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Effects of black-tailed deer, *Odocoileus hemionus*, on vegetative understory at Asilomar State Beach and conference grounds

Emily J. Buffon
San Jose State University

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**EFFECTS OF BLACK-TAILED DEER, ODOCOILEUS HEMIONUS, ON
VEGETATIVE UNDERSTORY AT ASILOMAR STATE BEACH
AND CONFERENCE GROUNDS**

A Thesis

Presented to

**The Faculty of the Department of Biological Sciences
San Jose State University**

**In Partial Fulfillment
of the Requirements for the Degree
Master of Science**

By

Emily J. Buffon

December, 1994

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APPROVED FOR THE DEPARTMENT
OF BIOLOGICAL SCIENCES

Dr. William E. Bros

Dr. Michael J. Kutilek

Dr. Rodney G. Myatt

APPROVED FOR THE UNIVERSITY

ABSTRACT

EFFECTS OF BLACK-TAILED DEER, ODOCOILEUS HEMIONUS, ON THE UNDERSTORY VEGETATION AT ASILOMAR STATE BEACH AND CONFERENCE GROUNDS

By Emily J. Buffon

The California Department of Parks and Recreation is concerned that the Columbian black-tailed deer (*Odocoileus hemionus*) population at Asilomar State Park is having a negative impact on the understory vegetation, and in particular on restoration efforts. In this study, we compared plant height, species composition, and ground cover over a one year period between plots that excluded deer via an exclosure to similar plots that allowed deer access. We also conducted a deer census using total area counts.

Results indicated that deer reduce plant height; herbs were affected in the spring, shrubs were affected in the fall, and grass was shorter over the year. Impacts on restoration were mixed. Deer have a negative effect on some desirable native species and also on some undesirable invasive non-native species. Deer did not affect plant cover over the one year period.

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INTRODUCTION

Conservation biologists are acknowledging a growing and difficult problem; opportunistic native species such as deer (*Odocoileus spp.*) that can thrive in close proximity to human development may cause the decline and extirpation of more sensitive and rare native species (Alverson 1988, Diamond 1992, Garrott et al. 1993). Overbrowsing by deer can cause shifts in plant species composition (Graham 1958, Alverson et al. 1988, Tilghman 1989, Anderson 1994). Anderson (1994) documented the decline of white-flowered trillium (*Trillium grandiflorum*) from the understory of a deciduous forest in Illinois due to a high intensity of deer browsing.

The nature and the severity of the impact of deer have been shown to vary with deer density (Graham 1958, Beals et al. 1960, Hough 1965, Anderson and Loucks 1979, Tilghman 1989). Deer favor certain plant species at different times of the year and individual plant species vary in their sensitivity to browsing pressure. At higher deer densities, biomass intake is greater and less favored species may be impacted. In a hardwood forest in Pennsylvania, sites with low white-tailed deer density had a higher abundance of blackberries and few ferns, while sites with higher deer density had few blackberries and thick patches of fern cover (Tilghman 1989).

Tilghman (1989) found that forest density mediated the effect of deer browsing; in a thinned hardwood forest, deer densities of 15 deer/km² caused changes in plant height and species composition, but in an uncut forest only deer densities of 30 deer/km² produced a comparable effect. Graham (1958) reported high white-tailed deer densities to be favorable to the growth of desirable species in some areas of a forest in Michigan and detrimental in others.

The California Department of Parks and Recreation (CDPR) directs park ecologists to attempt to restore State Parks to an ecological condition that existed before the settlement of Europeans. Restoration involves the protection and cultivation of native plants and animals and the eradication of invasive non-native biota. At Asilomar State Beach and Conference Grounds, Pacific Grove, California, the CDPR has organized an extensive restoration effort incorporating the dunes and Monterey pine (*Pinus radiata*) forest (Smith 1992). The restoration has included the propagation and planting of native plants and the eradication of invasive non-native plants. The CDPR is concerned that the native Columbian black-tailed deer (*Odocoileus hemionus columbianus*) population may be contributing to the loss and replacement of the native flora by exotic species, thus limiting the success of the restoration efforts at Asilomar.

Private efforts by local citizens to feed the deer population in the neighborhoods surrounding Asilomar may have contributed to a deer density

problem. Supplemental feeding can greatly increase population size (Ozoga and Verme 1982). Extensive private feeding was practiced for many years in a neighborhood next to Asilomar, but some of it was stopped in the summer of 1992. An increased deer population may put additional pressure on an already heavily browsed understory.

