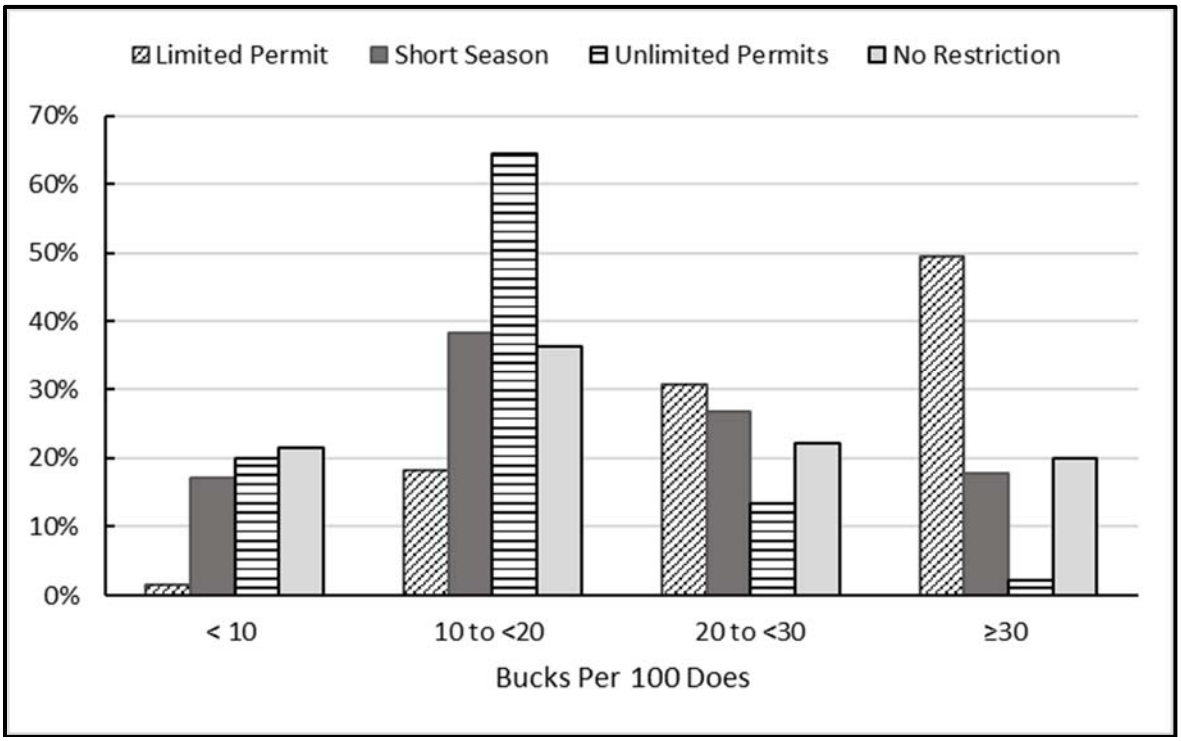


Figure 2. Percentage of hunting district-years in four categories of buck:doe ratios by season restriction.

The HD with unlimited permits that had a buck:doe objective of 25:100 met that objective in only 1 of 13 years or 7.7% of the time. Most of the RSHDs with unlimited permits had an objective of maintaining at least 10 bucks per 100 does. In those HDs, there was a minimum of 10 bucks:100 does in 62 of 76 HD-years or 81.6% of the time. In all HDs with unlimited permits the buck:doe ratio was above 30:100 2.2% of the time, above 20:100 15.5% of the time, and above 10:100 79.9% of the time (Fig. 2).

There were 76 areas that allowed any buck to be harvested on the general license with survey data on buck:doe ratios. In those HDs, the buck:doe ratio was above 30:100 19.9% of the time, above 20:100 42.1% of the time, and above 10:100 78.4% of the time (Fig. 2).

Model Fitting

The third model, representing an effect of the restriction type on the response variable that varied through time differently for each restriction type, performed as well as, or better than, other models for the proportion of bucks harvested with four or more points, the post-season buck:doe ratios, and the number of deer counted on trend areas (Table 6). For all the response variables that were standardized on number per 100 mi^2 and for fawns:100 adults the second model, representing an effect in the response variable due to restriction type that was consistent through time, performed as well as or better than the third model (Table 7). In every case, models that contained an effect for season restriction out-performed the model with no effect for season restriction.

Table 6. Results of AIC analysis for models of the proportion of bucks harvested with four or more points, post-season buck:doe ratios, and the number of deer counted on trend areas. For each response variable, Delta AIC refers to the difference in AIC between the third model and second model.

Response Variables	Delta AIC
Proportion of Bucks ≥4 pts	23.4
Bucks:100 Females	2.0
Total Deer Counted on Trend Areas	24.0

Table 7. Results of AIC analysis for response variables that were standardized on number per 100 mi^2 and for fawns:100 adults. For each response variable, Delta AIC refers to the difference in AIC between the second model and the first model.

