Owens Valley Vegetation Conditions 2011

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TABLE OF CONTENTS

TABLES AND FIGURES

Tables

Figures

Abstract

A primary goal of the Long Term Water Agreement between Inyo County and Los Angeles Department of Water and Power is to manage groundwater and surface water while maintaining healthy groundwater-dependent vegetation communities found in the Owens Valley. Each year the Inyo County Water Department monitors a subset of vegetation parcels within the valley to ensure these goals are met. This report addressed two main questions regarding vegetation conditions. First it assessed changes among groups of parcels with respect to the effects of groundwater management using control and wellfield parcels. Second, it addressed cover decreases or changes over time within particular vegetation parcels. In general, wellfield parcels have been below baseline measurements while control parcels have maintained baseline conditions or actually exhibit higher cover than baseline. The 2011 reinventory data show that several individual vegetation parcels are below their baseline measurements. For example, in the Laws wellfield, perennial cover is below baseline in 61% of parcels sampled in 2011. Valley-wide conditions indicate shrub cover is increasing in wellfield parcels as grass cover decreases. Individual parcels that do not exhibit changes overall perennial cover may be experiencing a conversion in vegetation type from grass-dominance to shrub-dominance.

Introduction

This report presents an analysis of the 2011 vegetation conditions measured by the Green Book Line Point Monitoring Program (LPT). Each year, the Inyo County Water Department monitors vegetation conditions in parcels on the floor of the Owens Valley. The goals of this monitoring, according to the technical appendix to the LTWA (the Green Book), are to detect any "significant decreases and changes in Owens Valley vegetation from conditions documented in 1984 to 1987". Vegetation conditions, i.e. live cover and species composition, documented during the 1984-87 mapping effort were adopted as the baseline for comparison with each annual reinventory according to the LTWA. These reference measurements are hereafter referred to as the 'baseline'.

The Green Book details the decreases and changes in vegetation that must be avoided according to vegetation community types. Baseline vegetation communities that required more moisture for evapotranspiration than was provided by precipitation were classified as groundwater-dependent communities; referred to as Types B, C, and D. These phreatophytic communities are dependent on shallow groundwater for moisture, particularly in years with low rainfall (Sorensen et al., 1991; Steinwand, et al., 2006). For these parcels, according to the Green Book, "the goal is to manage groundwater pumping and surface water management practices so as to avoid causing significant decreases in live vegetation cover" and to prevent a significant amount of vegetation from changing to a "vegetation type that precedes it alphabetically (for example, Type D changing to either C, B, or A vegetation)." Essentially the goal is to prevent a change to a vegetation community type with lower water requirements. A large proportion of groundwater-dependent parcels were mapped during baseline as Type C alkali meadows (61%), and the Agreement seeks to prevent these meadows from changing to shrub-dominated communities (Type B). Alkali meadows were also given specific attention is because they are particularly

susceptible to water table decline (Naumberg et al. 1996; Elmore et al. 2006). Because alkali meadow only comprises 0.1% of the vegetation community types in California and most (80%) is found in the Owens Valley (Davis et al., 1998), proper local management of this community type is essential to its preservation in the state of California.

To evaluate the effects of water exportation on Owens Valley vegetation cover and communities, data were analyzed at two scales, among- and within-parcels. We addressed two questions at the among (grouped) parcel scale to assess differences between parcels affected by groundwater pumping and those that are relatively unaffected. These questions include: (1) whether cover in wellfield and control groups of parcels has changed over time as a result of groundwater management, and (2) whether shrub and grass cover have changed over time. To address conditions at a smaller landscape scale, two main questions were addressed within individual vegetation parcels: (1) whether changes in perennial vegetation cover have occurred over the twenty-year reinventory period, and (2) whether shrub proportion has changed over time. Because depth-to-water (DTW) data were not available at the parcel scale, current vegetation conditions were not assessed with respect to changes in the water table. This topic will be assessed in future Water Department reports.

Methods

Study Site

The Owens Valley is located in east-central California, entirely within Inyo County. The valley is bounded by the Sierra Nevada to the west and the White/Inyo Mountains to the east. Runoff from the Sierra Nevada maintains a shallow groundwater basin that has historically supported phreatophytic vegetation communities including alkali, Nevada saltbush and rabbitbrush meadows. Perennial grasses dominate the alkali meadow vegetation communities, while shrubs and grasses co-dominate mixed meadows (Manning, 1997).

Vegetation Sampling

Using the Greenbook line point protocol, ICWD sampled 111 of the 2126 vegetation parcels (223,168 acres) mapped during baseline in the summer of 2011 (Table 1). The average size of a vegetation parcel was approximately 88 acres (range 13-565 acres) for a total of 9740 acres sampled. The criteria for parcel selection were described in previous Inyo County reports (Manning, 1994). Between 19 and 41 transects were sampled in each vegetation parcel. Transect start locations were generated randomly using ArcGIS 10.0 software (ESRI, 1995-2011; Jabis, 2010). Estimates of perennial vegetation cover using Spectral Mixture Analysis (SMA) were generated by Dr. Andrew Elmore using satellite imagery for the time period from 1985 to 2011 (Elmore et al., 2001).

Table 1. Parcels sampled in 2011, listed by wellfield and control status. Column headings indicate: wellfield or control status, *W/C*; plant community type based on Holland (1986), *Plant Community*; number of acres in the parcel, *Acres*; presence of baseline transect data, *BaseTransData*; presence of Greenbook line point data during the entire time period from 1992-2011, *LPT'92-2011*; and presence of line point data during the complete time period from 1991-2011, *LPT'91-2011*.

	Parcel	W/C	Plant Community	Acres	BaseTransData	LPT '92-2011	LPT '91-2011
1	BGP019	C	Rush/Sedge Meadow	110.2	Y		
2	BGP031	C	Alkali Meadow	19.4	Y	Y	
3	BGP047	C	Alkali Meadow	47.5	Y		
4	BIS055	C	Alkali Meadow	146.3	Y		
5	BLK115	C	Alkali Meadow	154.2	Y	Y	
6	FSL187	C	Alkali Meadow	74.2	Y	Y	
7	IND064	C	Alkali Meadow	64.5	Y		
8	IND067	C	Nevada Saltbush Meadow	96.0	Y		
9	IND096	C	Nevada Saltbush Scrub	73.5	Y	Y	Y
10	IND119	C	Alkali Meadow	73.0	Y		
11	IND122	C	Nevada Saltbush Scrub	82.3	Y		
12	IND151	C	Alkali Meadow	40.4	Y		
13	IND163	C	Alkali Meadow	301.8	Y	Y	Y
14	LNP018	C	Alkali Meadow	59.0	Y	Y	
15	LNP019	C	Nevada Saltbush Scrub	49.4	Y		
16	LNP050	C	Alkali Meadow	85.6	Y		
17	LNP095	C	Alkali Meadow	96.4	Y		
18	MAN014	C	Nevada Saltbush Meadow	22.8	Y		
19	MAN060	C	Alkali Meadow	13.5	Y	Y	
20	PLC024	C	Alkali Meadow	53.7	Y	Y	
21	PLC028	C	Alkali Meadow	170.2	Y		
22	PLC056	C	Rabbitbrush Meadow	54.1	Y		
23	PLC059	C	Nevada Saltbush Scrub	65.1	Y		
24	PLC072	C	Rabbitbrush Scrub	60.7	Y		
25	PLC088	C	Alkali Meadow	52.7	Y		
26	PLC092	C	Rabbitbrush Scrub	38.4	Y		
27	PLC097	C	Alkali Meadow	34.3	Y		
28	PLC106	C	Rabbitbrush Meadow	14.1		Y	Y
29	PLC121	C	Alkali Meadow	52.5	Y	Y	
30	PLC136	C	Alkali Meadow	80.0	Y		
31	PLC137	C	Rabbitbrush Meadow	115.4	Y		
32	PLC144	C	Alkali Meadow	70.0	Y		
33	PLC223	C	Alkali Meadow	75.1	Y	Y	Y
34	UNW029	C	Alkali Meadow	29.7	Y	Y	
35	UNW031	C	Rush/Sedge Meadow	73.9	Y		

	Parcel	W/C	Plant Community	Acres	BaseTransData	LPT '92-2011	LPT '91-2011
36	UNW039	C	Nevada Saltbush Scrub	407.4	Y	Y	Y
37	UNW074	C	Alkali Meadow	78.1	Y		
38	UNW079	C	Nevada Saltbush Meadow	49.0	Y		
39	BGP086	W	Alkali Meadow	88.7	Y		
40	BGP154	W	Nevada Saltbush Meadow	27.9	Y	Y	Y
41	BGP157	W	Rabbitbrush Scrub	44.7	Y		
42	BGP162	W	Nevada Saltbush Scrub	286.0	Y	Y	Y
43	BIS085	W	Rabbitbrush Meadow	45.3	Y		
44	BLK002	W	Rabbitbrush Scrub	280.1	Y		
45	BLK009	W	Alkali Meadow	152.0	Y	Y	Y
46	BLK016	W	Alkali Meadow	247.8	Y	Y	Y
47	BLK021	W	Nevada Saltbush Scrub	43.5	Y		
48	BLK024	W	Nevada Saltbush Meadow	259.8	Y	Y	Y
49	BLK033	W	Alkali Meadow	37.9	Y	Y	
50	BLK039	W	Alkali Meadow	66.9	Y	Y	
51	BLK044	W	Rabbitbrush Meadow	33.6		Y	Y
52	BLK069	W	Desert Sink Scrub	234.9		Y	Y
53	BLK074	W	Nevada Saltbush Scrub	141.2		Y	
54	BLK075	W	Alkali Meadow	55.4	Y	Y	
55	BLK077	W	Desert Sink Scrub	44.9	Y		
56	BLK093	W	Alkali Meadow	65.6	Y		
57	BLK094	W	Alkali Meadow	333.5	Y	Y	Y
58	BLK095	W	Alkali Meadow	115.1	Y		
59	BLK096	W	Desert Sink Scrub	81.7	Y		
60	BLK099	W	Alkali Meadow	170.8	Y	Y	Y
61	BLK142	W	Alkali Meadow	35.5	Y		
62	BLK143	W	Alkali Meadow	21.6	Y		
63	FSL053	W	Alkali Meadow	41.8	Y		
64	FSL064	W	Alkali Meadow	40.6	Y		
65	FSL065	W	Alkali Meadow	79.2	Y		
66	FSL116	W	Alkali Meadow	88.2	Y		
67	FSL120	W	Alkali Meadow	119.1	Y		
68	FSL123	W	Alkali Meadow	17.9	Y		
69	FSP004	W	Rabbitbrush Meadow	68.7	Y		
70	FSP006	W	Alkali Meadow	24.6		Y	Y
71	IND011	W	Alkali Meadow	71.1	Y	Y	
72	IND019	W	Alkali Meadow	90.8	Y		
73	IND021	W	Rabbitbrush Meadow	78.1	Y		
74	IND024	W	Alkali Meadow	75.8	Y		
75	IND026	W	Alkali Meadow	43.0	Y		