The primary focus of this study was to assess the impact of deer on the understory vegetation at Asilomar. We compared plant height, species composition, and ground cover between plots that excluded deer via an exclosure to similar plots that allowed deer access. The design was set up as a series of matched pair plots. A difference in plant height between matched plots would show whether deer browsing was inhibiting or enhancing plant growth. Shorter plants would provide less browse and might indicate less plant vigor. By monitoring changes in species composition between matched plots, we assessed whether the deer were adversely effecting restoration efforts.

We censused the resident deer population in the park. By comparing our census data to an earlier census taken at Asilomar (Smith 1992), as well as published censuses taken in similar habitats (Alverson 1988), we could get an indication if the population was abnormally high, declining, or stable. We distinguished fawns from adults in our count. A high percentage of fawns would indicate short-term population growth.

METHODS

Study site

The study area encompassed approximately 40 ha (100 acres) of deer habitat in an open Monterey Pine forest in Asilomar State Beach and Conference Grounds, Pacific Grove, California. The climate is typical of the northwest Pacific coast (Barbour and Major 1977). Summers are cool and foggy, but dry with the highest mean monthly temperatures in September (17°C). Winters are alternately rainy and clear with slightly cooler temperatures (the lowest mean temperature is 10° C). Average annual precipitation is about 465 mm (18 inches)

The study area was divided into two sampling sites, Upland and Seaside habitats. Each site was characterized by a distinct soil type and assemblage of understory plant species (Table 1). Restoration efforts at each site reflect the characteristics of the area. Monterey Pines dominate the overstory at both sites. Coast Live Oak (*Quercus agrifolia*) is the second most important tree species. Oaks of all ages are scattered throughout the park. Areas of the grounds covered by structures (e.g., buildings, parking lots) were excluded from sampling.

The Upland area is farther inland from the beach and is dominated by grasses and sedges: rattlesnake grass (*Briza maxima*), Italian rye, (*Lolium multiflorum*), ripgut (*Bromus diandrus*), oats (*Avena fatua*), giant rye (*Elymus*

Table 1. Plant list for the Upland and Seaside sampling areas (common and scientific names). Scientific names of plants follow the Jepson Manual 1993 (Hickman 1993). * Non-native species

UPLAND AREA		SEASIDE AREA	
Bedstraw	<i>Galium spp.</i>	Beach aster	<i>Corethrogyne californica</i>
Blackberry	<i>Rubus ursinus</i>	Bed straw	<i>Galium spp.</i>
Bolander pea	<i>Lathyrus vestitus</i>	Bracken fern	<i>Pteridium aquilinum</i>
Bracken fern	<i>Pteridium aquilinum</i>	Common fiddleneck	<i>Amsinckia menziesii</i>
California brome grass	<i>Bromus carinatus</i>	Coyote Bush	<i>Baccharis pilularis</i>
Clover	* <i>Melilotus spp.</i>	Douglas iris	<i>Iris douglasiana</i>
Coast live oak	<i>Quercus agrifolia</i>	Dune sedge	<i>Carex pansa</i>
Coffeeberry	<i>Rhamnus californica</i>	Fireweed	* <i>Erechtites arguta</i>
Douglas Iris	<i>Iris douglasiana</i>	French broom	* <i>Genista monspessulana</i>
Dune sedge	<i>Carex pansa</i>	Iceplant	* <i>Carpobrotus spp.</i>
French broom	* <i>Genista monspessulana</i>	Lotus (woolly)	<i>Lotus heermannii</i>
Giant wild rye	<i>Elymus condensatus</i>	Lotus (deerweed)	<i>Lotus scoparius</i>
Hedge nettle	<i>Stachys bullata</i>	Lupine (yellow bush)	<i>Lupinus arboreus</i>
Italian rye	* <i>Lolium multiflorum</i>	Lupine (silver beach)	<i>Lupinus chamissonis</i>
Kikuyu grass	* <i>Pennisetum clandestinum</i>	Milk vetch	<i>Astragalus nuttallii</i>
Miners lettuce	<i>Montia perfoliata</i>	Mock heather	<i>Ericameria ericoides</i>
Monkey flower	<i>Mimulus aurantiacus</i>	Monkey flower	<i>Mimulus aurantiacus</i>
Oxalis	* <i>Oxalis spp.</i>	Monterey pine	<i>Pinus radiata</i>
Pacific pea	<i>Lathyrus vestitus</i>	Poison oak	<i>Toxicodendron diversilobum</i>
Poison oak	<i>Toxicodendron diversilobum</i>	Rattlesnake grass	* <i>Briza maxima</i>