Response Variables	Delta AIC
Bucks Harvested:100 Mi^2	446.0
4-Pt Bucks Harvested:100 Mi^2	226.0
Number Hunters: 100 Mi^2	58.0
Number Hunter Days:100 Mi^2	39.0
Fawns:100 Adults	3.0

Number of Bucks Harvested per 100 mi^2

Over all HDs statewide there was a significant annual loss of 0.738 bucks per 100 mi^2. All HDs with restrictions on buck harvest had a lower number of bucks harvested per 100 mi^2 than HDs with no restrictions. HDs with limited permits had the greatest loss in harvest

and HDs with unlimited permits had the smallest loss in harvest (Table 8). All districts, regardless of season type, had a continual decline in buck harvest, predicted to continue to the point of 0 bucks harvested per 100 mi^2, which is unrealistic and only a function of the linear models (Fig. 3)

Number of 4-point Bucks Harvested per 100 mi^2

HDs with a shortened season and limited permits had a significantly lower number of 4-point bucks harvested per 100 mi^2 while the lower number of 4-point bucks harvested per 100 mi^2 in HDs with unlimited permits was not significantly different than the HDs with the unrestricted season type. In addition, statewide there was a significant annual decline in the number of 4-point bucks harvested per 100 mi^2 for all season types (Table 8; Fig. 3). As with the total number of bucks harvested per 100 mi^2 the decline in the number of 4-point bucks harvested per 100 mi^2 was greatest for HDs with limited permits, followed by HDs with shortened seasons and HDs with unlimited permits (Fig. 3).

Proportion of Bucks Harvested with 4 or More Points

HDs with limited and unlimited permit season types had a significantly higher proportion of bucks with 4 or more points in the harvest compared to the unrestricted season type, while the lower proportion of bucks with 4 or more points in the harvest in the shortened season type was not significant. The proportion of bucks with 4 or more points in the harvest increased annually in HDs with shortened seasons, limited permits, and without restrictions on buck harvest (Fig. 4). The proportion of bucks with 4 or more points in the harvest increased the most in HDs with the limited permit season type (Fig. 4). The proportion of bucks with 4 or more points in the harvest increased the least, annually, in unlimited permit HDs (Table 9).

Bucks:100 Does

There was a great amount of variation in the number of bucks per 100 does observed on individual trend areas across the state. HDs with limited permit seasons had significantly higher buck:doe ratios than HDs without buck hunting restrictions following initiation of these restrictive season types. Buck: doe ratios were lower (statistically insignificant) in HDs with shortened seasons compared to HDs without buck hunting restrictions (Table 9). There was a statistically insignificant increase of .052 bucks per 100 does annually. Following the initial decline in buck:doe ratios, HDs with a shortened season, showed an annual increase that was statistically significant (Table 9). Our model indicated that HDs with limited permits followed by HDs with shortened seasons and then HDs with no restrictions showed the greatest increasing trends in the number of bucks per 100 does while HDs with unlimited permits showed a stable unchanging trend in the number of bucks:100 does (Fig. 4).

Number of Hunters and Hunter Days per 100 mi^2

HDs with limited and unlimited permits had significantly lower hunter numbers per 100 mi^2 than HDs without restrictions. HDs with shortened seasons had hunter densities that were also lower than HDs without restrictions, though this difference was not significant. Statewide, all HDs had a statistically significant annual decline of 2.13 hunters per 100 mi^2 (Table 8). Relative to HDs with no restrictions, HDs with limited permits, unlimited permits and shortened seasons had the greatest to least losses of hunters (Fig. 5).

All HDs with restricted buck hunting seasons had lower hunter days per 100 mi^2 than HDs without restrictions, although only the loss in HDs with limited permits was significant (Table 8; Fig. 5).

Fawns:100 Adults

HDs with shortened seasons had a significantly higher fawn:100 adult ratio than HDs without restrictions, and while HDs with limited permits and unlimited permits also had higher fawn:100 adult ratios than HDs without restrictions, this difference was not statistically significant (Fig. 6; Table 8). Over all HDs, regardless of season type, there was a statistically significant declining trend of 0.207 fawns:100 adults annually.

Number of Deer on Trend Areas

Mule deer numbers in trend areas with limited and unlimited permits were higher than HDs without restrictions following implementation of these seasons types, then numbers of deer in trend areas with these restricted season types gradually declined. In HDs with shortened seasons, mule deer numbers were significantly lower than areas without restrictions, following implementation of the season restriction, and then mule deer numbers gradually increased over time. HDs with no restrictions had a very minor decrease in number of mule deer on trend areas over time (Table 9; Fig. 6).

Table 8. Effect of mule deer buck restrictions on response variables. In our analyses, hunting districts (HDs) with no restrictions were treated as the base category, so the coefficients here should be interpreted as relative to HDs with no restrictions. Restriction year is interpreted as the expected annual change since season type implementation, for all HDs.