	Parcel	W/C	Plant Community	Acres	BaseTransData	LPT '92-2011	LPT '91-2011
76	IND029	W	Alkali Meadow	35.9	Y		
77	IND035	W	Alkali Meadow	70.0	Y	Y	
78	IND106	W	Nevada Saltbush Scrub	101.4		Y	Y
79	IND111	W	Nevada Saltbush Meadow	227.8	Y	Y	Y
80	IND132	W	Nevada Saltbush Scrub	110.5		Y	Y
81	IND133	W	Nevada Saltbush Scrub	29.9			
82	IND139	W	Nevada Saltbush Meadow	170.3	Y	Y	Y
83	IND205	W	Alkali Meadow	17.5			
84	IND231	W	Nevada Saltbush Scrub	61.5		Y	Y
85	LAW030	W	Alkali Meadow	62.7	Y		
86	LAW035	W	Alkali Meadow	43.3	Y		
87	LAW043	W	Rush/Sedge Meadow	36.5	Y		
88	LAW052	W	Alkali Meadow	18.8	Y		
89	LAW062	W	Rabbitbrush Meadow	48.6	Y		
90	LAW063	W	Desert Greasewood Scrub	37.6	Y	Y	Y
91	LAW065	W	Alkali Meadow	21.4	Y	Y	
92	LAW070	W	Rush/Sedge Meadow	15.5	Y		
93	LAW072	W	Alkali Meadow	24.2	Y		
94	LAW078	W	Alkali Meadow	38.9	Y		
95	LAW082	W	Rabbitbrush Meadow	30.2	Y		
96	LAW085	W	Alkali Meadow	32.5		Y	Y
97	LAW107	W	Alkali Meadow	28.3	Y	Y	
98	LAW109	W	Alkali Meadow	49.0	Y		
99	LAW112	W	Nevada Saltbush Meadow	22.2	Y		
100	LAW120	W	Alkali Meadow	53.9	Y	Y	Y
101	LAW122	W	Alkali Meadow	50.4	Y	Y	
102	LAW137	W	Rabbitbrush Meadow	108.4	Y		
103	LNP045	W	Nevada Saltbush Meadow	48.9	Y		
104	MAN006	W	Alkali Meadow	47.9	Y	Y	
105	MAN007	W	Nevada Saltbush Scrub	565.2	Y	Y	Y
106	MAN037	W	Nevada Saltbush Scrub	146.4	Y	Y	Y
107	TIN028	W	Desert Greasewood Scrub	163.8	Y	Y	Y
108	TIN050	W	Alkali Meadow	102.7	Y		
109	TIN053	W	Alkali Meadow	53.4	Y		
110	TIN064	W	Alkali Meadow	42.0	Y		
111	TIN068	W	Alkali Meadow	84.6	Y	Y	

Control vs. Wellfield Designations

Parcels were classified according to the level of water table drawdown to evaluate the effects of groundwater pumping on vegetation. The water table beneath 'control' parcels has been unaffected or only slightly affected by groundwater pumping while 'wellfield' parcels have experienced larger pumping-induced drawdown during the monitoring period. To classify parcels, the level of drawdown sustained by the parcel during heaviest period of pumping (1987-1993) was used to represent the maximum geographic extent of pumping effects. Two water table estimation methods were used to evaluate the level of drawdown; ordinary (OK) kriging of measured water levels since baseline and the groundwater modeling results shown on the baseline maps (Danskin 1998; LTWA Exhibit A: Management Maps; Harrington and Howard 2000; Harrington, 2003). Parcels with greater than 1m drawdown of the water table using kriged depth to water (DTW) estimates during the period 1987-1993 and within the modeled 10ft drawdown contour were classified as wellfield parcels. The modeled drawdown contour alone was used if the parcel had a surface water feature nearby; for example, a canal, river, an adjacent groundwater source, or if kriged DTW estimates were not reliable. Unreliable DTW estimates result from inadequate test well coverage near vegetation parcels (see Harrington, 2003 for details). Not all parcels in the wellfield category presently have depressed water table conditions compared to water levels during the baseline mapping period, but they all were affected by pumping in the past and could be affected in the future. Parcels designated as controls experienced less than 1m drawdown according to kriged estimates between the time period 1987-1993 and were outside of the modeled 10ft drawdown contour. If water table estimates using kriging were not reliable, the 10m drawdown contour alone was used. Some parcels located within the 10ft drawdown contour but also near a surface water source, i.e. a canal, sewer pond, creek, river, or a ground water seepage source that would moderate potential drawdown were classified as controls.

Statistical Analysis

Among-Parcel

To measure changes with respect to groundwater management at the valley-wide scale, three questions were assessed using the control and wellfield parcel groups. We first considered whether perennial cover in control and wellfield groups has changed over the entire time period. Second, we assessed perennial cover between baseline and 2011 for the wellfield and control groups using two datasets described below. Third, we evaluated whether shrub and grass cover have changed over time in wellfield and control groups.

The number of parcels sampled each year has varied for a number of reasons including staffing and advances in technology. If the goal is to analyze the entire monitoring record since 1991, using only the set of parcels that have a complete time record is essential to avoid confounding the evaluation of the effects of environmental conditions on cover with the effects of varying the sample size between years. The set of parcels sampled each year from 1992-2011 was used in analyses on parcel groups. This time period was chosen because the sample size (n = 45) is greater than the set of parcels sampled each year from 1991-2011 (n = 21). The set of consistinously sampled parcels will hereafter be referred to as the 'rarefied' (or reduced) set.

The subset of parcels sampled each year is not, however ignored. It is instead used for a comparison of current conditions, in any given monitoring year, to baseline measurements. To make this comparison with baseline, these parcels need to also have baseline transect-level

data. The set of parcels sampled in 2011 that have baseline transect data will hereafter referred to as '2011 parcels' (n = 100).

To assess whether wellfield parcels differ from control parcels over time, a repeated measures MANOVA was used for the set of parcels that have been sampled each year between 1992-2011 (n = 45), and for alkali meadow parcels sampled during this period (n = 27). A repeated measures MANOVA was chosen for two reasons. It allows testing of all years simultaneously because it controls the family-wise error rate (to prevent the rejection of a true null hypothesis of no difference), and it accounts for the dependence of subjects between years (to prevent the violation of statistical independence). In essence it is an extension of the paired t-test for datasets with multiple years and subjects.

To examine the difference in perennial cover between baseline and all reinventory years, mean annual cover for all rarefied parcels were graphed by control and wellfield status (Figure 2). Perennial cover changes between baseline and 2011 for the rarefied set (n = 45) of wellfield and control parcels were assessed using, a paired t-test performed in JMP 8.0 (JMP, 1989-2007). A paired t-test is designed to assess differences between two time-periods for a set of subjects in a single time period. Similarly, to assess changes in perennial cover for all parcels sampled in 2011 that have baseline transect data (n = 100), a paired t-test was performed to compare wellfield and control perennial cover in 2011 with mean baseline perennial cover.

To examine changes in mean perennial cover by lifeform (grass, herb, or shrub) perennial cover was graphed for each year between 1992 and 2011 using the rarefied set of parcels (n = 45) to view potential changes in cover and community type over time. This was followed with a paired t-test of perennial grass cover between baseline and 2011 for both wellfield and control parcel groups using the rarefied set of parcels. Mean perennial cover was also graphed by lifeform for '2011 parcels' (n = 100), and followed by a paired t-test of perennial grass cover between baseline and 2011 by parcel type for wellfield or control groups. Finally a regression of mean shrub and grass cover against time was analyzed for the rarefied set of wellfield and control parcels (n_T = 36: n_W = 24, n_C = 12 for the total rarefied set, *t*, wellfield, *w*, and control, *c*, groups respectively).

Within-Parcel

Two main questions were addressed for individual parcels; whether changes in vegetation cover have occurred during the 1991-2011 time record, and whether shrub proportion has changed with time. To test whether a single parcel's vegetation cover changed over time, a weighted ANOVA was performed followed by Dunnett's test to compare each year to baseline measurements in *R* ver. 2.14 (2011). A weighted ANOVA was chosen because of heterogeneous levels of variation in vegetation cover between baseline and reinventory means; weights account for unequal variance between the baseline mean and the 2011 parcel mean. The Dunnett's pairwise test controls the alpha level when multiple comparisons are employed (Zar, 1999). Results of these tests performed using 2011 parcel data were grouped into three categories: significantly below baseline, no difference from baseline, and significantly above baseline in 2011 and shown on the map in Appendix 2.

To assess whether composition has changed within a vegetation parcel, a regression of shrub proportion (shrub cover/total perennial cover) against time was performed for all parcels

with baseline transect data and at least 10 years of vegetation data (including baseline). A total of 91 parcels met these criteria.

Results

Cover Changes

Wellfield vs Control

Wellfield and control parcels had different overall responses during the 20-year monitoring period. Perennial cover in the rarefied set of wellfield parcels (n = 32) was below baseline while cover in control parcels (n = 13) was above baseline (Figure 1a, n = 45, *P* = 0.004, repeated measures MANOVA). However, the magnitude of difference between mean cover in control and wellfield parcels has generally decreased over time. Although group means show a different response since baseline, inter-annual trends in the two groups have tracked one another for much of the latter portion of the reinventory period, particularly between 2000 and 2006. In 2011, wellfield and control groups show different responses from the prior year; in wellfields perennial cover decreased from 2010 while control cover increased. For alkali meadow parcels sampled each year during this same time period (1992-2011), the general pattern is the same; however, the difference between wellfield (n = 17) and control (n = 10) parcels over time was not significant (Figure 1b, n = 27, *P* = 0.34) possibly due to the smaller sample size.

Differences between baseline and perennial cover for all reinventory years in the rarefied dataset are displayed in Figure 2 according to wellfield or control status. In 2011, mean perennial cover in rarefied wellfield parcels (n = 32) was 27.8%; 0.8% below average baseline and control (n = 13) cover was 29.5%; 4.5% above baseline. These changes were not significant for rarefied wellfield or control parcels in 2011 (Figure 2, *P* = 0.63, and *P* = 0.10 respectively). For the '2011 parcels' set (n = 100), mean perennial cover in wellfield parcels was 29%; 5% below average baseline and control cover was 32.8%; 2% above baseline. Wellfields (n = 63) were significantly lower than baseline in 2011 (Figure 3a, *P* = 0.004), while control (n = 37) cover was not different than baseline (Figure 3b, *P* = 0.36) according to paired t-tests.

Individual Parcels by Wellfield

Statistical testing of perennial cover in individual parcels compared to baseline measurements revealed changes in several parcels. See Appendix 1 for graphs of Greenbook line point vegetation cover (where available) depicting results of a weighted ANOVA on cover for the entire time period for each parcel followed by pairwise testing, and SMA cover for the time period 1985-2011. Appendix 2 presents maps of vegetation parcels color-coded by statistical significance of current conditions compared to baseline for the 2011 season.