Rattlesnake grass	<i>* Briza maxima</i>	Ripgut grass	<i>* Bromus diandrus</i>
Ripgut grass	<i>* Bromus diandrus</i>	Sand mat	<i>Cardionema ramosissimum</i>
Snowberry	<i>Symphoricarpos mollis</i>	Sagewort	<i>Artemisia pycnocephala</i>
Western ryegrass	<i>Elymus glaucus</i>	Seaside daisy	<i>Erigeron glaucus</i>
Wild cucumber	<i>Marah fabaceus</i>	Western ryegrass	<i>Elymus glaucus</i>
Wild oat	<i>* Avena fatua</i>	Yarrow	<i>Achillea borealis</i>
Willow	<i>Salix lasiolepis</i>		
Yerba buena	<i>Satureja douglasii</i>		

condensatus) and dune sedge (*Carex pansa*). Poison oak (*Toxicodendron diversilobum*), hedge nettle (*Stachys bullata*), monkey flower (*Mimulus aurantiacus*), bedstraw (*Galium spp.*) and bracken fern (*Pteridium aquilinum*) are other common species. The soil is classified as loamy sand. Parts of the upland area were formerly commercial and residential and were added to the park in 1972 (Smith 1992). During the residential period, herbicides were used to control poison oak and as a side effect, much of the native understory was destroyed. Since the area has been incorporated into the park, native plants such as poison oak, hedge nettle and monkey flower have been protected, and non-natives such as broom (*Genista spp.*) and Kikuyu grass (*Pennisetum clandestinum*) have been treated individually with a herbicide.

The seaside habitat, adjacent to the beach, has sandy soil and the plant species composition is dominated by sagewort (*Artemisia pycnocephala*), mock heather (*Ericameria eriocoides*), yarrow (*Achillea millefolium*), lotus (*Lotus spp.*), dune sedge (*Carex pansa*), and rattlesnake grass (*Briza maxima*). Restoration efforts in the seaside area have included extensive removal of non-native iceplant (*Carpobrotus spp.*) and the revegetation of the cleared areas.

Impact of browsing on vegetation

To assess the impact of deer on the vegetative understory, we measured plant height and cover, and species composition over a one year period in a series of randomly selected matched pair plots. Each matched pair consisted of two 1 x 2 m plots, one of which was enclosed by a fence to exclude deer (Figure 1). The exclosures were approximately two meters high, three meters wide, and four meters long. All fences were constructed with heavy gauge wire mesh with two meter tall metal posts at one meter intervals. Within the center of the exclosure, a 1 x 2 m sampling plot was delineated by a metal rod at the center of each one meter side. The unfenced 1 x 2 m plots were marked with metal posts at the four corners. The metal rods were covered with white plastic pipe to protect both deer and people from injury. A 1 x 2 m grid with thirty-two 25 cm square quadrats was constructed as a portable measuring tool. The grid was constructed of one-half inch plastic pipe and fine metal wire. To avoid crushing the vegetation while measuring, the grid was held above the vegetation with removable legs fitted to the corners; legs of different length were used to accommodate different heights of vegetation.

To assess plant growth at a site, we examined differences in two measures, average plant height and variation in plant height, between the enclosed and open plots. Average plant height is an indicator of overall biomass in a plot. Variability in plant height is a measure of another type of

A. Fenced plot, top view

B. Fenced plot, side view

Figure 1. Diagrams of fenced plot. A. Fenced plot, top view. B. Fenced plot, side view

effect; small variation indicates that plants are of uniform height, while high variation indicates large differences in heights among plants within a plot.

To obtain both measures, we selected (randomly) 12 quadrats from the 32 quadrats in a plot and, in each, measured the height of the middlemost plant in each of three categories, Grass, Herb and Shrub. The Grass category included grasses and sedges. The Shrub category was defined as all woody vegetation which included tree saplings. The Herb category included all nonwoody plants that did not fit into the Grass category. For each category, mean plant height and the associated standard deviation were computed from the twelve measurements for each plot of the matched pair. A univariate randomized complete block analysis of variance (RCB ANOVA, Zar, 1981) with site as a block was used to detect changes in both average plant height (Mean) and variation in plant height (Std. dev.) between enclosed and non-enclosed matched plots for each of the three categories: Grass, Herb, and Shrub.

Deer browsing could also have selective effects on the heights of plants among the three categories (e.g. browsing causes a decrease in herb height, but no change in the others). A multivariate randomized complete block analysis of variance (RCB MANOVA, Johnson and Wichern 1982) was used to measure differences in proportions of average plant height and variation in plant height among the three categories between matched pair plots.