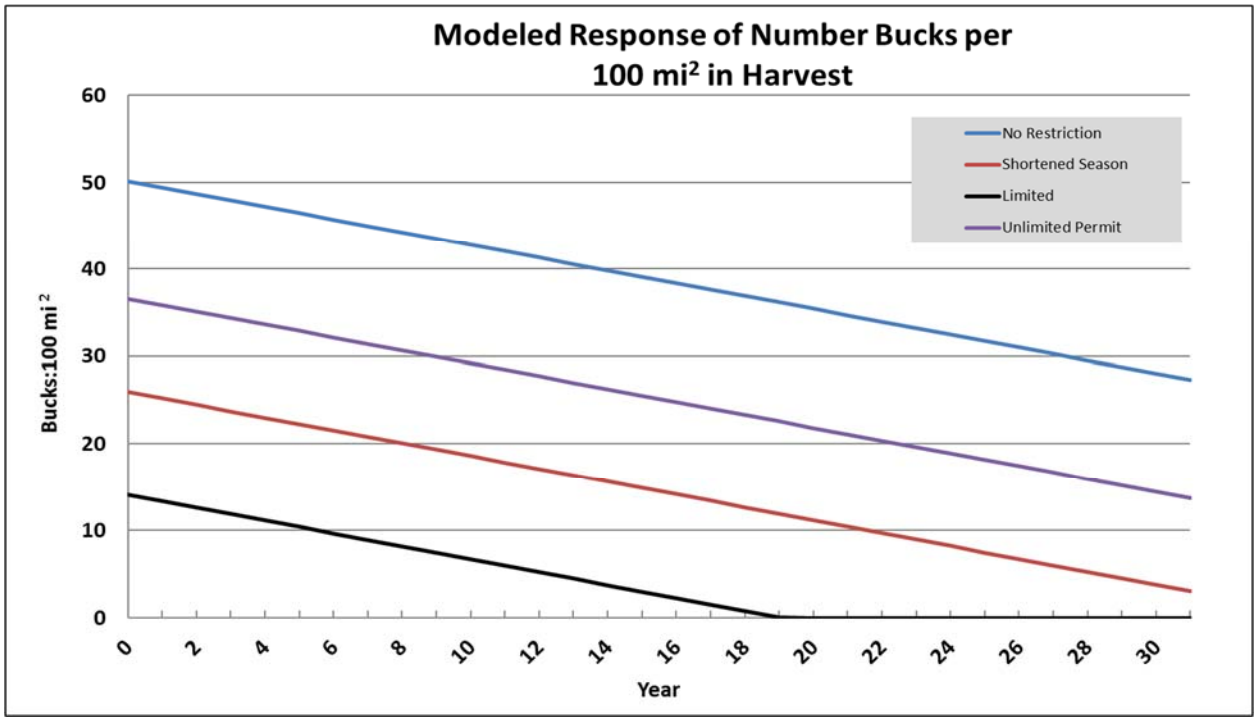
	Model 2 - No Interaction Effect									
	Intercept		Short Season		Limited Permits		Unlimited Permits		Restriction Year	
Response Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Harvested Bucks per 100 Mi^2	**50.181**	3.15	**-24.259**	10.638	**-36.106**	11.575	**-13.612**	2.597	**-0.738**	0.110
Harvested 4-point Bucks per 100 Mi^2	**21.589**	1.56	**-9.743**	3.620	**-10.324**	4.377	-0.604	1.344	**-0.188**	0.063
Hunters per 100 Mi^2	**269.608**	19.12	-59.250	39.930	**-127.100**	49.154	**-68.778**	16.313	**-2.129**	0.554
Hunter Days per 100 Mi^2	**1334.440**	117.73	-147.249	228.194	**-669.007**	309.624	-168.764	97.649	-1.343	2.967
Fawns per 100 Adults	**47.737**	1.95	**9.679**	2.837	1.570	2.905	2.272	2.466	**-0.207**	0.082

Bold indicates significance.

Table 9. Effect of mule deer buck restrictions on response variables. In our analyses, hunting districts (HDs) with no restrictions were treated as the base category, so the coefficients here should be interpreted as relative to HDs with no restrictions. Restriction year is interpreted as the expected annual change for HDs with no restrictions.

	Model 3 - Interaction Effect															
	Intercept		Short Season		Short Season:RYear		Limited Permits		Limited:Ryear		Unlimited Permits		Unlimited:Ryear		Restriction Year	
Response Variable	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Harvested Proportion of bucks ≥ 4 pts	**0.468**	0.017	-0.046	0.060	0.002	0.001	**0.176**	0.038	**0.006**	0.001	**0.100**	0.021	-0.002	0.002	**0.003**	0.001
Bucks per 100 Does onTrend Areas	**20.886**	1.419	-3.563	2.875	**0.209**	0.084	**6.765**	3.393	0.166	0.101	3.214	3.287	-0.048	0.139	0.052	0.047
No. of Deer in Trend Areas	520.332	47.679	**-117.832**	59.523	3.192	1.786	**198.278**	95.430	**-11.564**	2.894	**226.050**	104.092	**-13.724**	4.042	-0.745	0.974

Bold indicates significance.



