Control/exclosure monitoring of tule elk effects on Tomales Point vegetation, Point Reyes National Seashore, 1998-1999.

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Executive Summary

Cattle were removed from Tomales Point at Point Reyes National Seashore, and native tule elk were re-introduced, in 1979. The elk herd is confined to an approximately 2,600 acre area at the tip of the point, and it has grown exponentially from 15 animals in 1979 to 451 in 2000 (Gogan 1986, Point Reyes National Seashore 2000). The vegetation of the elk range exhibits signs of release from cattle grazing by increased shrubbiness, and changes in the abundance and distribution of some plants that were palatable to cattle (Bartolome 1993). Management objectives are to maintain a healthy elk herd on Tomales Point, within a healthy ecosystem that supports populations of an endangered butterfly and several listed plants (National Park Service 1993). The objectives of this study are to make an assessment of the role of tule elk grazing in vegetation succession on the elk range; and provide an early warning system for the development of undesirable characteristics in the vegetation, both in terms of vegetation management for a sustainable native ecosystem and for elk nutritional needs.

Data on habitat use indicate that the elk congregate and feed more intensely in some areas of Tomales Point than others. Therefore, vegetation degradation is likely to proceed at a faster rate in the heavily used areas than elsewhere. These areas may be retarded in their recovery toward a more balanced, healthy ecosystem. Alternatively, they may reach an undesired degraded condition faster that other areas as elk density increases. One goal of this study is to evaluate whether impacts to vegetation are substantially greater in high use areas than in low use sites, within the three main vegetation types on the elk range.

Twelve pairs of fenced and unfenced plots are used in this study to monitor vegetation over the long term in both high and low elk use areas of the three main vegetation types of Tomales Point. Exclosure fences were installed in early spring of 1998. Vegetation was sampled in spring and summer 1998 and 1999. The 1998 data were taken soon after the fences were installed, so they were not expected to show effects of release from elk herbivory. Rather the 1998 data establish the baseline characteristics of the vegetation. The 1998 and 1999 data were used in an analysis of variance to evaluate differences in the rate of change in vegetation in high and low use areas of each vegetation type, and to show the initial effects of exclusion from elk grazing.

Results show that there are differences among the vegetation types in species composition and apparent recovery processes for individual species. Changes detected through the monitoring thus far are for the most part consistent with predictions from ecological observations of recovery from grazing release in similar systems. The range is similar to other northern coastal sites that have been heavily grazed by cattle in the past, and there are no apparent widespread and systematic problems with erosion, lack of ground cover or loss of important elk forage plants. It is impossible to see trends yet, with only one transition between 1998 and 1999 to evaluate. Addition of the 2001 monitoring data to the analysis should bring better resolution to patterns hinted at in these data. And,

longer term monitoring will allow for trend analyses that show the effects of elk on the vegetaion, and provide early warning of undesirable conditions in the vegetation.

Introduction

The natural vegetation at Tomales Point prior to ranching was likely a mosaic of northern coastal prairie and northern coastal scrub (Kuchler 1977). Vegetation studies at Pt. Reyes (Grams et. al. 1977, Russell 1983, Lathrop and Gogan 1985, Gogan 1986) and other nearby areas (McBride and Heady 1968, Barbour 1970, Elliot and Wiehausen 1974, McBride 1974, Hektner and Foin 1977, Foin and Hektner 1986) show that succession following removal of cattle and sheep tends to go from annual grassland to a perennial grassland/shrubland mosaic, and finally toward forest in the most inland areas. These changes are evident through an increase in native and non-native perennial grass abundance, the spread of shrubs into grassland areas, an increase in shrub density within shrub patches, an increase in the number and diversity of plant species, greater total biomass, and increasing litter accompanied by decreasing soil erosion through time. The particular trajectories and rates of change depend on local factors such as soil type, distance inland from the coastal bluff, the community that persisted through grazing, and the surrounding vegetation that supplies propagules for recovery.