To assess changes in species composition, we measured the relative abundance of plant species in all plots. For each species we recorded presence/absence in each of the thirty-two 25 cm² quadrats; maximum relative abundance for any species was thirty-two. Root presence was recorded for Grasses and Herbs, and shoot presence was recorded for Shrubs. An RCB ANOVA with site as a block was used to detect changes in relative abundance of the species between enclosed and non-enclosed matched plots. An RCB MANOVA was used to measure differences in proportions (species composition) of the various species between the matched pair plots.

Cover was measured using the line intercept method (Kershaw and Looney 1985) at ground level, one-half meter above ground, and one meter above ground along a 2 m transect through the center of the 1 x 2 m grid. Cover for Grass, Herb or Shrub categories was computed as the sum of the distances that each patch of each category (e.g. Grass) eclipsed a 2 m line held at ground level or an above ground level. Bare ground was measured at ground level. An RCB ANOVA with site as a block was used to detect changes in cover of the categories (e.g. Bare ground, Grass) between enclosed and non-enclosed matched plots. An RCB MANOVA was used to measure differences in proportions of the three to four categories between the matched pair plots.

All statistical analyses for our paired design included two tests of significance. The main test, the Treatment effect, assesses the difference in the

understory vegetation between the fenced plots (deer excluded) and the matched unfenced plot. The Block effect, the second statistical test, assesses the degree of variation between all matched pair plot sites for each area (Upland or Seaside). If the Block effect is significant ($p < .05$), there is high variation among paired plot sites; high variation indicates that the paired plot design was necessary to detect differences between fenced and unfenced plots.

A preliminary survey, utilizing the methods above, was initiated in July, 1992 to determine the optimum sample size (number of matched pair plots) for our design. The ability to detect differences is affected by sample size; the smaller the sample size, the less likely that small differences can be detected. Limitations in space and/or funding place limitations on the upper limits of sample size. The optimum sample size is one that is small enough to be feasible but large enough to detect reasonable differences. The Expected Minimum Detectable Difference (MDD) (Zar, 1981) is a measure of how well a particular test can detect differences between treatments (i.e. deer vs. no deer). Sample variances from the preliminary survey were used to compute the expected minimum detectable differences. We used a sample size of fifteen pairs in the upland habitat. With a sample size of fifteen pairs, we predicted a 90% probability of detecting a difference of 4-6 cm for plant height and approximately 20 cm for cover. Because of limited space in the seaside habitat,

we used a sample size of thirteen pairs for that area. With thirteen pairs, the detectable differences were approximately the same as the differences for fifteen pairs in the upland habitat.

After randomly selecting a plot site, two plots that appeared similar in plant height, cover and species composition were selected. We took all measurements in each plot and analyzed the measurements to insure equivalency in plant height, plant cover, and species composition between matched pairs. An RCB ANOVA with site as a block was used to insure similarity in plant height and cover. If the null hypothesis was accepted with $p > .05$, the plots were considered equivalent.

Czechanowski's Quantitative Similarity Index was used to measure similarity in species composition between the matched pair plots (Bray and Curtis 1957, Bloom 1981). Matched pair plots with a similarity score > 0.7 were considered equivalent. If a pair did not meet these criteria, one or both of the paired sites was moved until the criteria was met.

The next phase of the study began in October 1992 with the building of the first fence and continued until our final measurements in September of 1993. Exclosures were constructed for the Upland during the month of October 1992, and baseline measurements to insure equivalency were taken and analyzed for the Upland in the last week of October. After 23 weeks, in the first week of April, a series of measurements were made and analyzed for each of the matched

pair plots in the Upland area. The measurements were repeated 16 weeks later and reanalyzed in the last week of July. Seaside exclosures were built in November and December 1992, and baseline measurements were taken and analyzed in late December 1992. Repeat measurements for the Seaside sampling area were taken and reanalyzed in June and September of 1993.

Deer census

We used total area counts to census deer (Dasmann and Taber, 1955). This method could be used because the deer in the park spend most of their time in a small area and the deer move very little when approached (Dasmann, 1953). One person walked in a crisscross fashion through the park to tally deer. Counts were taken in the morning or evening as these times have been established as the best observation times (Dasmann and Taber, 1956). Sex and age of deer were recorded. Three categories were recognized: Adult males (included male yearlings as well as older adult males), Adult females (included female yearlings because they are hard to distinguish from older adult females), and Fawns (deer of either sex less than one year old). Female yearlings do not usually produce fawns (Robinette and Gashwiler, 1950, Crane and Jones, 1953); they ordinarily produce their first fawn when they are two years old. Lumping female yearlings with breeding females impacts the fawn to female ratio (Dasmann and Taber, 1956). If fawn to yearling survival has been high, the fawn

to female ratio can be interpreted as low, or conversely if the fawn to yearling survival has been low, the fawn to female ratio might appear high.