Parcel changes were assessed by wellfield to identify specific problem areas that may require management adjustments or a Technical Group assessment of whether an impact to vegetation has occurred. Of all wellfields assessed, the Laws area contained the most parcels with perennial cover significantly lower than baseline measurements. In 11 of 18 or 61% of Laws parcels sampled in 2011, perennial cover has been consistently below baseline during all, or a majority of the reinventory period from 1991 to 2011. These parcels include: LAW035, LAW043, LAW052, LAW062, LAW065, LAW070, LAW072, LAW078, LAW082, LAW085, and LAW107. In three Bishop parcels; BIS085, FSL116, FSL120 and PLC106, cover has been lower

than baseline in the past several years, although this change was not statistically significant in 2011. In Big Pine, one parcel, BGP205 was significantly below baseline in 2011 and three other parcels: BGP019, BGP047, and BGP162 were also significantly below in 2011 and have been for the majority or all of the reinventory period. In the Taboose-Aberdeen wellfield, perennial cover was significantly below baseline in parcel BLK021 and has remained so during the majority of the reinventory period. In parcels BLK009, BLK033, and TIN064, perennial cover measured below baseline but not significantly, and has been below baseline for much of the reinventory period. Three parcels in the Thibaut-Sawmill (TS) wellfield show decreased cover, IND026, BLK075 and BLK077, but this change was not significant in 2011. Parcel BLK094, however, was significantly below baseline in 2011 and has been in this condition for most of the reinventory period. In the Independence-Oak wellfield, three parcels are significantly below perennial baseline cover; IND064, IND067, and IND119. In the Symmes-Shepard wellfield, cover in IND132, IND139, IND151, MAN007 and MAN014 were below baseline, but this result was not significant. In Bairs-Georges, cover in parcel UNW029 was significantly below baseline. In MAN037 cover was below baseline and has been for most of the reinventory period, although this result was not statistically significant in 2011. Finally, in the Lone Pine wellfield cover in LNP050 was significantly below baseline while in LNP045 below baseline cover was not statistically significant.

Composition Changes—

Wellfield vs Control—

Changes in composition are occurring according to analyses completed using both the rarefied (n = 45) and the '2011 parcels' set (n = 100). According to the rarefied set of parcels, wellfield and control grass cover was not significantly lower than baseline in 2011 (Figure 4, P = 0.06 and P = 0.24 respectively, paired t-test). Using the '2010 parcels' set, however, wellfield perennial grass cover in 2011 was significantly lower than baseline, while in control parcels grass cover did not change (Figure 3, P = 0.001, and P = 0.05 respectively). According to regression, perennial shrub cover increased over the time period 1992-2011 in the rarefied set of wellfield parcels (Figure 5, n = 24, r^2 = 0.25, P = 0.021), but did not change in control parcels (r^2 = 0.00, P = 0.99). Regression also indicates that grass cover was not correlated with time in either rarefied wellfield or control parcels during the same time period (r^2 = 0.0024, P = 0.83, and r^2 = 0.048, P = 0.339 respectively).

Individual Parcels by Life Form—

Shrub proportion in 36 of 91 parcels sampled in 2011 was significantly correlated with time (Table 2 and Appendix 3). Only eight of these 36 parcels showed decreasing shrub proportion while 28 parcels show increasing shrub proportion (Table 2). Eleven of these parcels were control parcels while 17 were wellfield parcels. Wellfield parcels with the strongest increase in shrub proportion over time include: IND035, FSL065, IND029, FSL116, BLK094, BLK044, IND011, FSP006 LAW052, and BLK075; listed by strongest correlations first. Many wellfield parcels showed weak correlation with time because of high shrub proportions present during the baseline period, a shortage of reinventory data between baseline and recent years or were not assessed due to a limited number of years with reinventory sampling data.

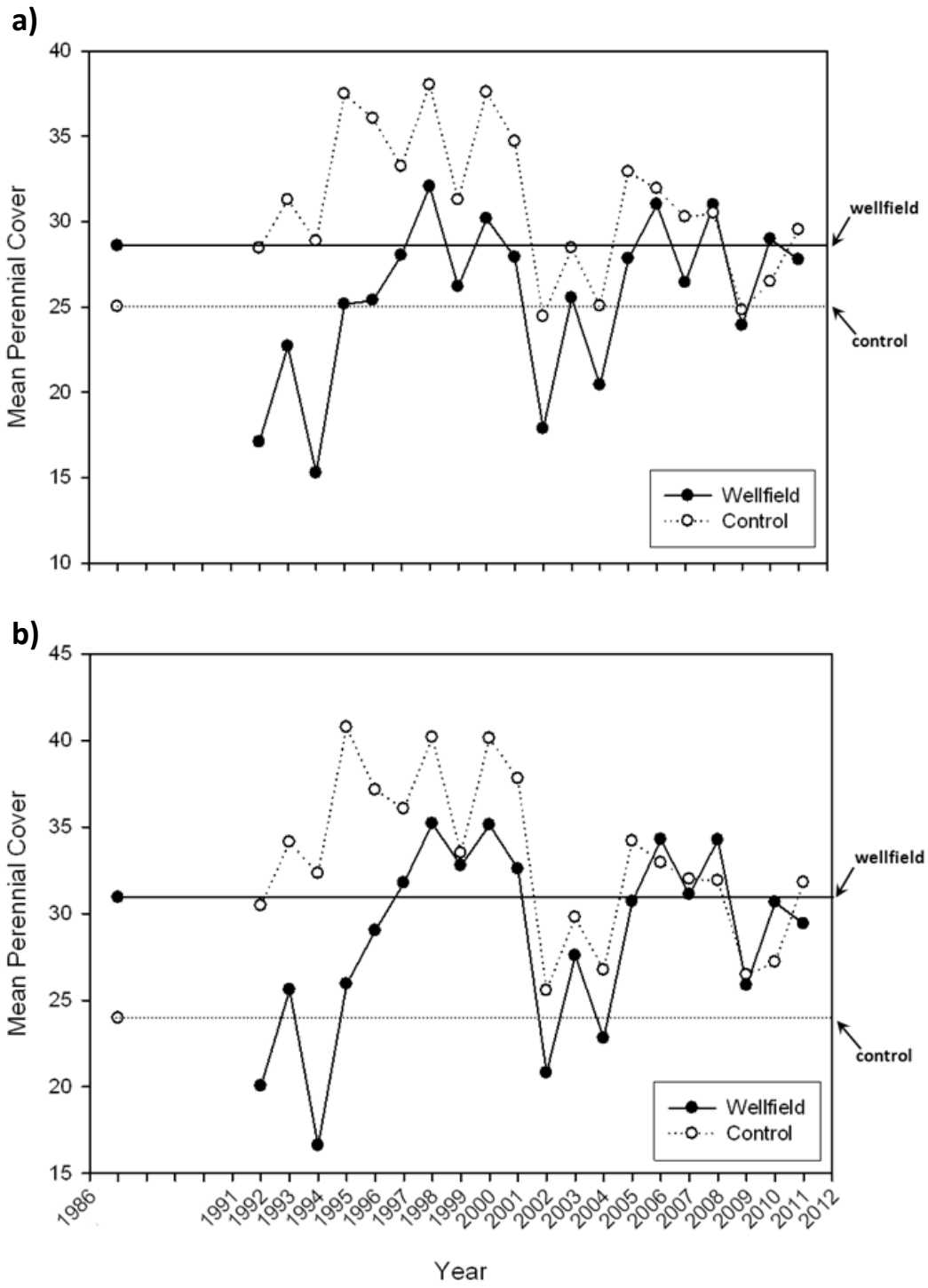

Figure 1. Repeated measures MANOVA results; *a)* parcels sampled each year between 1992 and 2011 (n = 45). During the entire time period, wellfield parcel perennial cover was significantly below its baseline while control parcel cover is above baseline measurements ($P = 0.004$). For *b)* Alkali meadow parcels sampled each year from 1992-2010 (n = 27), the general pattern is the same, however, no difference over time between wellfield or control baseline and reinventory cover was found ($P = 0.34$).

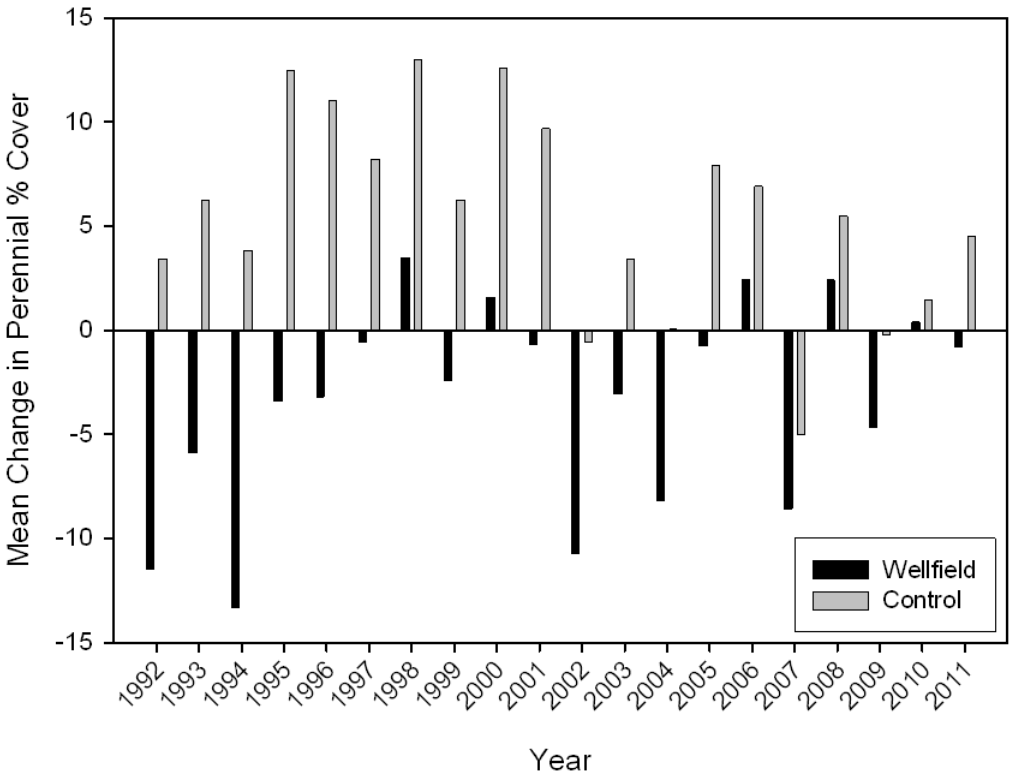

Figure 2. The difference in mean perennial cover between baseline and each reinventory year for the rarefied set of parcels, sampled each year between 1992 and 2011. Mean wellfield and control cover are not significantly different than baseline in 2011 for this set of parcels ($P = 0.63$, and $P = 0.10$).