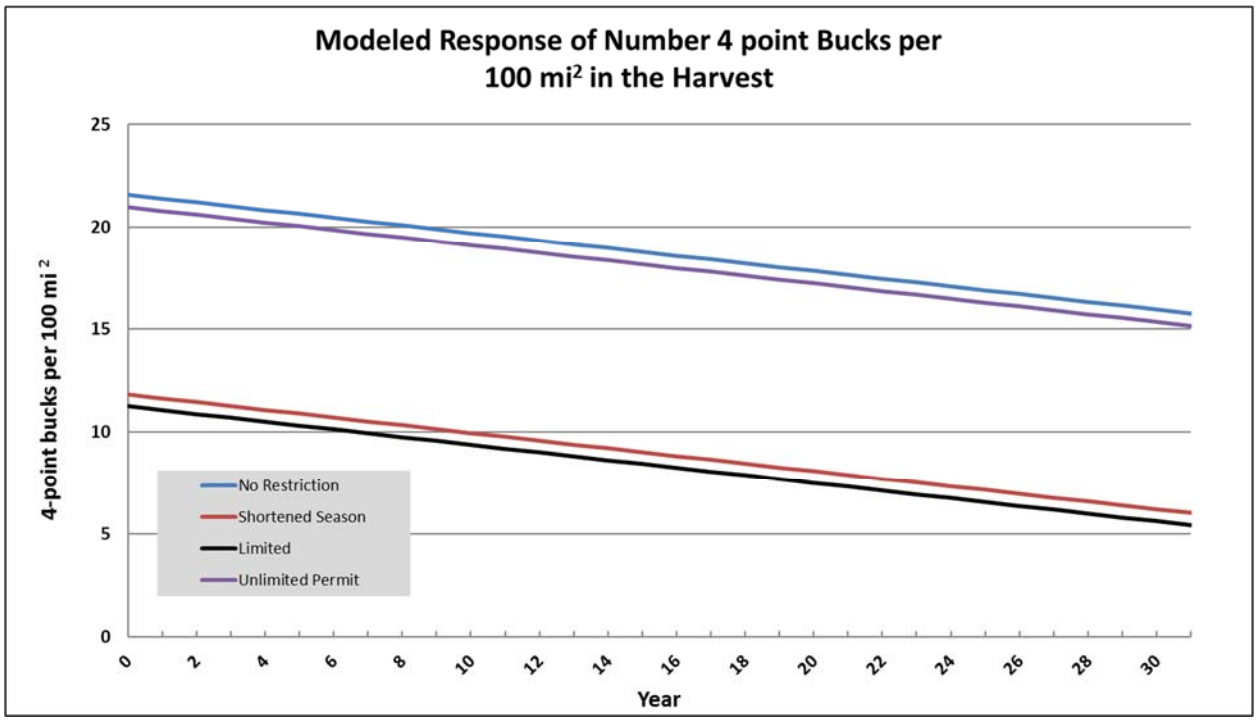
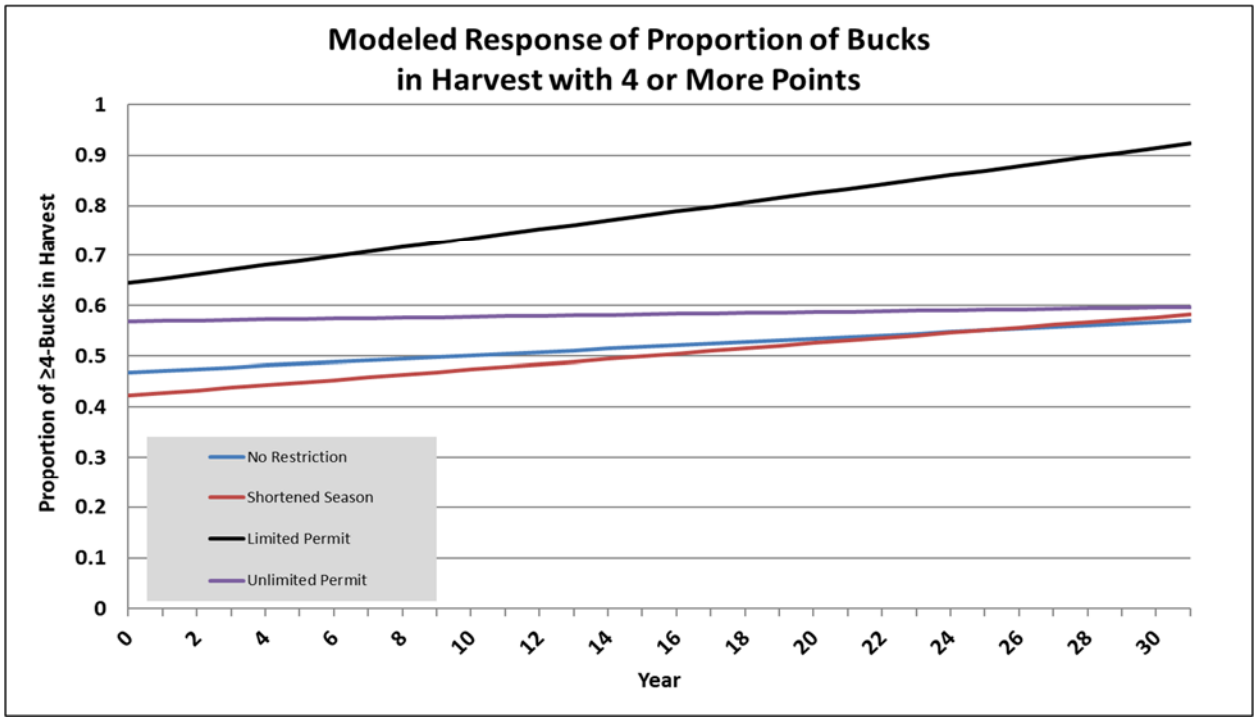


Figure 3. Predicted average effects of season type and year on number of bucks and number of 4 - point bucks harvested per 100 mi^2.