RESULTS

Understory-Upland

During the first five month period (Oct 92-Apr 93) in the Upland area, deer browsed differentially among the three plant height categories: Grass, Herb, and Shrub; grass height and herb height were impacted. The RCB MANOVA indicated a proportional shift in plant height between the three categories (Table 2). The reduction in grass height and herb height were proportionately greater than the reduction in shrub height in the open (deer present) plots (Figure 2). Also, herbs tended to be more uniform in height when deer were present.

For the same five month period, univariate tests confirmed that deer browsing was causing shorter grass, and more uniform grass and herb heights. The RCB ANOVA showed that grass height was significantly lower (Table 3) in the open plots (30.8 cm) than in the enclosed plots (39.4 cm). The standard deviation in height of grasses and herbs was significantly more uniform in the open plots (10.0 cm and 4.5 cm, respectively) than in the enclosed plots (12.0 cm and 9.2 cm, respectively). For the individual univariate tests, neither herb height nor shrub height varied significantly between deer and no deer

Table 2. Multivariate test (RCB - MANOVA) of Mean Plant Height and Standard Deviation in Plant Heights for three categories of plants (Grass, Herb and Shrub) in the Upland Area.

SOURCE	WILKS' LAMDA	DF	F	PROB
For April, 1993				
Deer Present/Absent	0.258	6,9	4.313	0.025
For July, 1993				
Deer Present/Absent	0.474	6,9	1.663	0.236

Measure
 Figure 2. Multivariate effect for RCB ANOVA of Upland Area in April 1993. The main effect is Treatment (Deer present or Deer absent). The Block is a matched pair site.

Table 3. Univariate tests (RCB ANOVA) of Mean Plant Height and Standard Deviation in Plant Heights for three categories of plants (Grass, Herb and Shrub) in the Upland Area.

Main Effect: Deer Present/Absent (April 1993)

VARIABLE	DF	MS	F	PROB
Grass Hgt.	1,14	560.563	24.819	>0.000
Grass Std. Dev.	1,14	28.149	9.716	0.008
Herb Hgt.	1,14	106.861	4.324	0.056
Herb Std. Dev.	1,14	164.971	5.336	0.037
Shrub Hgt.	1,14	9.656	0.339	0.570
Shrub Std. Dev.	1,14	2.149	0.158	0.697

Main Effect: Deer Present/Absent (July 1993)

Grass Hgt.	1,14	685.548	11.807	0.004
Grass Std. Dev.	1,14	20.667	1.699	0.213
Herb Hgt.	1,14	121.686	1.357	0.263
Herb Std. Dev.	1,14	30.220	2.503	0.136
Shrub Hgt.	1,14	121.980	1.028	0.328
Shrub Std. Dev.	1,14	2.296	0.073	0.792

plots; the minimum detectable difference was 8.6 cm for herb height and 14.0 cm for shrub height.

By the summer, in the dry season, the only detectable difference between matched plots was shorter grass in the plots accessible to deer. For the measurements in July, the RCB MANOVA showed no detectable difference in proportion for grass, herb, or shrub height between enclosed and non-enclosed matched pair plots (Table 2). The Univariate test (RCB ANOVA) for grass height was significant (Table 3); in July, mean grass height was lower in the open plots (62.7 cm) than the enclosed plots (72.3 cm) . Again, neither herb or shrub height varied significantly between the deer present and deer absent plots; the minimum detectable difference was 12.6 cm for herb height and 15.8 cm for shrub height.

There was no detectable change in species composition as a result of deer browsing in the Upland area over the nine month period from October to July. The RCB MANOVA indicated no significant changes in species composition between enclosed and open matched pair plots for the first five month period (October to April) or the next three month period (April to July). The Univariate tests also showed no significant differences in mean frequency of occurrence for individual species. Mean minimum detectable difference for all plant species was a difference in occurrence in 4.9 plot quadrats in April and 4.6 plot quadrats in July.