Gogan (1986) studied Tomales Point vegetation in 1980-81, one year after tule elk were introduced and cattle were removed. Gogan's data, and a vegetation map made by Lathrop and Gogan (1985), indicate that the vegetation was a mosaic of grass and scrub vegetation. Grasslands dominated by non-native annual grasses from the Mediterranean areas of Europe occupied the high central ridge of the Point and its western, windward slopes. Scrub communities dominated by native coyote brush (*Baccharis pilularis*) covered the southern and eastern slopes, interspersed with grassland on ridge tops and in exposed sites. The northernmost tip of the point was covered with yellow bush lupine (*Lupinus arboreus*). In a 1993 range analysis of Tomales Point, Bartolome (1993) re-mapped the four community types identified by Gogan, resampled Gogan's grassland transects, and analyzed residual dry matter. His results showed that the post-livestock successional trajectories demonstrated elsewhere are occurring on Tomales Point. These include slight shifts in grassland species composition toward greater abundance of several native perennial grasses, along with other non-native perennial and annual grasses; increased productivity inferred from residual dry matter plots; and *Baccharis* and *Lupinus* spread into grassland areas in some locations. Changes in shrub density as indicators of release from grazing should be interpreted cautiously. *Baccharis* spread has been shown to be related to decreases in grazing pressure (McBride and Heady 1968, McBride 1974), whereas *Lupinus arboreus* populations are known to cycle in response to insect feeding on stems and roots (Davidson and Barbour 1977, Dick 1994, Harrison and Maron 1995). Consequently, *Lupinus* spread at Tomales Point may be a response to both relaxation in grazing pressure and recovery from population decline related to insect predation. Bartolome interpreted his results as a range scientist, concluding that gains in grass abundance were offset by increases in unpalatable shrubs, for no net improvement in the condition of Tomales Point vegetation for herbivores.

Management of Tomales Point for tule elk habitat is a major goal at Point Reyes National Seashore. However, several other parallel goals (National Park Service 1993) require that the ecology of Tomales Point be understood not merely as range for elk, but also as an ecosystem supporting a diversity of organisms in perpetuity. These other goals include maintenance of at least minimum viable populations of the endangered Myrtle's silverspot butterfly (*Speyeria zerene myrtleae*), recovery of the listed Point Reyes Blennosperma (*Blennosperma nanum var. robustum*), conservation of populations of the candidate plant, San Francisco owl's clover (*Triphysaria floribunda)*, conservation and restoration of native plant communities, and protection of soils of Tomales Point from further erosion. The best way to ensure that management addresses all of these concerns is to develop a baseline database and long-term monitoring program that tracks change in components of the Tomales Point ecosystem that are both sensitive to changes in elk density and important for sustaining the butterfly, the two species of rare plants, and the native plant communities (McCullough et al. 1993).

Myrtle's silverspot butterfly populations occur at Tomales Point and near North Beach in the Point Reyes National Seashore (U.S. Fish and Wildlife Service 1995). Studies of the North Beach population (Launer et. al. 1992) indicate that the blue violet is probably the sole larval host plant. The violet is widespread on Tomales Point (G. Fellers, pers. comm.), and it does not appear to be limiting myrtle's silverspot population distribution (Launer et. al. 1992.) Historically, native plants provided nectar for the adults during the flight time in late spring and summer. However, the nectar plants that are now used by the insect in upland areas such as Tomales Point are exotic thistles (*Cirsium* and *Carduus spp*.) These are weedy species that generally increase with moderate to heavy grazing pressure, and *Cirsium vulgare* is targeted for eradication through the exotic plant eradication program at Point Reyes (National Park Service 1993). Since these plants thrive in disturbed communities, they could decline in abundance as communities recover from grazing, affecting butterfly fecundity.

Point Reyes Blennosperma and San Francisco owl's clover were mapped and inventoried in 1983 (Clark and Fellers 1986), and populations have been surveyed by California Native Plant Society teams on a nearly annual schedule since then (G. Fellers, pers. comm.; unpublished data, Point Reyes National Seashore.) Results indicate that populations of these rare plants fluctuate in response to rainfall and summer drought. There is no apparent decline associated with tule elk presence, although the data need to be analyzed more fully to contrast trends on Tomales Point with those from other parts of the seashore.