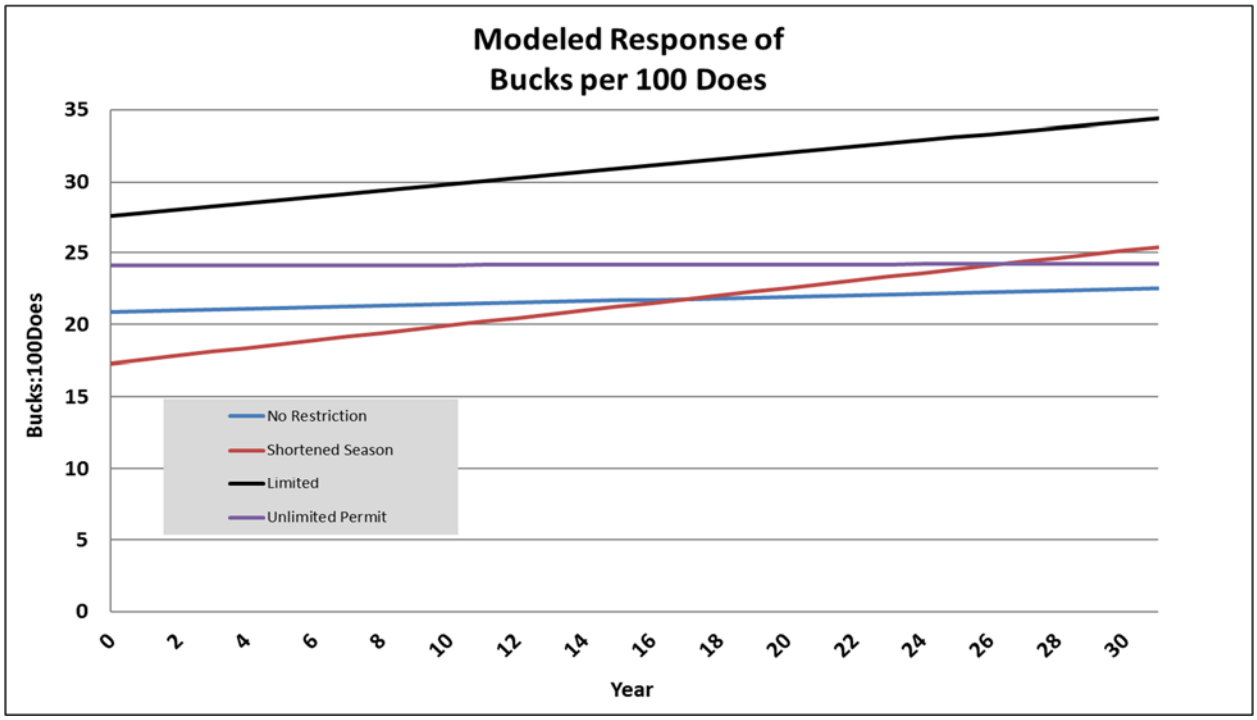
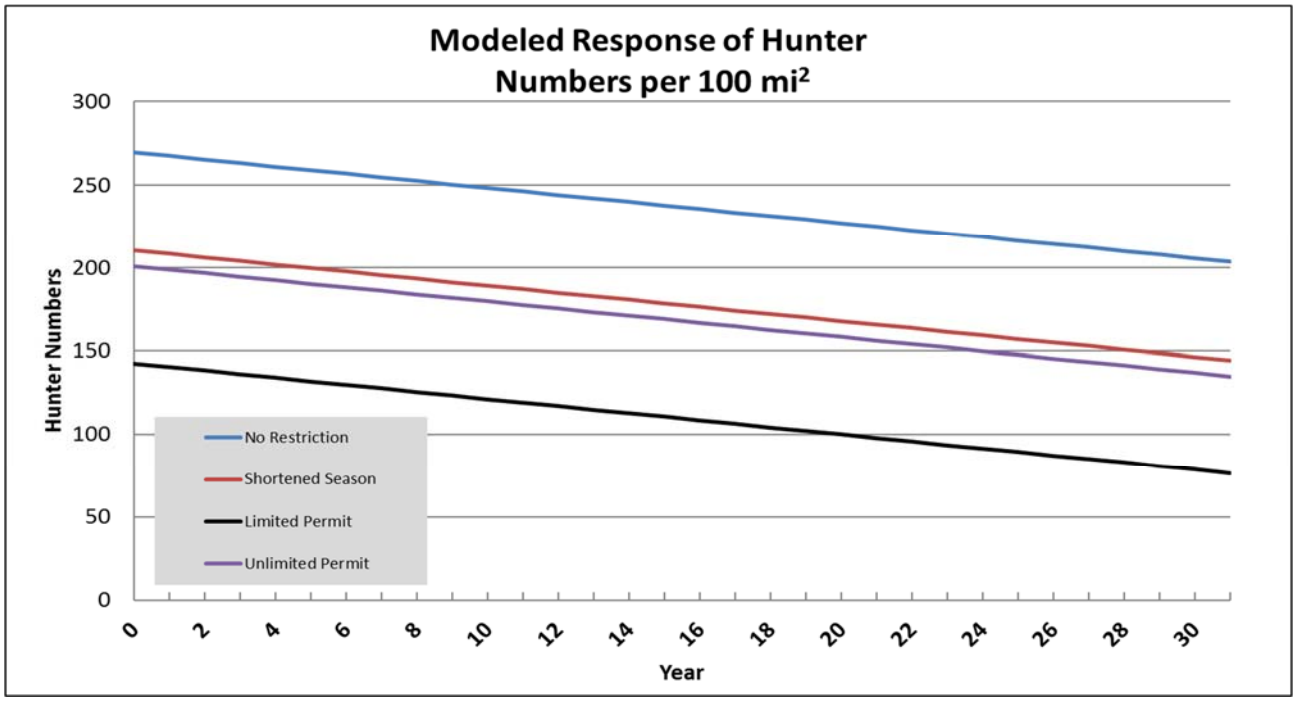


Figure 4. Predicted average effects of season type and year on proportion of bucks in harvest with 4 or more points and number of bucks per 100 does observed on trend areas.