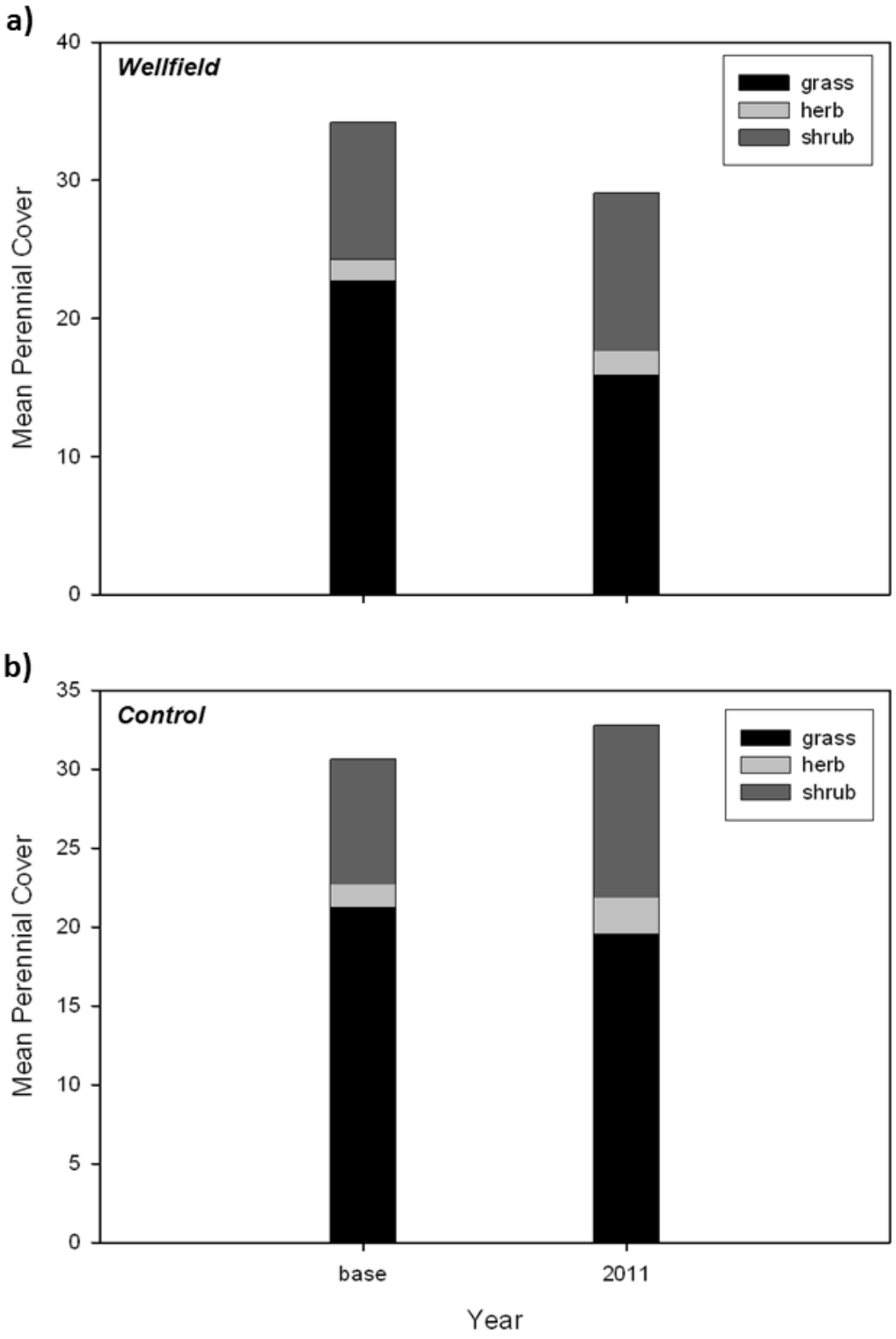

Figure 3. For all parcels sampled in 2011 that have baseline transect data, in *a)* wellfield parcel cover was significantly lower than baseline while in *b)* control cover was not ($P = 0.004$ and $P = 0.36$ respectively). In addition, a significant decrease in grass cover was found in wellfield parcels (*a)*, while no change occurred in control parcels (*b*) ($P = 0.001$, and $P = 0.501$ respectively).

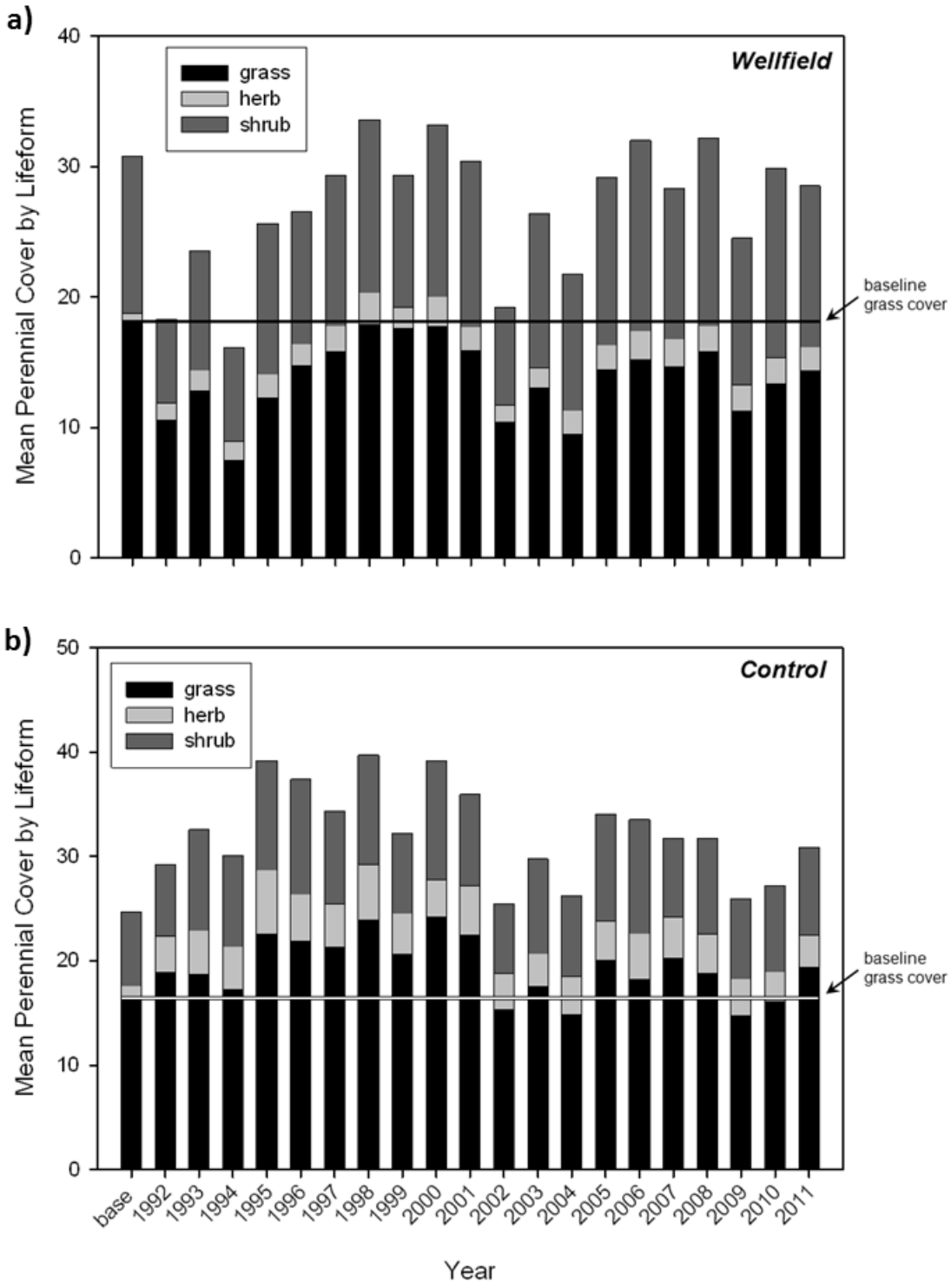

Figure 4. Mean perennial cover by life form for the set of parcels sampled each year between 1992 and 2011. In *a)* a decrease in grass cover is apparent in wellfield parcels, while in *b)* an increase in grass cover is apparent in control parcels ($P = 0.06$ and $P = 0.24$ respectively). Note: this is the same perennial cover data as shown in Figure 1a.

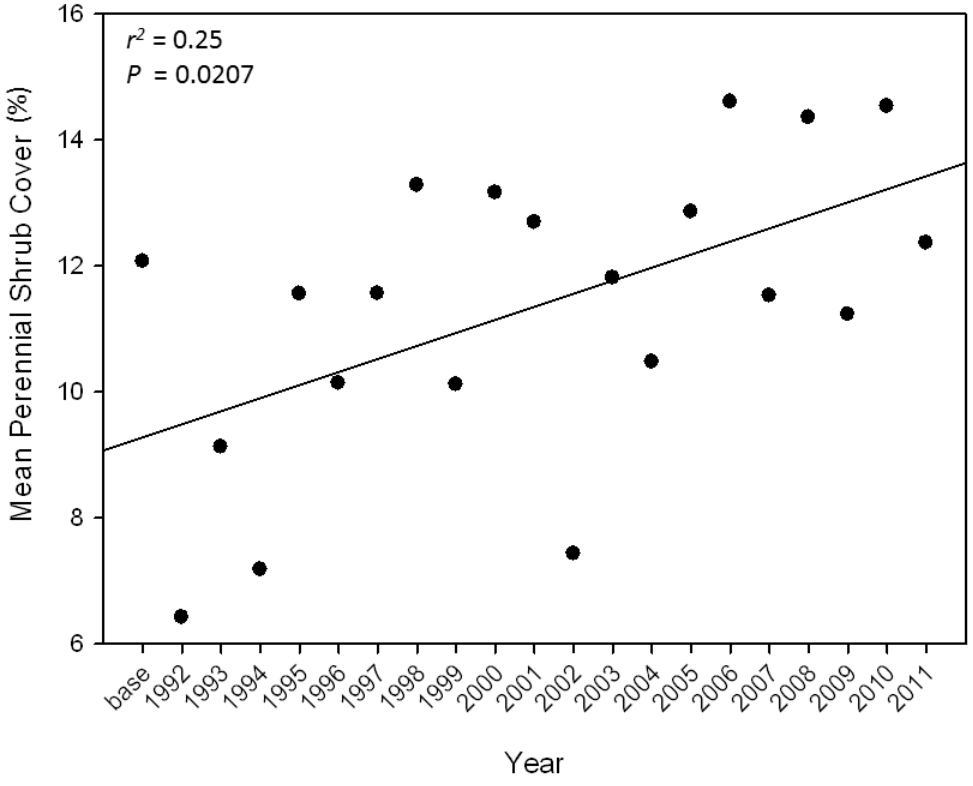

Figure 5. Perennial shrub cover increase over time in wellfield parcels sampled each year between 1992 and 2010 (n = 24, r^2 = 0.25, P = 0.0207).

Table 2. Shrub proportion regressed against time in parcels with baseline transect data and at least 10 years of line point data. Columns indicate: wellfield or control parcel status, *W/C*; the coefficient of determination, r^2; the p-value, *P*; and the slope direction (positive or negative) of the relationship, *Slope*. Bold text indicates significant regressions at the $\alpha = 0.05$ level.