Gogan (1986) and others (Gogan and Barett 1987, Gogan et. al. 1989, Gogan and Barrett 1995) studied the feeding habits and plant species utilization of elk on Tomales Point, while others have documented food preferences of elk at other sites (Korfhage, Nelson and Skovlin 1980, Hobbs et. Al. 1982, Wickstrom et. Al. 1984, Leslie, Starkey and Vavra 1984, Gogan and Barett 1994Wilmshurst, Fryxell and Hudson 1995). They find that tule elk are herb-grass feeders, utilizing herbs in the spring and summer when productivity is highest, and switching to grasses in the fall and winter. The dietary ratios of herbs, grasses and shrubs varied within herds by year, according to rainfall and nutrient content of the vegetation. The exotic herb, English plantain (*Plantago lanceolata*), constituted a large portion of both elk and deer diets on Tomales Point (Gogan and Barrett 1995), probably because it stays green longer into the summer months when most other forage is dry and cured. Gogan (1986) found that elk forage selection supports the model of optimal nutrient intake (Westoby 1974, Belovsky 1978). The elk appeared to be maximizing the mix of nutrients in their bulk diets, rather than feeding in proportion to availability in the flora (eg. MacArthur and Pianka 1966, Emlen 1966.) Gogan predicted that the elk were likely to continue to search out the plants that provide the best nutrient mix, even as those plants become rarer. Such feeding behavior could contribute to population decline in favored food plants (Westoby 1974), and it could exacerbate inter-specific competition between elk and deer as food resources become scarce (Gogan and Barrett 1995). Roberts (pers comm 2000) studied elk feeding patterns on Tomales Point in 1999-2000. She found that the elk are generally feeding in proportion to their occurrence in the plant community, with a few exceptions. *Plantago lanceolata* and *Rumex acetosella* were eaten in much higher proportion than expected from their cover in the plant community. Her results generally support Gogan (1986), but indicate that elk nutritional stress may have relaxed a bit as the elk range has recovered from cattle grazing.

Two alternative models of tule elk population growth and its effects on Tomales Point vegetation have been presented for Point Reyes management consideration (Gogan 1986, McCullough et. al. 1993), drawing on theories formulated by Caughley (1976, 1981). Under the first scenario (Caughley 1976), herbivore populations grow at a rapid rate to a population size above the environmental carrying capacity, then decline rapidly in response to nutritional stress to some lower, population density. The vegetation becomes stressed as carrying capacity is approached and exceeded, exhibiting changes in species composition and increased soil erosion as cover declines. The second herbivore-vegetation interaction model (Caughley 1981) predicts that total consumption by elk decreases as shrub density, along with abundance of other unpalatable species, increases. In response, the elk population growth rate declines and stabilizes at some low figure. Both of these models predict stabilization of the herbivore-vegetation system at some point. Such a stable configuration, or fluctuation about an equilibrium configuration, would be sustainable from a management perspective as long as it provides ample food and shelter for the butterfly, does not contribute to decline in Blennosperma or San Francisco owl's clover, and consists of predominantly native plant communities with low rates of soil erosion.

Exclosure study methods

Field methods

Twelve elk-proof exclosures were established on the Tomales Point elk range in the winter and spring of 1997–1998. The exclosures are in contrasting high and low elk-use areas of the range determined by monitoring of elk habitat use from October 1996 to October 1997 (Howell et al 2000). There are four exclosures in each of the three main vegetation types identified by Gogan (1986) and resampled by Bartholome (1993) on the range, with two in high use areas of each vegetation type and two in low use areas of each type. The vegetation types are: open grassland, lupine grassland, and *Baccharis* grassland. Exclosure locations were decided upon by overlaying vegetation maps made by Bartolome with elk-use maps of Howell et al (2000), and selecting locations at random from a grid system for exclosure placement. Each exclosure is paired with an adjacent unfenced control area, also chosen at random (Table 1). The exclosures and control areas are approximately 0.10 hectare (ha; 1 ha = 2.47 acres) each. Plant cover was sampled in 1998 and 1999 in the exclosures and in the control areas along three randomly located and permanently staked point-line-intercept transects each (Bonham 1989) for a total of six permanent transects at each exclosure-control area pair.

Table 1. Sample design and naming convention for exclosure – control area elk effects monitoring sites on Tomales Point, Pt. Reyes National Seashore.