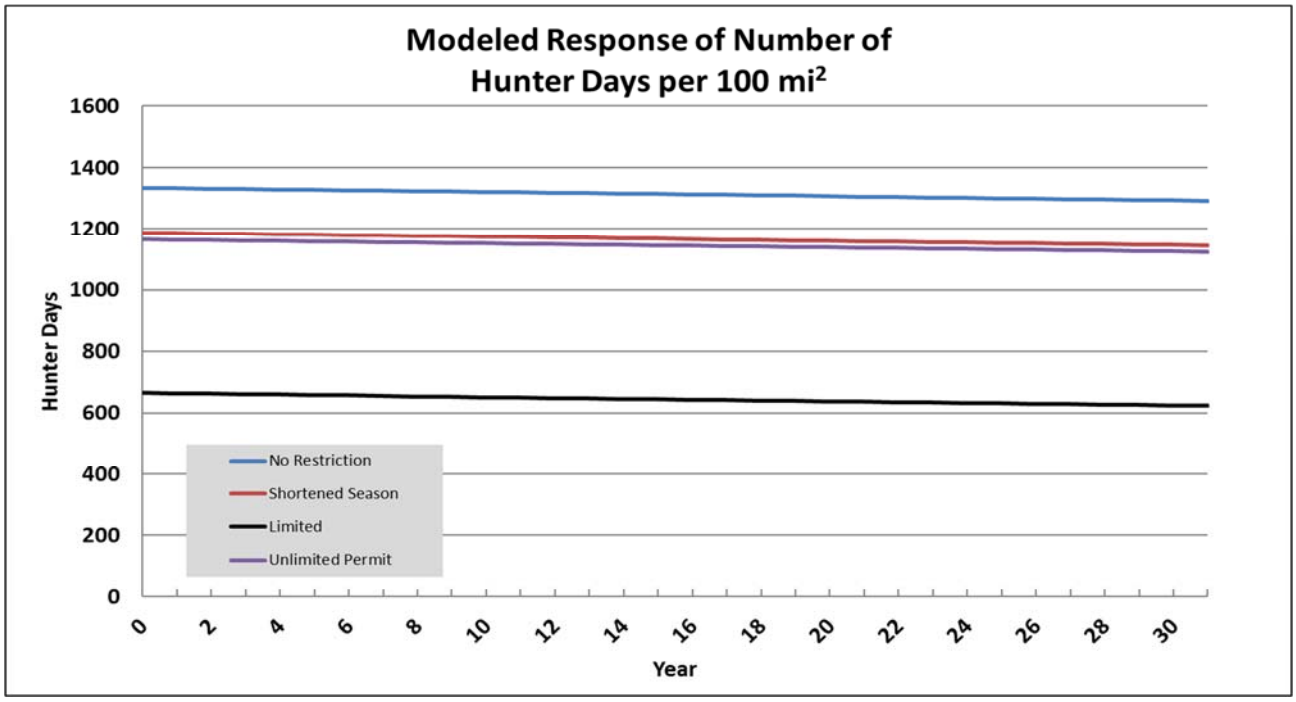
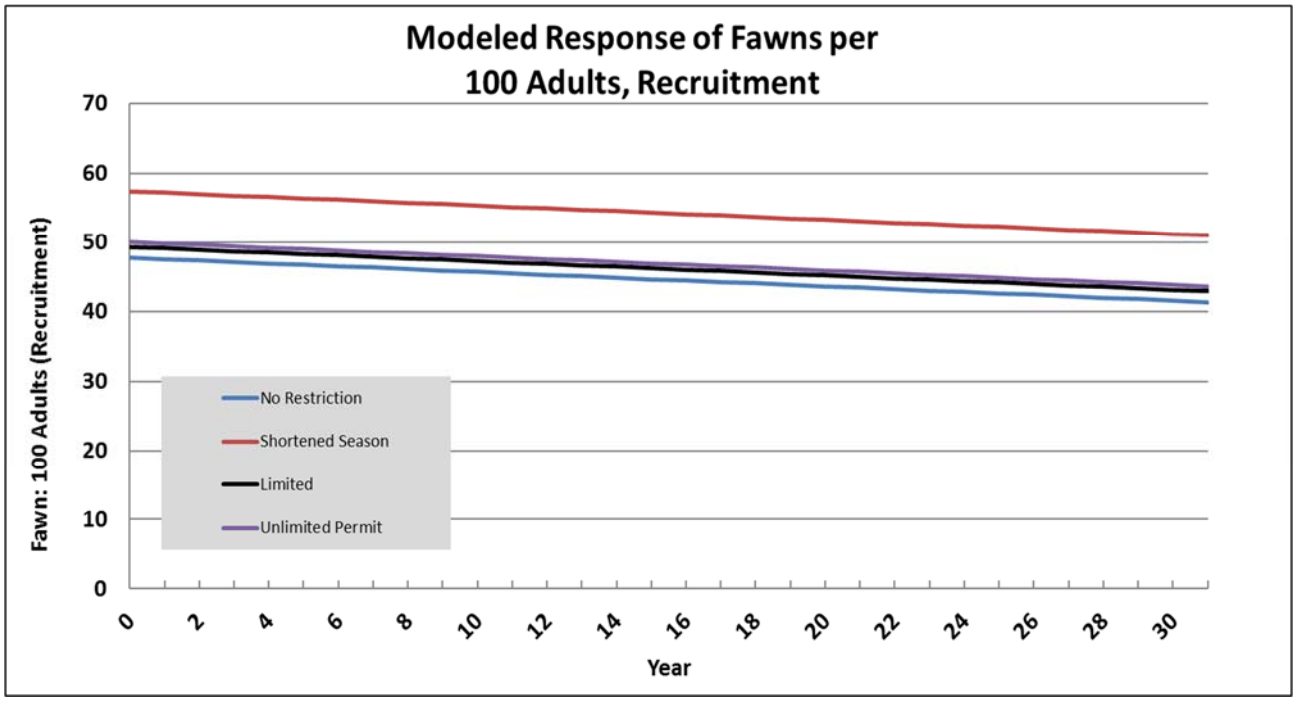


Figure 5. Predicted average effects of season type and year on number of hunters, and hunter days per 100 mi^2.