	W/C	Parcel	r^2	P	Slope
1	C	BGP031	0.02	0.5899	
2	C	BGP047	0.21	0.0634	
3	C	BGP204	0.28	0.1120	
4	C	BGP205	0.1	0.3098	
5	C	BIS055	0.08	0.3360	
6	C	BLK115	0.05	0.3463	
7	C	FSL187	**0.19**	0.0490	+
8	C	IND064	**0.54**	0.0044	+
9	C	IND067	0.12	0.2140	
10	C	IND096	**0.37**	0.0027	-
11	C	IND119	**0.3**	0.0189	+
12	C	IND122	0.08	0.3931	
13	C	IND163	**0.4**	0.0015	+
14	C	LNP018	0	0.7661	
15	C	LNP019	0.25	0.0555	
16	C	LNP050	**0.76**	0.0000	+
17	C	MAN014	0	0.8085	
18	C	MAN060	0.14	0.0887	
19	C	PLC024	**0.23**	0.0264	+
20	C	PLC056	0.09	0.3965	
21	C	PLC072	0	0.9239	
22	C	PLC092	0.1	0.2295	
23	C	PLC097	0	0.7843	
24	C	PLC106	**0.2**	0.0447	+
25	C	PLC113	0.02	0.7270	
26	C	PLC121	**0.34**	0.0053	+
27	C	PLC136	**0.38**	0.0064	+
28	C	PLC137	0.04	0.4103	
29	C	PLC223	**0.2**	0.0388	+
30	C	UNW029	**0.32**	0.0080	+
31	C	UNW039	**0.37**	0.0027	-
32	C	UNW079	**0.26**	0.0261	-
33	W	BGP086	**0.43**	0.0040	-
34	W	BGP154	**0.24**	0.0199	+
35	W	BGP157	**0.54**	0.0019	-
36	W	BGP162	0.04	0.3719	
37	W	BIS085	0.09	0.3261	
38	W	BLK002	0.08	0.4020	
39	W	BLK009	0	0.9638	
40	W	BLK016	0.03	0.4513	
41	W	BLK021	**0.33**	0.0119	+
42	W	BLK024	**0.25**	0.0177	+
43	W	BLK033	**0.26**	0.0185	+
44	W	BLK039	0.06	0.2700	
45	W	BLK044	**0.51**	0.0003	+
46	W	BLK069	0.02	0.5642	
47	W	BLK074	0.08	0.2338	
48	W	BLK075	**0.37**	0.0033	+
49	W	BLK077	0.08	0.3621	
50	W	BLK094	**0.63**	0.0000	+
51	W	BLK099	0.01	0.6463	
52	W	BLK142	0.2	0.0584	
53	W	FSL065	**0.81**	0.0000	+
54	W	FSL116	**0.69**	0.0027	+
55	W	FSL123	0.1	0.1820	
56	W	FSP004	**0.27**	0.0330	-
57	W	FSP006	**0.4**	0.0019	+
58	W	IND011	**0.47**	0.0006	+
59	W	IND019	0.1	0.2543	
60	W	IND029	**0.78**	0.0002	+
61	W	IND035	**0.82**	0.0000	+
62	W	IND106	0.03	0.4317	
63	W	IND111	0.02	0.5495	
64	W	IND132	**0.22**	0.0316	+
65	W	IND133	0.46	0.1139	
66	W	IND139	0.12	0.1109	
67	W	IND231	0	0.9176	
68	W	LAW030	**0.68**	0.0001	-
69	W	LAW035	0.28	0.1195	
70	W	LAW052	**0.39**	0.0077	+
71	W	LAW062	0	0.8502	
72	W	LAW063	0	0.7708	
73	W	LAW065	0.1	0.1732	
74	W	LAW078	0.02	0.5770	
75	W	LAW082	0.2	0.0737	
76	W	LAW085	0	0.8743	
77	W	LAW107	0	0.9542	
78	W	LAW110	0.06	0.4859	
79	W	LAW112	0.03	0.4937	
80	W	LAW120	0.17	0.0540	
81	W	LAW122	0.04	0.3686	
82	W	LAW137	0.01	0.6985	
83	W	LNP045	0.18	0.0691	
84	W	MAN006	0.05	0.3430	
85	W	MAN007	0.13	0.0947	
86	W	MAN037	**0.35**	0.0037	-
87	W	TIN028	0.04	0.3603	
88	W	TIN050	0.22	0.0897	
89	W	TIN053	0.31	0.0924	
90	W	TIN064	**0.28**	0.0418	+
91	W	TIN068	**0.24**	0.0230	+

Discussion

Overall conditions in the Owens Valley can be assessed with a variety of methods. The LTWA and the Green Book refer to assessing both changes in vegetation cover and to changes in composition. Changes in cover alone may not depict actual changes if one vegetation type is replacing another; therefore, both cover and compositional changes are addressed in this report.

Cover Changes

When perennial cover conditions were assessed over the entire time period from 1992-2011, parcels subject to groundwater pumping were on average below their baseline measurements while control parcels were above or consistent with baseline (Figure 1). In 2011, perennial cover was not below baseline measurements according to the rarefied set of wellfield parcels (n = 32, Figure 2) but was significantly below using the '2011 parcels' set (n = 100, Figure 5). For control parcels in 2011 both the rarefied dataset and the '2011 parcels' set indicate perennial cover was above baseline, but this finding was not significant.

All wellfield units in the valley contain one or more parcels with reduced perennial cover in 2011 when compared with baseline conditions. Many vegetation parcels in Laws were in poor condition; eleven of 18 parcels (61%) reinventoried in this wellfield show decreased perennial cover since the baseline period (see Appendix 1 and 2). Of all wellfields sampled under the LTWA, this wellfield is in the worst condition with respect to changes in perennial cover and needs a change in water management practices to recover vegetation. In Big Pine, three parcels have been routinely below baseline; BGP019, BGP047, and BGP162 (Appendix 1 and 2). In the Taboose-Aberdeen and Thibaut-Sawmill wellfields, seven parcels including BLK021, BLK009, BLK033, BLK075, BLK077, BLK094, and IND026 have remained below reference conditions during the majority of the reinventory period. In the Independence-Oak wellfield, three parcels are significantly below baseline perennial cover; IND064, IND067 and IND119 and have been for much of the reinventory period. In the Symmes-Shepard wellfield, cover in parcels IND132, IND139, IND151, MAN007, MAN014, and MAN037 were below baseline in 2011 and for much of the reinventory period. In the Bairs-Georges and Lone Pine wellfields, cover in parcels MAN037, LNP045, and LNP050 have been below baseline for much of the reinventory period. Some of the parcels described above in poor condition are control parcels, but the majority are wellfield parcels subject to the effects of groundwater extraction.

Composition Changes—

While changes in cover are important, changes in particular species or vegetation types may be more indicative of conditions in the parcel or wellfield. Because Alkali meadows were initially defined based on their proportion of perennial grass cover, perennial grass vigor is a strong indication of healthy meadow communities in the Owens Valley and deserves special consideration (Manning, 1997). In both the rarefied set of parcels, and the '2011 parcels' set, perennial grass cover was below baseline in 2011, while grass cover in control parcels was not different than baseline (Figures 3 and 4). Concurrently, shrub cover has increased during the 18-year sampling period in wellfield parcels (Figure 5, n = 24), but not in control parcels. Lack of correlation with grass cover and time in wellfield parcels during the entire time period may be due to increased runoff and low pumping between the years 1995-1998 (Figure 4a). Although grass cover is currently below baseline and has remained in that condition since the 2001

growing season, recovery between 1997 and 2000 stabilized grass cover change for a period of approximately four years restoring cover to near baseline conditions.

Some wellfield parcels that show no change or little change in perennial cover did exhibit a measurable change in composition, particularly an increase in the proportion of shrubs. These include parcels: BGP154, BGP157, BLK044, FSP004, IND011, BLK033, BLK075, FSL116, IND132, MAN037, TIN064, BLK024, FSL065, FSP006, IND029, IND035, LAW030 and TIN068. In these parcels, the increase in shrub cover reveals unfavorable changes to vegetation not detected in the analysis of overall perennial cover. If associated with LADWP water management, these changes in composition can eventually lead to changes in overall community type that could result in violations of the Water Agreement goals.

Figure 1 shows relative recovery of perennial cover in wellfields in recent years, however two results suggest a community-level change in vegetation may be occurring. In wellfield parcels, shrub cover overall has increased measurably since baseline while grass cover has concurrently declined (Figures 3 and 4). With no parallel change occurring in control parcels, this change in composition is likely due to the effects of groundwater pumping.

Phreatophytic Vegetation and Water Table Reductions –

Phreatophytes are dependent on a shallow groundwater table because they obtain a significant portion of their water requirements from the zone of soil saturated with groundwater (the phreatic zone), or from just above this zone in what is called the capillary fringe. Reductions in the water table have been found to reduce cover of more shallowly-rooted phreatophytes in favor of more deeply rooted species. This usually results in a replacement of native phreatophytic grasses with native shrubs (Stromberg et al. 1996; Cooper et al. 2006; Trammell et al. 2008; Goedhart and Pataki, 2010). In alkali soils, reductions in the groundwater table usually reduces the amount of dissolved salts wicked to the surface via capillary action (Cooper et al. 2006; Patten et al. 2008). This process is further reinforced as rainwater leaches these salts deeper below the surface of the soil. The combination of these two processes has led to replacement of halophytes (plants adapted to saline environments) with non-halophytic species (Patten et al. 2008). *Distichlis spicata*, or saltgrass, a native dominant species present in Owens Valley alkali meadows, would be expected to be replaced due to both of the above-described processes. The measured changes in the wellfield parcels cover and in particular composition are consistent with published literature; grasses are being replaced by more deeply-rooted native shrubs.

Shrub Encroachment –

Many studies have documented changes in North American grassland communities favoring native shrub species. Often referred to as shrub encroachment, these studies report changes in grassland composition over the last century are often due to disturbance such as large-scale cattle introductions and fire suppression, with climate change cited as a potentially contributing background factor (Brown and Archer, 1999; Van Auken, 2000; Berlow et al. 2002). Encroachment of native shrubs coincides with a reduction of native grass cover and this can lead to changes in the availability of resources both spatially and temporally causing a positive feedback loop favoring the continuation of shrub invasion even after the initial disturbance abates.

Conclusions

Vegetation conditions following the 2011-monitoring season can be summarized by four main patterns. First, during the time period, 1992-2011 wellfield parcels were on average below baseline measurements while controls were above this reference period. Second, in 2011 no change was detected in overall wellfield perennial cover according to the rarefied dataset (n = 45), while the '2011parcels' set (n = 100) indicates perennial cover has decreased in wellfield parcels. Both datasets indicate that control parcel cover has increased. Third, shrubs have been increasing in wellfield parcels concurrent with an overall decline in grass cover moderated by a four-year period in the late 1990's-2000 coinciding with relatively shallow water tables and above normal precipitation (check this) for much of the valley. Finally, several individual vegetation parcels, particularly parcels subject to groundwater pumping, exhibited increases in shrub proportion which can explain a lack of change in perennial cover in some parcels.

Almost a quarter of the parcels (22%) mapped during the initial vegetation inventory were alkali meadows; this was the single most dominant vegetation community type mapped during the baseline period. The Owens Valley contains a majority of the alkali meadows present in the state; however, these systems are rare, comprising only 0.1% of the vegetation community types in California (Davis et al., 1998). Water management practices should therefore provide for periods of water table recovery to maintain these rare alkali meadows. Perennial phreatophytic plants can extend their root systems to accommodate a deepening aquifer (Sorensen et al., 1991); however a growth limit will eventually be reached; therefore periodically restoring a shallow groundwater table in pumped areas is necessary to achieve this goal. This growth limit triggers the decline of perennial grasses in favor of more deeply-rooted native shrubs. Land and water management practices, including reduced pumping in impacted areas, in combination with water spreading, prescribed burning and revegetation where appropriate would allow recovery in impacted sites to prevent further loss and facilitate recovery of ground-water dependent meadows.

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Appendix 1 –

Figures 1-168 depict mean perennial vegetation cover response over time for the 168 vegetation parcels ever sampled since 1991 using the Green Book Line Point monitoring program, and updated SMA average cover data. Asterisks depict years that perennial cover is significantly different from the baseline period (sampled between 1984 and 1987) using a weighted ANOVA followed by Dunnett's multiple comparisons.