	Open grassland	**Lupine grassland**	**Baccharis grassland**
High use	2 control / exclosure pairs: OGH1 & OGH2	2 control / exclosure pairs: LGH1 & LGH2	2 control / exclosure pairs: BGH1 & BGH2
Low use	2 control / exclosure pairs: OGL1 & OGL2	2 control / exclosure pairs: LGL1 & LGL2	2 control / exclosure pairs: BGL1 & BGL2

There are three permanently located cover transects in each exclosure and control area. Each transect is 30 meters long. Hits on plants and substrates were recorded every 30 centimeters (cm; 1 cm = 0.39 inches) along the transects, for a total of 100 points per transect. Data were recorded in the field on palmtop computers and downloaded into Excel spreadsheets. Plants were identified in the field according to the Jepson Manual (Hickman, ed 1993). The Tomales Point tule elk effects monitoring manual (McEachern et al 2001) gives the exclosure and control plot locations, a schematic showing how transects are located within each plot, and the locations of each sampling transect for each exclosure and control plot.

In addition to the cover sampling, shrub density was sampled in the *Baccharis* grassland exclosures and control areas to get better resolution on changes in that species. Ten 1-meter by 5-meter (m; 1 m = 39.37 inches) density plots were randomly located within each exclosure and control area. All shrubs rooted in the density plots were counted by size class in 1998, but not in 1999. Finally, soil penetrometer readings were taken in 1998 at five-meter intervals along each transect, for a baseline estimate of soil compaction.

Data analysis

The 1998 and 1999 data were summarized by control and exclosure treatments, within high and low elk use levels for each vegetation type. Samples from the three transects in each plot were considered subsamples, and were simply added together for the analyses. Absolute species frequency and relative cover were calculated for 1998 and 1999, along with cover of each substrate type encountered on the ground below the vegetation. Species richness, diversity and evenness (Shannon-Wiener functions, see Bonham 1979) indices were calculated. Soil penetrometer readings collected in 1998 were averaged for the study plots. Shrub density data collected in 1998 at the Baccharis grassland plots were summarized by size class.

Fourteen response variables were selected for study in a split-plot analysis of variance (Table 2). Several of these variables reflect holistic characters of the vegetation that have been hypothesized to change with changes in grazing regimes in northern California coastal ecosystems (McBride and Heady 1968, McBride 1974, Elliot and Wehausen 1974, Foin and Hektner 1986). Others were chosen as indicators of elk feeding habits, based upon Gogan's tule elk studies at Tomales Point 1979-1982 (1986), and others (Korflage et al 1980, Caughley and Lawton 1981, Hobbs 1982, Wickstrom et al 1984, Gogan et al 1989, Gogan and Barrett 1994, and Roberts' elk diet analyses conducted in 1999-2000 (pers comm).

Table 2. Response variables analyzed in a paired exclosure – control plot study of tule elk effects on vegetation at Tomales Point, Pt. Reyes National Seashore, 1998-1999.

Vegetation parameters expected to increase with release from cattle grazing:

- Species diversity
- Species richness
- Species evenness
- Native plant relative abundance
- Herb relative abundance
- Shrub relative abundance

Vegetation parameter expected to decrease with release from cattle grazing:
- Grass relative abundance

Shrub expected to increase without cattle and elk grazing:
- *Baccharis pilularis* absolute abundance

Grasses expected to respond to grazing by increased sprouting, resulting in an increase in cover over areas not grazed:
- *Lolium perenne* absolute abundance
- *Lolium multiflorum* absolute abundance
- *Holchus lanata* absolute abundance

Herbs utilized more by elk when nutritionally stressed:
- *Claytonia perfoliata* absolute abundance
- *Plantago lanceolata* absolute abundance
- *Rumex acetocella* absolute abundance

Inspection of the 1998 vegetation monitoring data showed that showed that there were important differences in baseline species frequency and cover between control and exclosure plot pairs for some elk use levels and vegetation types. To eliminate the effects of these differences for the analysis of variance, each response variable in 1999 was subtracted from the response variable in 1998 to create a "difference" variable between the two years. The analysis was conducted on these "differences" rather than on the raw data. The difference response variables were analyzed using a split-plot analysis of variance (Snedecor and Cochran 1980). Main plot variables included "Elk Use: Hi vs. Low" and "Vegetation: Baccharis grassland, Lupine grassland, or open grassland". Sub-plot variables included "Treatment: Exclosure vs. Control", "Treatment-by-Use" interaction, and Treatment-by-Vegetation" interaction.

Residuals were tested for normality using the Anderson-Darling test (Snedecor and Cochran 1980). For eight response variables, the residuals were non-normal due to large differences in variation between the three vegetation communities: relative abundance of shrubs, and absolute abundance of all seven individual species. These response variables were analyzed separately for each vegetation community. Where there were significant differences identified by the split plot analysis of variance, a mean separation test was performed using the Least Significant Difference test at the 95% confidence level. The analysis software used was SAS version 8.