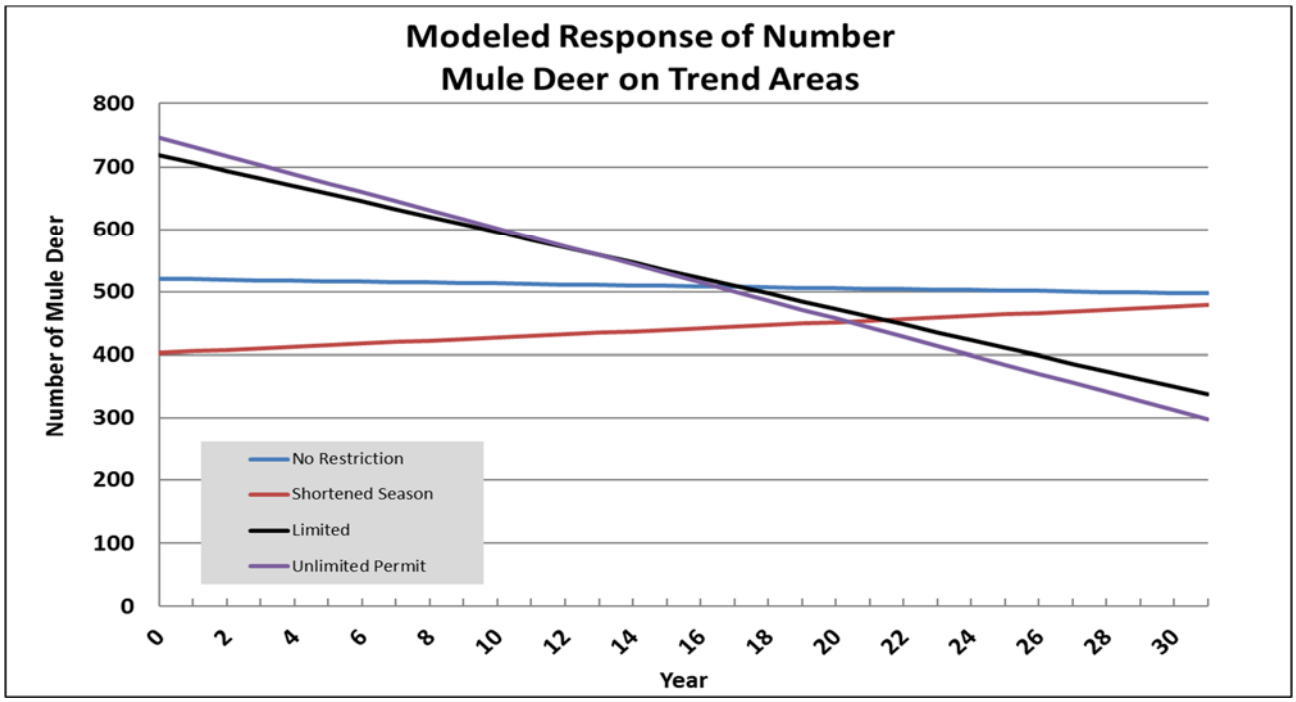


Figure 6. Predicted average effects of season type and year on recruitment, and number of mule deer counted on trend areas.

DISCUSSION

Newell and Lukacs (2011) reported that, due to the great amount of variability among HDs, it was often difficult to detect differences among regulation types and that the high amount of variability sometimes masked meaningful results. Because we were able to increase sample sizes for all the harvest response variables in this analysis, and add a large amount of survey data, the variance of our results is lower, and the analyses presented here are more reliable.

Overall, our results were similar to the results in Newell and Lukacs (2011). We found that mule deer buck season restrictions were successful at achieving specific buck objectives in many cases. In areas with limited permits, objectives of 25 bucks per 100 does or lower were met in most years and in most HDs, but objectives of 40 bucks:100 does were not met in most HDs, especially in the western part of the state. It is possible that further reductions in buck permit numbers may help to increase buck:doe ratios. However, Pac and White (2007) suggested that managers would have a difficult time improving numbers of mature males in the harvest and buck:doe ratios in areas where mule deer coexist with a diversity of large carnivores, as is the case in many HDs in the western part of the state.

About 80% of the time, objectives of maintaining more than 10 bucks per 100 does, post-season, were met in HDs with unlimited permits, but achieving and sustaining ratios much higher than 20 bucks:100 does is unlikely with this restriction type. In fact, our model for HDs with unlimited permits indicates that the increased buck:doe ratio in unlimited permit areas (as compared to HDs with no restrictions) fluctuates very little over time, compared to increasing buck:doe ratios in HDs with short seasons and no restrictions. Eventually HDs with shortened seasons or no restrictions would have buck:doe ratios higher than HDs with unlimited permits. Our results indicate that it would take 16 years in HDs with short buck seasons to achieve a buck:doe ratio similar to HDs without restrictions, and 26 years in HDs with short buck seasons to achieve ratios similar to HDs with unlimited permits.

Our results indicate that both number of bucks and number of bucks with 4 or more points harvested per 100 mi^2 declined following implementation of a buck restriction, followed by a declining annual trend for all season types. These declines, as compared to HDs with no restrictions, were highest for HDs with limited permits, then shortened seasons, followed by HDs with unlimited permits. In Newell and Lukacs (2011), total number of bucks and total number of bucks with 4 or more points in the harvest showed an increasing trend in HDs with shortened seasons, which we did not substantiate when focusing on density rather than absolute numbers. All HDs across the state showed annual increases in the proportion of 4-point bucks in the harvest with limited permit HDs having the highest annual increase and unlimited permit HDs having the lowest annual increase.