Many species were present in only a few of the fifteen paired plots and could not be evaluated by the statistical tests. However, blackberry (*Rubus ursinus*), french broom (*Genista monspessulana*), coast live oak (*Quercus agrifolia*), coffeeberry (*Rhamnus californica*), snowberry (*Symphoricarpos*) and Bolander pea (*Lathyrus vestitus*) were more abundant in the fenced plots at the time of the final measurement (Table 4). On the other hand, poison oak (*Toxicodendron diversilobum*) was more abundant in the open plots.

For french broom, the difference in the height of plants between matched pair plots was dramatic in the one pair of plots in which it was present. In January 1994, the total height of all broom plants was 488 cm in the fenced plot and 83 cm in the open plot. The three plants in the fenced plot were from 1 to 2 m tall, while the three plants in the open plot were browsed by deer and were from 20 to 32 cm tall. The fenced plants produced seed while the open plants did not.

Deer browsing caused no significant change in plant cover at ground level or the above ground level in the Upland over the period of the study. The RCB MANOVA showed no detectable difference in proportions of plant cover for bare ground, grass, herbs or shrubs at ground level or one-half meter between the enclosed and open matched pair plots. Univariate tests also indicated no significant changes. The mean minimum detectable difference was 27.1 cm for

Table 4. Occurrence of Selected Species in plot quadrats in the Upland Area.

	Baseline (Oct '92)		Remeasure (April '93)		Remeasure (July '93)	
Deer	Present	Absent	Present	Absent	Present	Absent
Blackberry	45	28	51	48	52	63
Broom	1	1	3	5	3	9
Coffeeberry	0	0	0	0	0	3
Oak	0	1	1	1	0	2
Pea	2	1	2	10	2	27
Poison Oak	19	35	133	108	102	86
Snowberry	0	0	1	25	1	8

ground level cover and 5.6 cm for cover at one-half meter. There was not sufficient data for analysis at one meter.

The results also showed that it is important to use a matched pair design to assess the effects of deer browsing. In the Upland, the Block effect was significant for the multivariate analyses of plant height in April and July and nine of twelve measures in the univariate analyses. The Block effect was significant for both multivariate analyses of species composition and thirteen of twenty-eight measures in the univariate analyses. Similarly, the Block effect was significant for both multivariate analyses of plant cover and four of eight univariate measures.

Understory-Seaside

There was no statistical evidence of differential browsing among the six plant growth categories for the Seaside area over the six month period from December 1992 to June 1993; however deer browsing did cause a reduction in grass height. The RCB MANOVA indicated no significant difference in proportion of the six categories for plant growth, however the Univariate test was significant for grass height. In June, mean grass height was shorter in the open (21.5 cm) than the fenced plots (26.3 cm). Neither herb nor shrub height varied significantly between the deer and no deer plots; the minimum detectable difference was 6.7 cm for herb height and 19.1 cm for shrub height.

For the final three month period from June to September, there was again no evidence of differential browsing; however, in this period, the dry season, shrub height was reduced by deer. The RCB MANOVA showed no significant difference in proportion for plant growth for the six categories, but the Univariate test was significant for shrub height. In September, mean shrub height was lower in the open (14.1 cm) than the fenced plots (19.0 cm). Grass height and herb height did not vary significantly between the deer present and deer absent plots; in September, the minimum detectable difference was 28.5 cm for grass height and 3.8 cm for herb height.

Deer browsing clearly impacted the species composition in the seaside area, but only after the first six month period. For the first six month period from December to June, the RCB MANOVA showed no significant proportional changes in species composition (Table 5) between the enclosed and non-enclosed matched pair plots; however, for the three month period from June to September, the RCB MANOVA did show a proportional shift in species composition. Abundances for lotus, mock heather, and sagewort were proportionately greater (Figure 3) in the fenced (deer absent) plots. Dune sedge had a proportionately greater abundance in the deer present plots.

Deer browsing decreased the abundance of Lotus, a low growing herb, for the entire measurement period, and also decreased the abundance of Mock Heather, a shrub, for the first six month period. For the period from December

Table 5. Multivariate test (RCB - MANOVA) of Species composition in the Seaside Area.

SOURCE	WILKS' LAMDA	DF	F	PROB
For June, 1993				
Deer	0.077	12,1	1.000	0.663
Present/Absent				
For September, 1993				
Deer	0.000	12,1	316.127	0.044
Present/Absent

Figure 3. Multivariate effect for RCB ANOVA for frequency of occurrence of species in plot quadrats for Seaside Area in April 1993. The main effect is Treatment (Deer present or Deer absent). The Block is a matched pair site.

to June, univariate tests (Table 6) indicated a greater mean frequency of occurrence (Figure 4) of Mock Heather (*Ericameria ericoides*) in the fenced plots (9.2) than the open (7.9) and a greater mean frequency of occurrence of Lotus (*Lotus spp.*) in the fenced plots (19.0 fence) than the open (14.1). For the period from June to September, the univariate tests again showed a greater mean frequency of occurrence of lotus in the fenced plots (5.3) than the open (1.3). The mean minimum detectable difference for all other species was a difference in occurrence in 6.6 plot quadrats in June and 5.6 plot quadrats in September.