Exclosure study results

<u>Community characteristics</u>

The vegetation at Tomales Point is dominated by several species of exotic perennial and annual grasses, along with a few exotic herbs. Grasses make up more than 50% of the cover in each of the vegetation types sampled, regardless of level of elk use (Table 3). Table 4 shows species with greater than five percent relative cover in the 1998 samples, averaged across the treatment plots for high and low elk use levels in three vegetation types. Appendix A shows mean absolute species frequency and relative cover in 1998 and 1999, by control and exclosure treatment and elk use level within each vegetation type. The native shrub, coyote brush (*Baccharis pilularis*), has high cover only in Baccharis grassland. Bush lupine (*Lupinus* *arboreus*) does not contribute greatly to plant cover in the Lupine grassland, although it gives the community a distinctive character. Several native grasses occur with high cover in the Open grassland, but not in the other two vegetation types. Bare, open rock or soil is very uncommon, with litter cover greater than 95% in all study plots in both years (Appendix B). The 1998 and 1999 samples show that patterns of plant species dominance and levels of ground cover are similar between high and low elk use areas within a vegetation type across the two years. However, species richness, diversity and evenness indices were all slightly lower in the high use areas than in the low use study areas in both years (Table 5).

Table 3. 1998 Tomales Pt. elk range control and exclosure vegetation monitoring. Relative cover for lifeforms and native/exotic guilds for three vegetation types by two elk use levels.

Baccharis Grassland - Relative cover[1] of Vegetation

	High Elk Use (n=12 transects)				Low Elk Use (n=12 transects)			
Lifeform	Mean	SE	Min	Max	Mean	SE	Min	Max
Grass - Annual	25.6	3.7	8.8	53.5	30.0	4.6	9.9	56.4
Grass - Perennial	30.6	2.3	16.3	46.1	26.7	3.1	12.9	45.8
Sedges/Rushes - Annual	0	0	0	0	0	0	0	0
Sedges/Rushes-Perennial	2.4	0.8	0.0	9.2	0.1	0.1	0.0	0.9
Herb - Annual	12.7	0.6	9.6	17.1	10.6	1.0	5.1	14.6
Herb - Perennial	11.8	0.5	9.7	14.1	15.5	1.0	10.3	24.2
Shrub	16.8	2.0	4.7	29.6	16.6	2.5	1.6	30.5

Lupine Grassland - Relative cover[1] of Vegetation

	High Elk Use (n=12 transects)				Low Elk Use (n=12 transects)			
Lifeform	Mean	SE	Min	Max	Mean	SE	Min	Max
Grass - Annual	59.1	1.9	47.5	66.9	60.8	1.7	45.3	68.8
Grass - Perennial	1.4	0.6	0	6.7	2.3	0.9	0	7.8
Sedges/Rushes - Annual	0	0	0	0	0	0	0	0
Sedges/Rushes-Perennial	0.05	0.05	0	0.6	0	0	0	0
Herb - Annual	27.9	1.4	21.0	35.8	19.7	1.4	10.1	26.9
Herb - Perennial	7.2	1.2	1.9	16.5	12.9	1.4	3.0	20.7
Shrub	4.2	0.6	1.2	9.2	4.3	1.3	0.3	16.8
Unknown	0.05	0.03	0	0.4	0.02	0.02	0	0.3

Open Grassland - Relative cover[1] of Vegetation

	High Elk Use (n=12 transects)				Low Elk Use (n=12 transects)			
Lifeform	Mean	SE	Min	Max	Mean	SE	Min	Max
Grass - Annual	23.8	1.6	14.8	32.5	56.7	1.5	46.2	65.0
Grass - Perennial	34.5	1.5	26.3	44.1	13.5	1.2	8.1	20.3
Sedges/Rushes - Annual	1.1	0.4	0	4.6	0	0	0	0
Sedges/Rushes-Perennial	6.6	0.9	2.0	11.3	0.1	0.1	0	0.6
Herb - Annual	4.0	1.0	0.5	11.3	16.4	1.8	6.9	26.6
Herb - Perennial	26.2	1.6	13.9	32.0	10.7	1.7	3.3	19.1
Shrub	3.2	0.9	0	11.1	2.5	0.7	0	7.5

[1]Relative cover = lifeform or guild hits/hits on all lifeforms or guilds

Table 4. 1998 Tomales Pt. elk range control and exclosure vegetation monitoring.