Limited permit, shortened season and HDs with no restrictions all showed an increasing trend in buck:doe ratios with time. The shortened season type had a loss of 3.6 bucks per 100 does, on average after implementation, followed by an annual gain of 0.26 bucks per

100 does. On average, it would take approximately 16 years for buck:doe ratios in HDs with shortened seasons to return to a level comparable to HDs with no restrictions. HDs with limited and unlimited permits had increases of 6.8 and 3.2 bucks per 100 does, respectively, following implementation. Limited permit HDs continued to see increases in the buck:doe ratio over time, while buck:doe ratios in unlimited permit HDs remained stable over time. Like the results reported here, Olson (1996) and Newell (1996) showed a trend of increasing buck:doe ratios in HDs with limited permits following changes in regulations in HDs 441 and 530. Likewise, Thompson (2007) saw an increase in buck:doe ratios in HD 640 over time following a change to a shortened season, however he found that the increase was a result of increased survival of immature bucks, not mature bucks. Bergman et al. (2011) in Colorado saw significant increases of 7.39 to 15.23 bucks per 100 does in areas that they considered to be moderately limited and 17.55 to 21.86 bucks per 100 does increase in areas that they considered to be highly limited. Moderately limited in Colorado was much more restrictive than any of the limited seasons in Montana. It appears that increasing buck:doe ratios is a consistent result of limiting hunter opportunity via a random drawing or by shortening the season.

All HDs with restrictions had lower hunter numbers than HDs with no restrictions. As in Newell and Lukacs (2011) HDs with no restrictions, limited permits, and unlimited permits all showed a downward trend in hunter numbers over time. Newell and Lukacs (2011) suggested that in the shortened season HDs there was a one-time loss in hunters following implementation of the season, followed by an increasing trend in hunter numbers, such that approximately 10 years following initiation of a shortened season one would see hunter numbers similar to HDs without restrictions. In this analysis we looked at the number of hunters per 100 mi^2 instead of numbers of hunters on the absolute scale, and our results suggest that hunter numbers per 100 mi^2 in HDs with shortened seasons will not return to levels as high as HDs with no restriction, however the decline in hunter numbers per 100 mi^2 in HDs with shortened seasons are not as large as those in HDs with unlimited and limited permits.

In all HDs we saw losses in the number of hunter days generated and like hunter numbers the greatest losses were in HDs with limited permits followed by HDs with unlimited permits and finally HDs with shortened seasons.

In Montana, Olson (1996) compared HD 441, a HD which allowed a general license holder to harvest a mule deer buck the first 3 weeks of the season and was on limited permits the last two weeks of the season, to HD 442, an adjacent area with no restrictions. He found that hunter days and numbers increased at a higher rate in HD 441 than in HD 442 over two time-periods, 1979-86 and 1987-95. Newell (1996) compared pre (1975-1986) and post-change (1987-1995) hunter numbers and days in HD 530 and found a large loss in both following the change to limited permits. The reason that HD 441 showed an increase while HD 530 showed a decrease in hunter use may be related, in part, to the fact that HD 441 had a portion of its mule deer buck season open to general license holders while HD 530 did not. Thompson (2007) compared hunter days in HD 640 when regulations were changed from a five-week either-sex season to a shortened season. He found a large decrease in the number of hunter days following implementation of the change in 2004.

Any changes in hunter numbers and hunter days across regulation types is influenced by the fact that most HDs with a restricted season type have whitetail populations, and in many cases a season on mule deer does, that allow hunters to deer hunt within the HD, independent of mule deer buck hunting regulations. Montana harvest reports do not distinguish between hunter numbers and days generated by whitetail, mule deer doe or mule deer buck hunters. Further, elk hunters also generate deer hunting effort if they are carrying a deer hunting license while elk hunting, thus generating additional hunter numbers and days. Therefore, the actual loss in mule deer buck hunter numbers may be much higher than reported here. In Colorado researchers did not estimate losses in hunters and hunter numbers following a statewide restriction in the harvest of mule deer bucks, however there was an immediate decline of 7.86 million dollars (51.2%) in annual revenue due to the reduction in deer license sales (Bergman et.al. 2011).

Newell and Lukacs (2011) reported an increase in the observed spring fawn:adult ratios in all HDs with restrictions even though the general trend was for decreasing fawn:adult ratios of approximately 0.83 fawn per year across all HDs. In this analysis we documented an increase in fawn:adult ratios in HDs with all 3 types of buck hunting restrictions. This increase was the highest for HDs with shortened seasons and lowest for HDs with limited permits. As in Newell and Lukacs (2011), we found an annual decreasing trend statewide in all HDs of 0.21 fawns:100 adults. A reduction of 0.21 fawns:100 adults per year seems small, but over a period of 20 years one could expect to see a reduction of over 4 fawns:100 adults on average. The increases in fawn recruitment in the restricted regulation HDs in Montana contrasted with Bergman et.al. (2011), who found that fawn:doe ratios decreased by 6.96 fawns per 100 does following implementation of limited-entry hunting for mule deer bucks statewide. Researchers in Colorado speculated that there was circumstantial evidence to suggest that fawns were being replaced by bucks in the population. We did not see this type of compensatory response in Montana, however our observed buck:doe ratios were much lower than those observed in Colorado (P. Lukacs, formerly Colorado Department of Wildlife, personal communication).

We found evidence that shifting to limited or unlimited buck permits resulted in an increase in total mule deer numbers on trend areas. However, because of the predicted annual decline we documented in HDs with limited or unlimited buck permits, we estimated that after approximately 17 years, HDs with no restrictions will have higher number of deer on their trend areas. HDs with shortened seasons had lower total mule deer numbers than HDs with no restrictions. However shortened season HDs showed a modest annual increase and we estimated that even after 30 years mule deer numbers would not equal numbers observed in HDs with no restrictions.

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