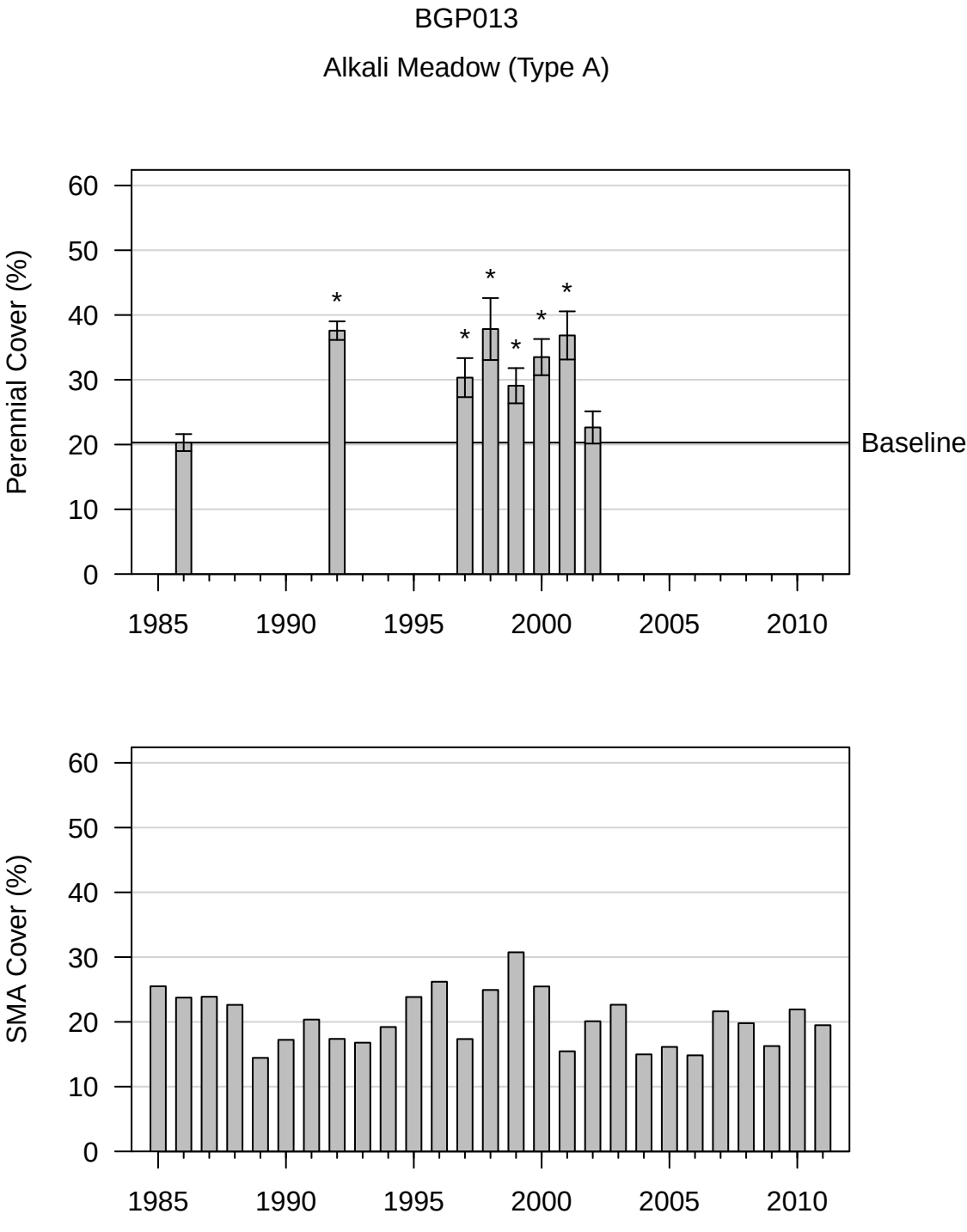


Figure 1: 2002 Control

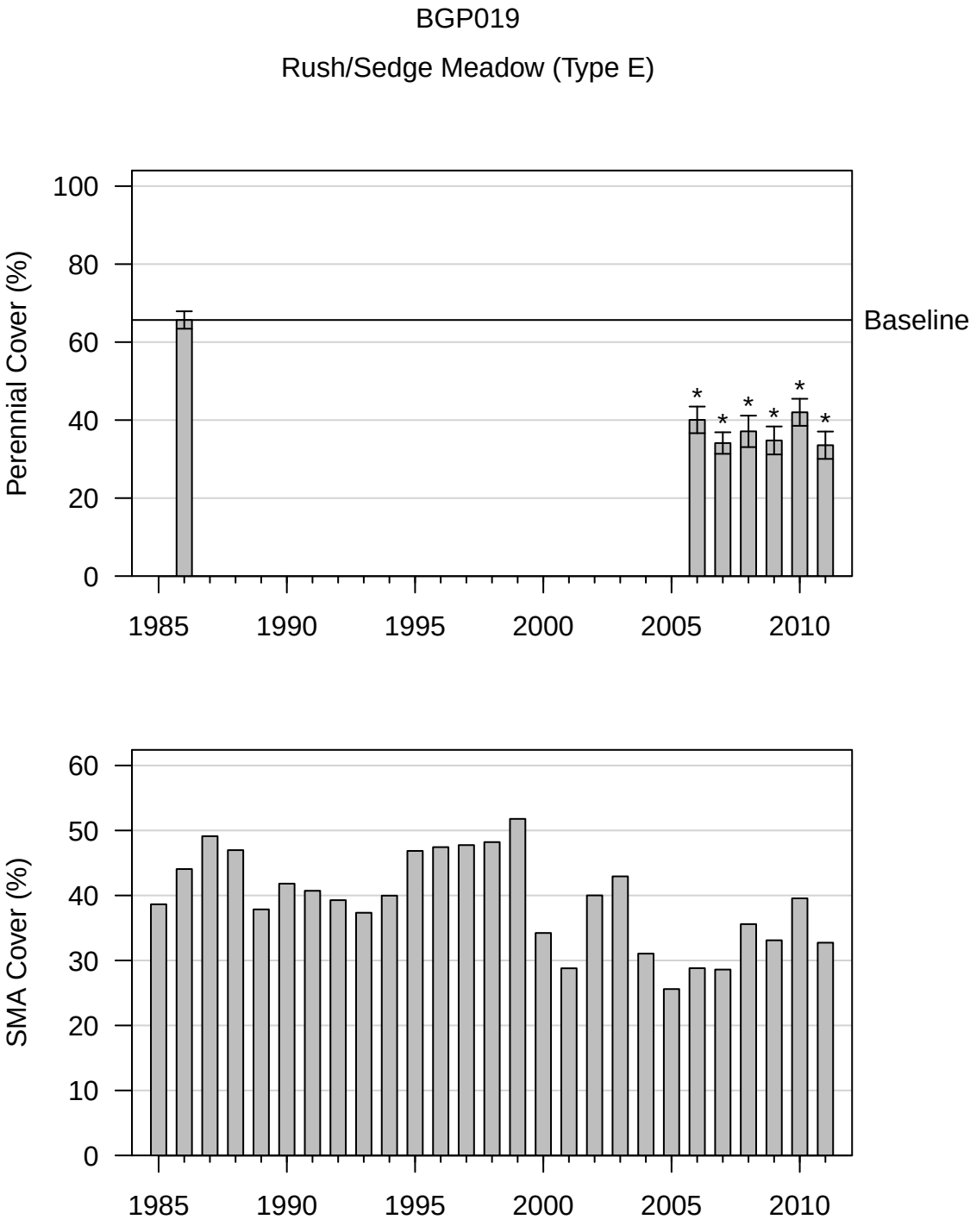


Figure 2: 2011 Control

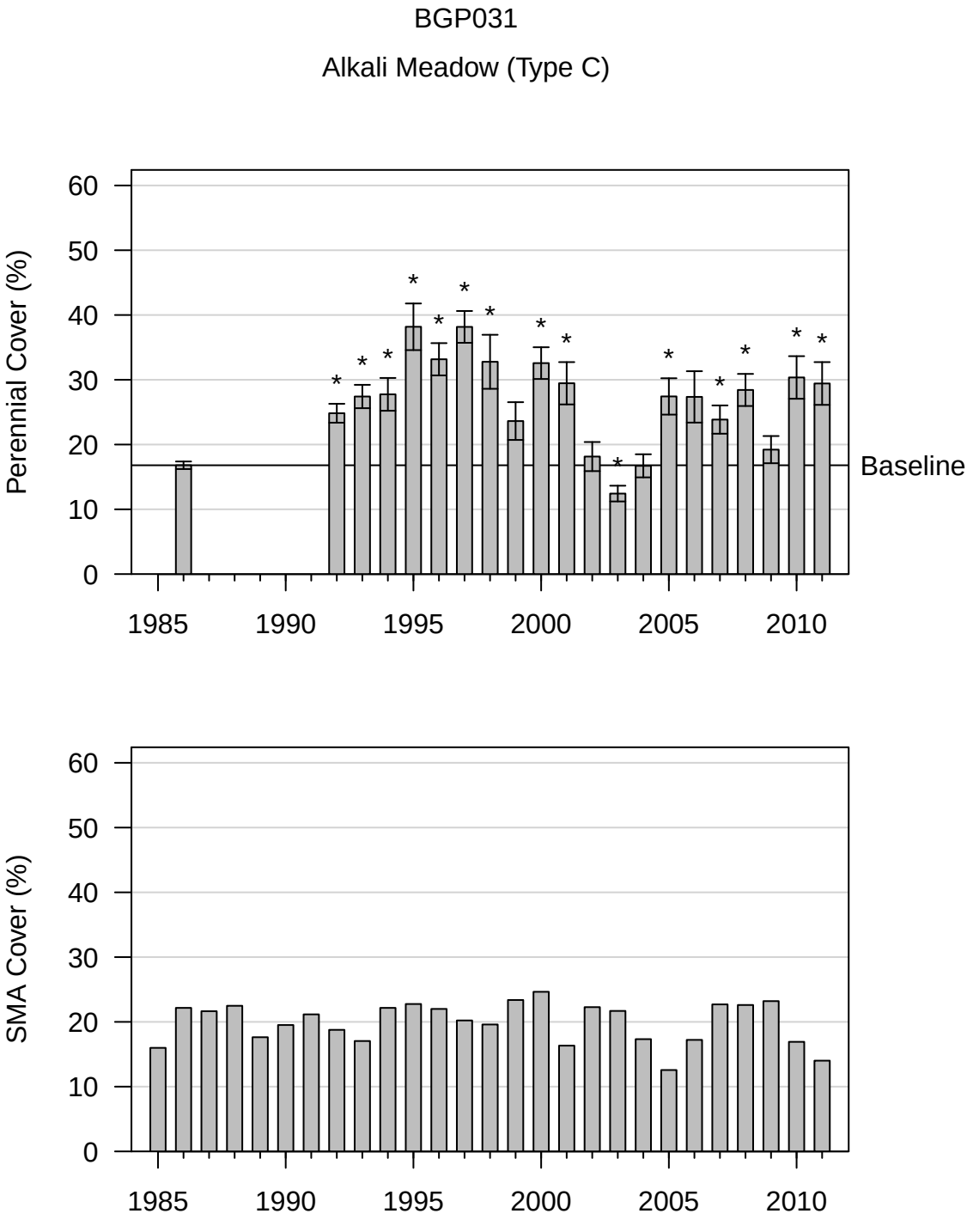