Iceplant (*Carpobrotus spp.*) occurred in just one pair of matched plots; however, iceplant appeared to have sustained growth only inside the enclosure. There were many small iceplants inside the fence, some of which were not in the plot, while iceplant was nearly absent in the surrounding areas outside the fence.

For the seaside area, deer browsing caused no significant change in plant cover at the ground level or the above ground level over the nine month period (Dec-Sept). The RCB MANOVA showed no detectable difference in proportions of plant cover for bare ground, grass, herbs, and shrubs at ground level or at one-half meter between the enclosed and open matched pair plots. Univariate tests for the seaside sites also indicated no significant changes. The

Table 6. Univariate tests (RCB ANOVA) of Occurrence of Specific Species in plot quadrats in the Seaside Area for June 1993.

Main Effect: Deer Present/Absent

VARIABLE	DF	MS	F	PROB
Beach Aster	1,12	1.385	1.929	0.190
Bracken Fern	1,12	5.538	1.774	0.208
Dune Sedge	1,12	22.154	2.420	0.146
Lotus	1,12	162.500	7.863	0.016
Monkey Flower	1,12	0.346	1.929	0.190
Mock Heather	1,12	9.846	4.892	0.047
Monterey Pine	1,12	0.615	1.684	0.219
Rattle Snake Grass	1,12	12.462	0.541	0.476
Ripgut Grass	1,12	4.654	0.226	0.643
Sagewort	1,12	22.154	2.689	0.127
Seaside Daisy	1,12	0.615	1.684	0.219
Yarrow	1,12	0.346	0.054	0.820

Figure 4. Significant treatment effect from RCB ANOVA for occurrence of Lotus and Mock Heather in plot quadrats for Seaside in June 1993. Main effect is Treatment (Deer present and Deer absent) and Block is the matched pair site.

mean minimum detectable difference for cover was 16.7 cm at ground level and 20.7 cm at one-half meter. There was not sufficient data for analysis at one meter.

The results for the Seaside clearly showed the importance of the matched pair design in assessing the effects of deer browsing. The Block effect was significant for all measures and analyses of plant height. For the assessment of change in species composition, the Block effect was significant for both multivariate analyses and twenty of twenty-four univariate measures. Finally, the Block effect was significant for both multivariate analyses of plant cover and eight of eleven univariate measures.

Deer census

The number of deer counted at Asilomar decreased over the year (Figure 5). Four deer census counts between December 1992 and February 1993 ranged from 15 to 22 with 4-5 fawns. Counts from April to September 1993 ranged from 0 to 10 with from 1-5 fawns. Two resident cohorts (a female and her offspring) were observed consistently in the same locations over the study period. These counts contrast sharply with counts taken in the summer of 1992. A report on census counts for the summer of 1992 (Smith 1992) before the cessation of private feeding, stated that 45 deer were using the park. The 1992 report did not include a fawn count.

Figure 5. Mean deer counts for the months, December 1992 to September 1993.

The private feeding, which was terminated in the late summer of 1992, took place at the same time of the day at a house near the beach just north of Asilomar. The deer would follow well delineated trails through Asilomar to gather at the residence for the daily feeding. Over the year after cessation of feeding, deer stopped moving through the park to the feeding station.

DISCUSSION

Plant height was reduced by deer browsing at Asilomar. These results confirm findings from exclosure studies with white-tailed deer in the Eastern United States (Graham 1958, Tierson et al. 1966, Blewett 1976, Kroll et al. 1986, Tilghman 1989, Anderson 1994). Tilghman (1989) reported that plant height was reduced by white-tailed deer at high densities in an uncut forest in Pennsylvania. Anderson (1994) also reported lower plant height in sampling areas accessible to deer in Illinois.

Grass height was reduced over the year, herb height was impacted in the spring, and shrub height was reduced in late summer. This pattern would confirm the results of rumen analysis of black-tailed deer (Taber 1956, Schauss and Coletto 1986) that showed a higher percentage of herbs in the diet in spring and a higher percentage of shrubs in the diet in summer and fall. In California the principal growth period for herbs and shrubs is in the spring when there is both adequate moisture and a sufficiently high temperature. The principal

growth period for grasses is in the winter after the first adequate precipitation (usually in October). Shrubs are browsed in the summer and fall, the hot dry season, when the herbs have died back and the grass is no longer green.