Relative species cover for three vegetation types by two elk use levels.

(Species with a relative cover of 5% or greater are highlighted in bold.)

Baccharis Grassland						
	Relative Cover (%)[1]					
	High Elk Use			**Low Elk Use**		
Species	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Baccharis pilularis	**16.6**	29.6	4.5	**9.9**	18.0	1.1
Bromus carinatus	1.6	5.1	0.0	**5.2**	10.9	0.0
Elymus glaucus	2.4	5.3	0.0	**7.0**	10.4	2.4
Holcus lanatus	**23.5**	38.8	10.1	**17.8**	40.2	2.7
Lolium perenne	**8.0**	13.9	3.8	**7.5**	11.1	3.2
Plantago lanceolata	**8.3**	14.0	1.1	**5.1**	12.9	0.0
Rubus ursinus	0.1	0.4	0.0	**6.5**	12.6	0.5
Rumex acetosella	**5.5**	9.5	3.4	4.3	7.2	1.0
Vulpia bromoides	**6.7**	13.4	0.0	0.2	1.3	0.0
Vulpia myuros	--	--	--	**5.9**	19.3	0.0
Lupine Grassland						
	Relative Cover (%)					
	High Elk Use			**Low Elk Use**		
Species	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Bromus diandrus	**9.0**	14.8	4.1	**9.3**	16.8	0.6
Lolium multiflorum	**12.9**	23.6	1.1	**13.7**	25.3	0.0
Lolium perenne	**23.0**	33.8	12.0	**15.8**	21.4	9.2
Rumex acetosella	**16.3**	24.7	4.8	**12.4**	20.8	2.9
Vulpia bromoides	**8.2**	16.5	1.0	**11.2**	22.6	0.9
Open Grassland						
	Relative Cover (%)					
	High Elk Use			**Low Elk Use**		
Species	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**
Aira caryophyllea	**8.3**	15.2	2.3	4.1	10.6	0.0
Bromus carinatus	0.3	1.9	0.0	**8.0**	16.6	0.4
Danthonia californica	**9.3**	16.3	2.1	0.7	2.6	0.0
Deschampsia cespitosa	**15.0**	28.0	3.7	--	--	--
Hordeum brachyantherum	0.0	0.3	0.0	**7.7**	18.2	0.6
Hypochaeris radicata	**5.1**	12.8	0.4	0.2	1.0	0.0
Lolium multiflorum	0.2	1.3	0.0	**7.1**	15.0	2.3

Lolium perenne	3.2	7.7	0.0	**11.6**	26.8	5.8
Plantago lanceolata	**18.2**	26.3	8.7	3.3	10.3	0.0
Rumex acetosella	0.8	3.6	0.0	**8.1**	16.4	2.8
Vulpia bromoides	2.4	8.6	0.0	**8.6**	25.7	0.0
Vulpia myuros	0.1	1.6	0.0	**5.4**	10.8	0.0
Vulpia unknown species	0.1	1.6	0.0	**7.7**	17.5	0.0

[1]Average number of hits per species / total hits on plants along transect.

Table 5. 1998 Tomales Pt. elk range control and exclosure vegetation monitoring.
Species richness, diversity and evenness for three vegetation types by two elk use levels.
(n=12 transects)

		Richness[1]		Diversity[2]		Evenness[3]	
Vegetation	**Elk Use Type**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Baccharis Grassland	High	20.17	0.92	2.37	0.066	0.791	0.016
Baccharis Grassland	Low	28.08	1.70	2.63	0.082	0.793	0.012
Lupine Grassland	High	22.92	1.20	2.33	0.078	0.746	0.014
Lupine Grassland	Low	27.08	1.58	2.46	0.077	0.749	0.012
Open Grassland	High	25.00	0.94	2.57	0.047	0.800	0.010
Open Grassland	Low	28.92	1.74	2.68	0.063	0.802	0.009

[1]Richness = Total number of species sampled

[2]Diversity = -sum ($P_i \times \log_N(P_i)$), where P_I = relative cover of species *i* (Shannon-Wiener function)

[3]Evenness = Diversity/$\log_N$(Richness)

Differences 1998 to 1999

Results of the split-plot analysis of variance on differences in fourteen response variables 1998 to 1999 are summarized in Table 6, followed by an explanation of where the differences are found in the data.