Figure 3: 2011 Control

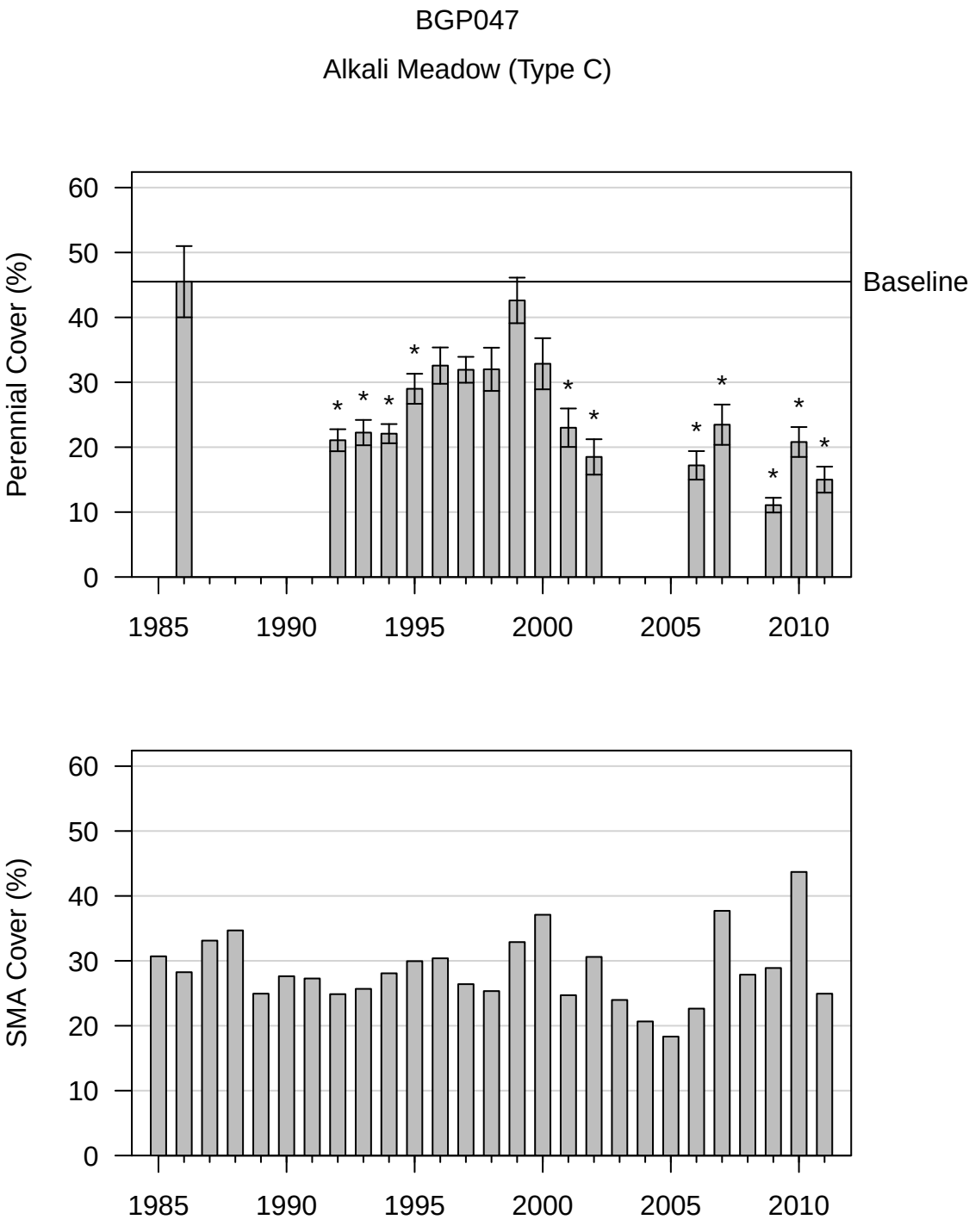


Figure 4: 2011 Control

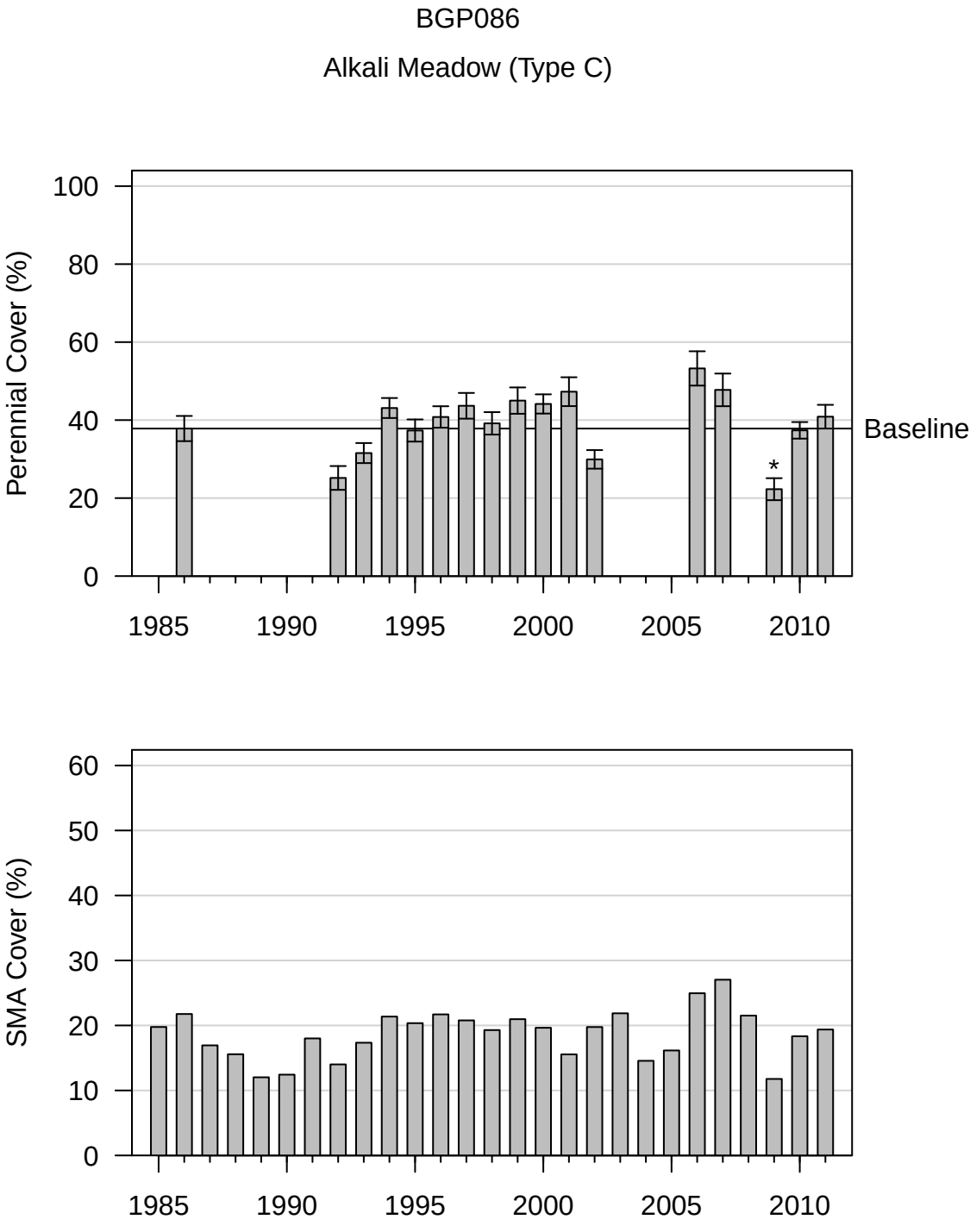
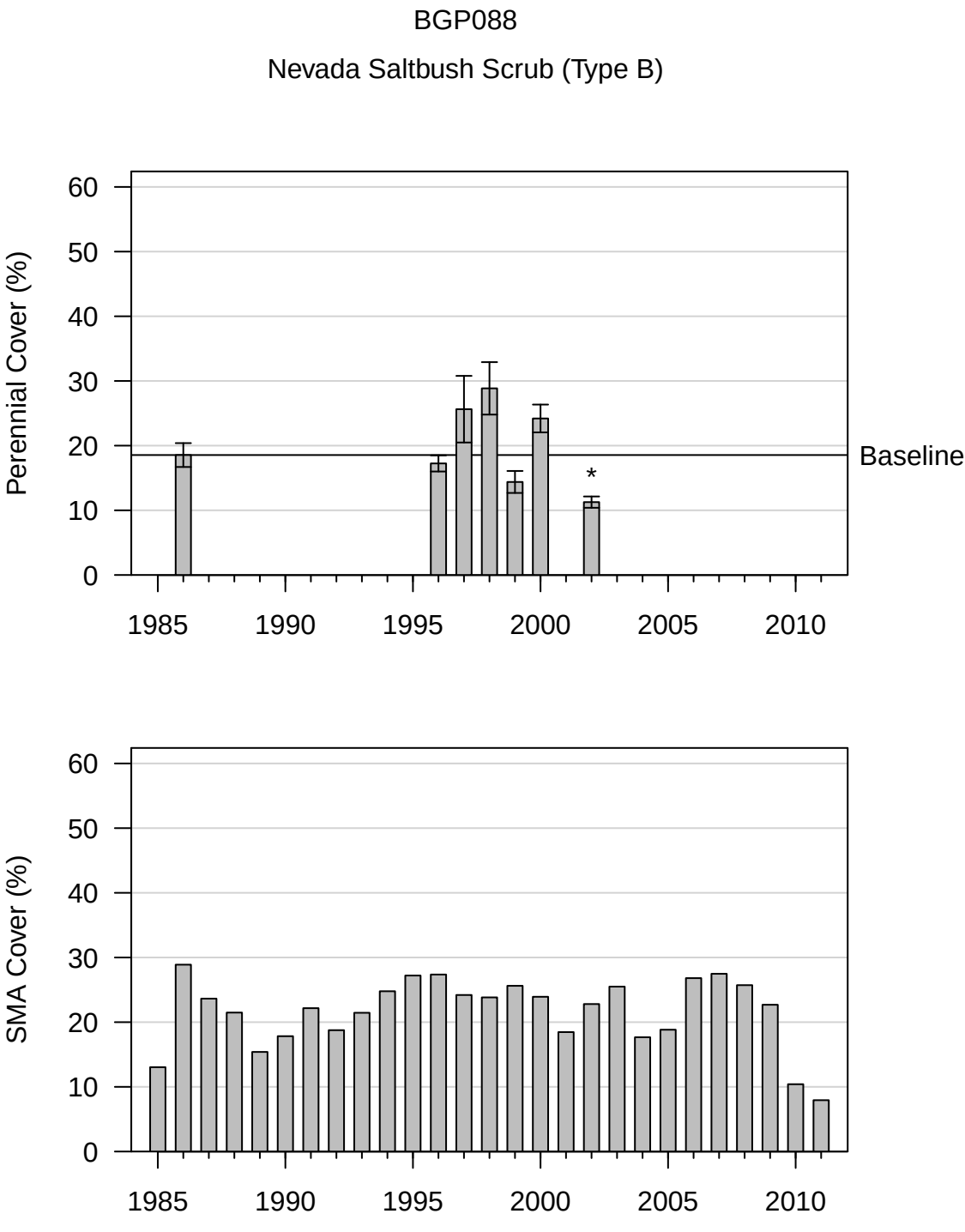