A reduction in both plant height and variability in plant height due to browsing would have variable effects on restoration. The responses of plants to herbivory (e.g. browsing) vary greatly (Lubbers and Lechowicz 1989). In most cases, yearly defoliation causes smaller plants and fewer flowering plants (Jameson 1963, Wilson and Price 1980, Anderson 1994). In a few cases, plant reproduction can be unaffected or enhanced by herbivory (Paige and Whitham 1987). The reduction of the variability in herb height in the spring indicates that deer are browsing the tallest herbs. We can assume that most but not all of the native and non-native herbs would be negatively impacted over the long term. The reduction in the height of non-native annual grasses would not negatively impact restoration; however, we were unable to make an important distinction in the summer between *Bromus diandrus*, an invasive annual grass, and *Bromus carinatus*, a native perennial. Native perennial grasses vary in their tolerance to grazing (Blumler 1992); *Bromus carinatus* seems to prosper at sites not open to cattle grazing. Deer browsing causes a reduction in shrub height and consequently an undesirable reduction in the density of the understory. Recreating a lush native understory is a part of the restoration plan.

Some of the impacts of deer on species composition at Asilomar are positive in terms of the Asilomar restoration plan. Some plants of invasive non-native broom are browsed nearly to the ground. These heavily browsed broom plants do not flower or produce seed. Deer seem to help inhibit the return of the non-native iceplant that was removed in the seaside area. The spread of native poison oak is not inhibited by deer; poison oak plants are shorter but cover a larger area in the plots accessible to deer. Although the oaks and pines are both native species, preservation of the Monterey pine forest is the prime concern of the CDP. The Monterey pine forest at Asilomar is part of the largest of only three native Monterey pine stands in the United States. Deer browse on coast live oaks and prevent the regeneration and growth of some oaks which would compete with the pines.

However, on the negative side, deer may be inhibiting the growth and propagation of many native species. Lotus, a low growing ground cover, that could stabilize some bare areas in the seaside section is heavily impacted. Other desirable natives may be impacted. Blackberry, coffeeberry, snowberry, Bolander pea, beach aster and western ryegrass were less abundant in the open plots at the time of the final measurement. Deer seem to remove flowers which could affect seed propagation of native species (Anderson 1994).

The deer population in the park is much lower than in the previous year probably due to the cessation of private feeding. There appear to be two

resident cohorts (adult female and her offspring) in the forested area. The ratio of fawns to females is less than one indicating slow growth for that year. The deer density at Asilomar (22 deer/km²) is still far greater than the density recommended by Alverson (1988) and Anderson (1994) (2-6 deer/km²) as necessary to preserve native understory species from white-tailed deer in the eastern United States. Using their criteria, one resident cohort would be desirable; however, the two cohorts at Asilomar are in separate areas of the park that are largely divided by fencing.

The paired plot design was essential in determining the impact of deer on vegetation because of the variability in the plant communities within each sampling area. The paired plot exclosure design isolates the changes in plant height, cover, and species composition due to the impact of deer, from changes due to other causes. Changes in the overstory impact the species composition of the understory (Stearns 1951, Arnold and Verme 1964, Lawrence and Biswell 1972, McInnes et al. 1992). Shade adapted plants decline and sunlight adapted plants increase when the overstory is opened. The Monterey pine forest at Asilomar is in a continuing process of change and management. The trees which form the overstory canopy are more than 76 years old, an age that is considered overmature (Smith 1992). Trees are being removed because of disease and beetle infestation. In some areas, the forest floor is more open, thus sunnier and drier.

In our study, we randomly picked paired plot sites from the entire park (divided into two sections) because we wanted to consider all possible impacts of deer browsing. We did not target specific areas or plant species. However, if targeting specific species (such as native grasses) were desired, it could be easily incorporated into the design. Heights of individual species in each quadrat for each plot could be recorded.

To increase the density of the understory, we recommend propagating and planting native species not negatively impacted by deer. Deer tend to eat the tallest plants (Anderson 1991). After more cover is established, more sensitive species can be planted away from deer trails and bedding sites and under the cover of less sensitive species.

Plants that have been shown to be negatively impacted can be protected by exclosures especially during flowering. The experimental exclosures will serve as small reservoirs for impacted plants. Larger areas could be fenced until the vegetation can recover.

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