Table 6. Vegetation parameters showing significant differences 1998 to 1999 at the 95% confidence level, Tomales Point elk effects exclosure monitoring, Pt. Reyes National Seashore.

Response variable	**N.S**	**Use: High vs Low**	**Vegetation type**	**Treatment: Ex vs control**	**Treatment *Use**	**Treatment* Vegetation**
Species Diversity	X					
Species Eveness	X					
Species Richness			0.0492			0.0330
Relative abundance of native plants			0.0075			
Relative abundance of grasses				0.0056		
Relative abundance of herbs				0.0171		
Relative abundance of shrubs	x					
Abs. Abundance of *Baccharis pilularis*	x					
Abs. Abundance of *Claytonia perfoliata*				0.0274		
Abs.abundance of *Plantago lanceolata*	x					
Abs. Abundance of *Rumex acetocella*	x					
Abs. Abundance of *Lolium perenne*		0.0258		0.0463		
Abs. Abundance of *Lolium multiflorum*				0.0144		
Abs. Abundance of *Holchus lanata*		0.0063				

Species Richness: The number of species increased 1998-1999 in the open grassland control treatment.
Relative abundance of native plants: Relative abundance of natives increased in lupine grasslands 1998-1999, but stayed nearly the same in open grassland and *Baccharis* grassland.
Relative abundance of grasses: The relative abundance of grasses was lower in the exclosures compared with the controls after one year.
Relative abundance of herbs: The relative abundance of herbs was higher in the exclosures compared with the controls after one year.
Absolute abundance of *Claytonia perfoliata*: Showed a much larger increase in the lupine grassland exclosures than in the lupine grassland control plots 1998-1999.
Absolute abundance of *Lolium perenne*: Showed a much larger increase in relative abundance the open grassland control plots than in the open grassland exclosures. Additionally, in lupine grassland, showed more of a decease in relative abundance in high elk use vs the low elk use sites.
Absolute abundance of *Lolium multiflorum*: Showed more of a decrease in lupine grassland exclosures than in control plots.
Abs. abundance of *Holchus lanata*: Showed more of an increase in open grassland high elk use areas than in open grassland low use areas.

Discussion

The 1998 and 1999 monitoring data show that plant species composition at the Tomales Point elk range is typical of grazed coastal scrub and coastal prairie systems in other northern California areas (Barbour 1970, Grams et al 1977, Hektner and Foin 1977, Kuchler 1977). It is not unusual to see high relative cover of non-native grasses in these areas. Studies indicate that certain successional trends may be expected with release from cattle grazing in areas like Tomales Point, where remnants of the original vegetation still existed through the grazing era (National Park Service 1993). These include an increase in species richness and diversity, driven by increases in native plant abundance and, for the short term, by increases in weedy species that were palatable to cattle. Total plant productivity should increase, paralleled by increases in ground cover. *Baccharis pilularis* has been shown to increase in cover with grazing release (McBride 1974), although there is other evidence that competition from annual grasses may inhibit reinvasion in the early stages of release (McBride and Heady 1968). A few non-native perennial grasses widely planted as forage (National Park Service 1993), including *L. perenne* and *L. multiflorum*, and the invasive *Holcus lanata*, have been shown to resprout vigorously and increase in cover when grazed (Bartolome 1993). Hence, these species are predicted to decrease in the absence of herbivory. Data presented by Bartholome (1993) hint that such predicted changes are occurring on the Tomales Point elk range.

All of these changes would be compatible with the Point Reyes National Seashore management goals of recovering and restoring native ecosystems and supporting healthy, self-sustaining populations of rare and sensitive native plants on Tomales Point (National Park Service 1993). However, an additional goal for Tomales Point is to support healthy herds of tule elk on the same range. Elk graze some of the same plants that are used by cattle, and so they could be expected to slow the rate of change toward this more native condition envisioned in the Resource Management Plan (National Park Service 1993). Elk also utilize herbs and woody plant tissue in ways that cattle do not. As a result, the presence of elk at near carrying capacity density on the Tomales Point elk range may change the successional recovery trajectories normally seen with total grazing release.

The Tomales Point elk populations have been growing exponentially since their introduction in 1979. As they approach or overshoot their carrying capacity, they could severely damage the vegetation so that the management goals for rare plants and endangered butterfly forage species are violated. There is evidence that elk may switch feeding habits as they become nutritionally stressed. Particularly, they have been shown to seek out *Claytonia perfoliata*, *Plantago lanceolata*, and perhaps also *Rumex acetosella* as nutritional stress increases (Gogan and Barret 1995). Gogan et al (1989) showed that this may have been happening early in the tule elk introduction to Tomales Point, when the range was less productive than it was in 1993. Roberts (pers comm) showed that in 1998-1999, elk were eating most plants in proportion to their occurrence in the vegetation community. But, *Plantago lanceolata* and *Rumex acetosella* were eaten in much higher proportion. In 1998-1999, elk diets consisted of roughly 30% *L. multiflorum* and *L. perenne*, 23% *Plantago lanceolata*, 13% *Rumex acetosella* and 11% *Holchus lanata*). Roberts interprets the data to indicate that nutritional stress may only be a seasonal problem now at Tomales Point. However, it would be best to detect stress before it results in a population crash, either of the elk population or the sensitive plants.

One way to anticipate an impending crash, and to inform management about progress toward its vegetation recovery goals, is to look at trends in certain indicators in the vegetation, with and without elk herbivory. Hence, the indicators listed in Table 2 were chosen for an initial pass at evaluating change in the grazed vs. ungrazed exclosure study.

The analysis of variance results are based on only one year-to-year transition in the study, and they really only provide a hint of the trends that may become evident over time. However, they do hint that some of the predicted effects of release from cattle and elk grazing may be occurring on Tomales Point. For example, the relative abundance of grasses was lower in the ungrazed exclosures than in the grazed plots after one year. This grass response was associated with an overall increase in herb abundance in the exclosures, regardless of vegetation type or elk use level. Bartholome (and unpublished Gogan transect data from 1999, USGS-BRD and National Park Service) showed that the range has been responding to cattle release by increases in cover of certain native grasses, herbs and shrubs. Apparently, succession toward greater native plant abundance might be occurring faster without elk. Another way to interpret this is that recovery is still occurring in the desired direction, even with the elk. What the elk appear to be influencing is the rate of change rather than the direction of change.

The analysis of variance results also indicate that there are differences in species composition among the three vegetation types, as measured by species richness and the overall presence of native plants in the vegetation. Therefore, each plant community may be responding at different rates to cattle release and to elk presence, because they had different starting conditions when the cattle were taken off Tomales Point. Indeed, the indicator species analyses show that there are vegetation type differences in the responses seen 1998-1999, between grazed and ungrazed plots and between high and low elk use areas. Some of these differences are consistent with predictions from the literature. For example, *Lolium perenne* and *L. multiflorum* showed a tendency toward lower abundance in the lupine grassland ungrazed control plots than in the exclosures, consistent with the prediction that they should decrease in cover when not grazed. A similar result is seen with *Holchus lanata*, which increased more 1998-1999 in the high elk use areas than in the low use sites. However, *L. perenne* decreased more in the lupine grassland high use areas – a trend not consistent with the predictions.

Clearly, there is high variance in the 1998-1999 data, which makes predicting trends from only one pair of years uncertain at best. It is encouraging that contrasts between vegetation types, elk use levels and grazing treatments are apparent in the data. Incorporating the year 2001 control and exclosure data into the analysis will help dampen the variance and bring better resolution to patterns hinted at in this analysis. Using plant species that are sensitive to elk feeding habits as indicators of change will help detect elk nutritional stress. Monitoring holistic plant community parameters such as species diversity and generalized cover by life form, will show whether progress is being made toward the vegetation recovery goals for the elk range. As monitoring continues, trend analyses can be used to further clarify the role of elk grazing in the successional processes at work as Tomales Point recovers from cattle grazing.

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Appendix A
1998 - 1999 Tomales Pt. elk range control and exclosure vegetation monitoring.

Absolute species frequency and relative cover, by control and exclosure treatment within vegetation types and elk use levels, 1998 – 1999

Appendix B
1998 - 1999 Tomales Pt. elk range control and exclosure vegetation monitoring.

Percent absolute cover of substrates underlying vegetation.