Figure 5: 2011 Wellfield



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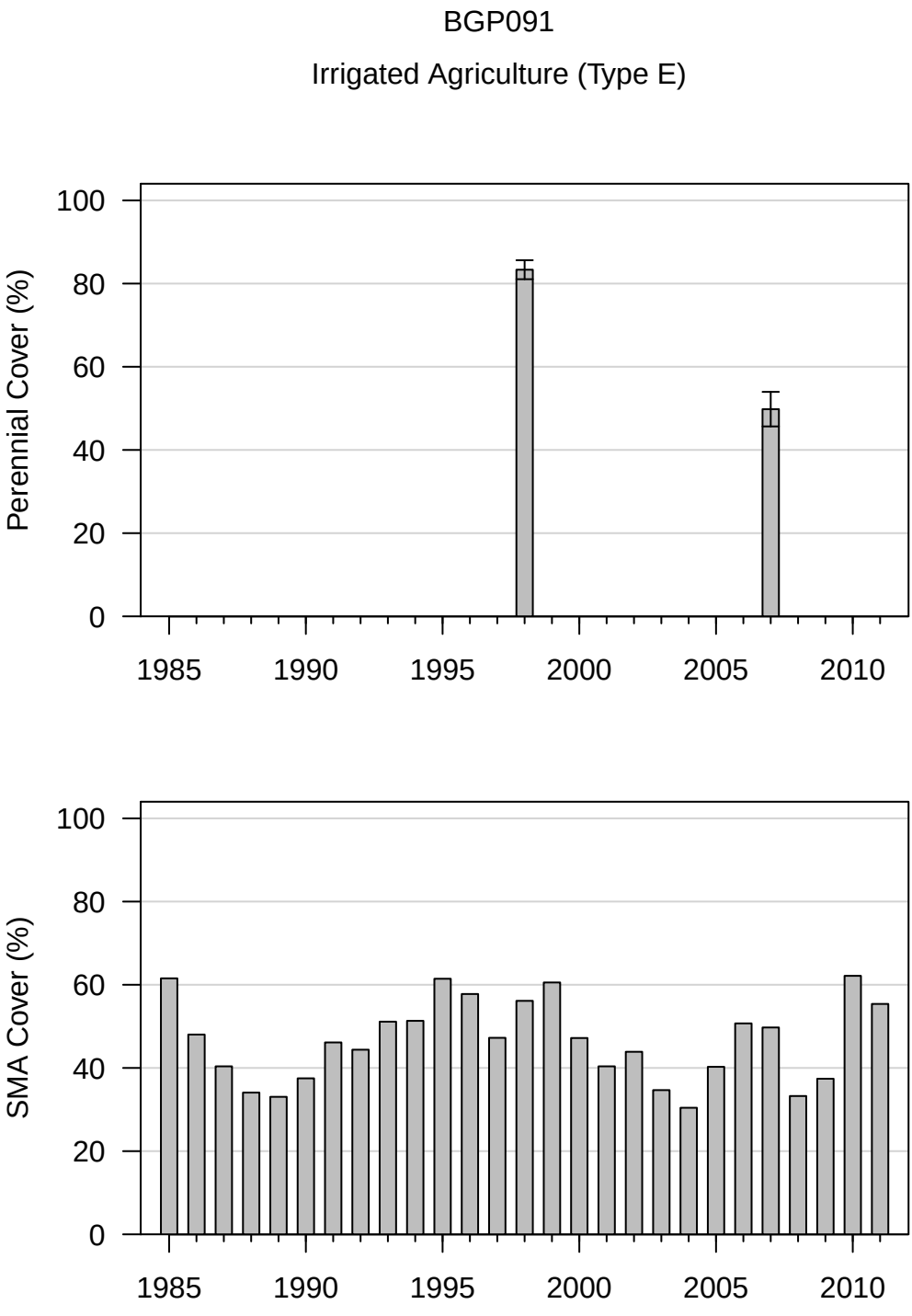
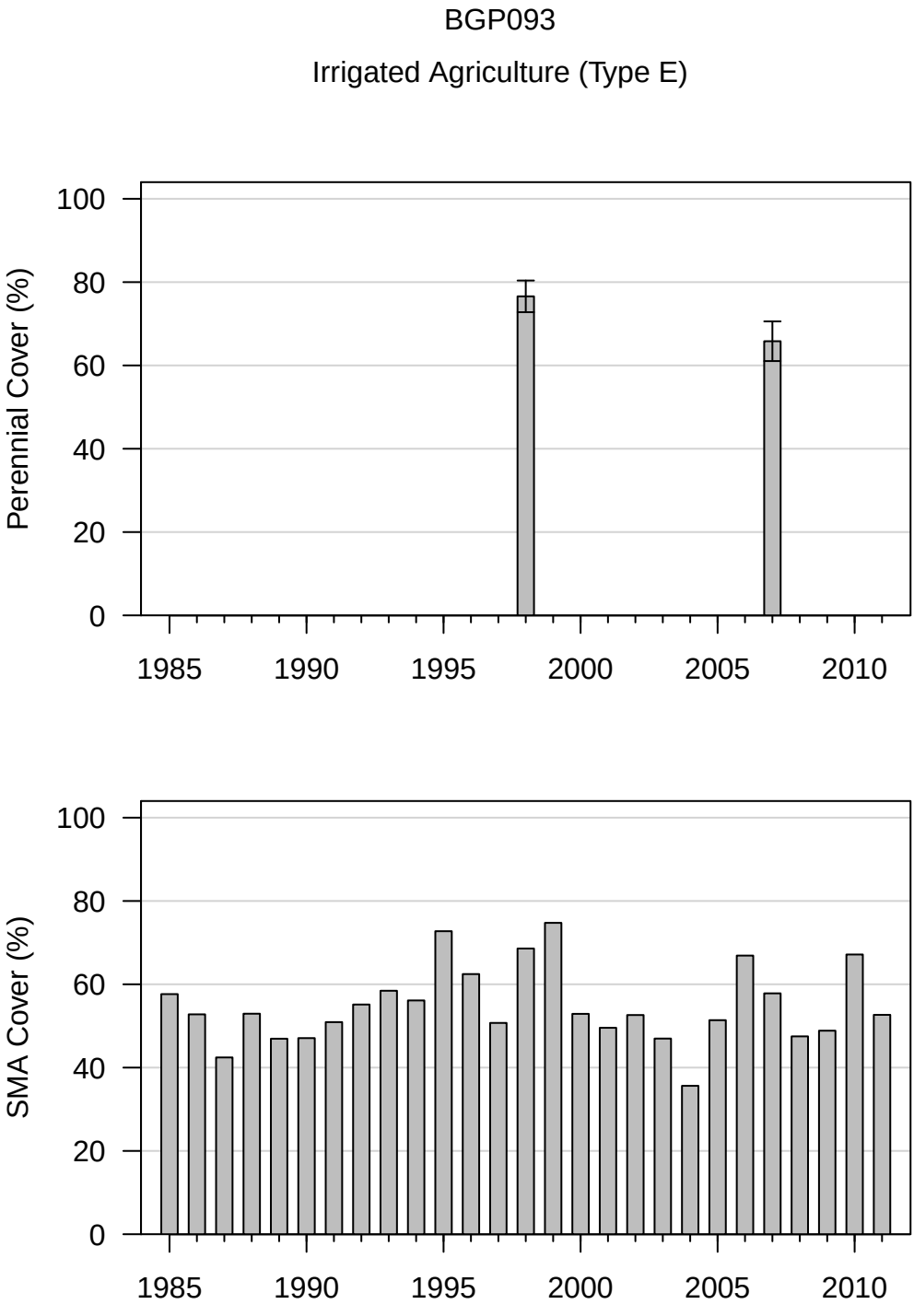


Figure 7: 2007 Wellfield



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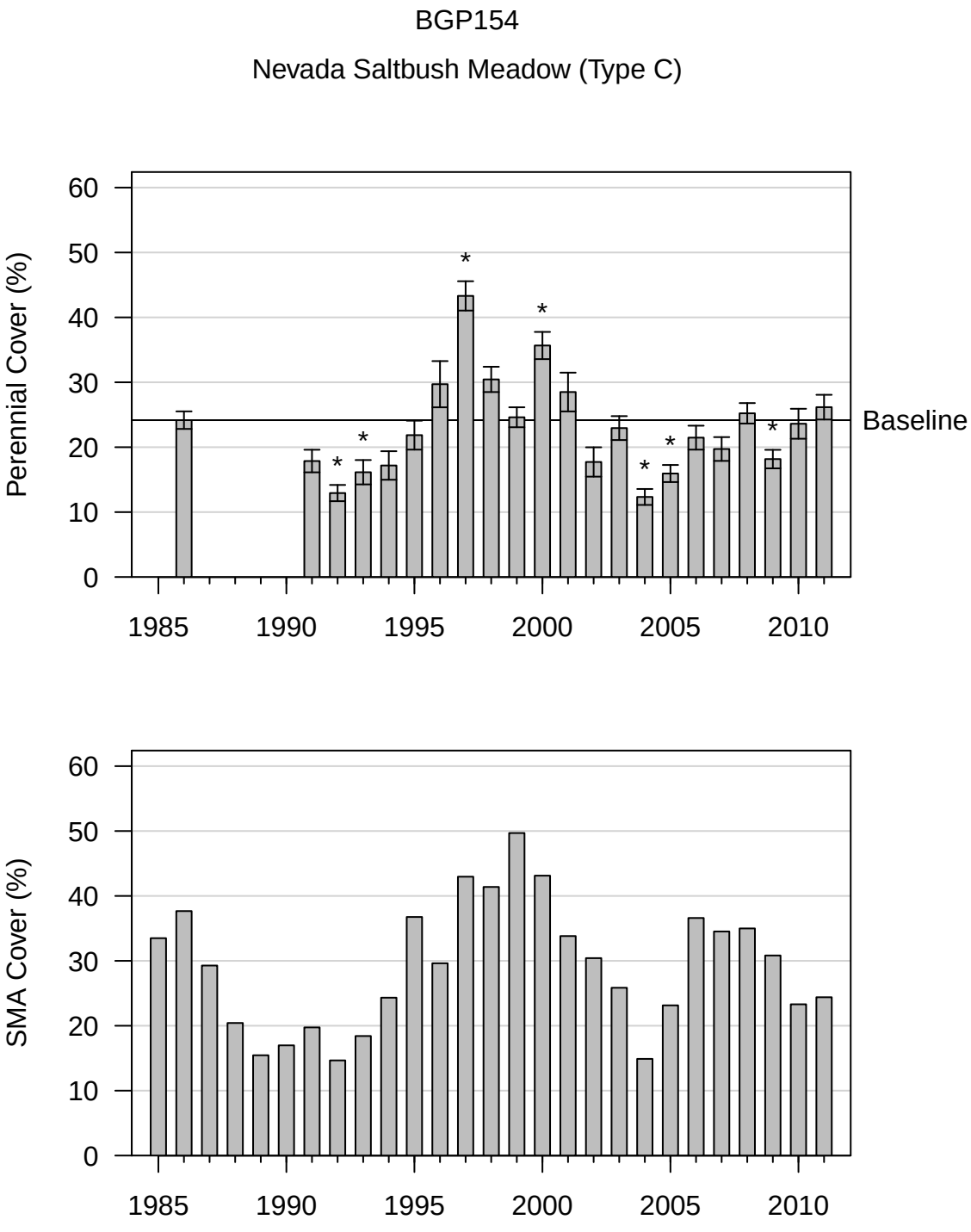


Figure 9: 2011 Wellfield

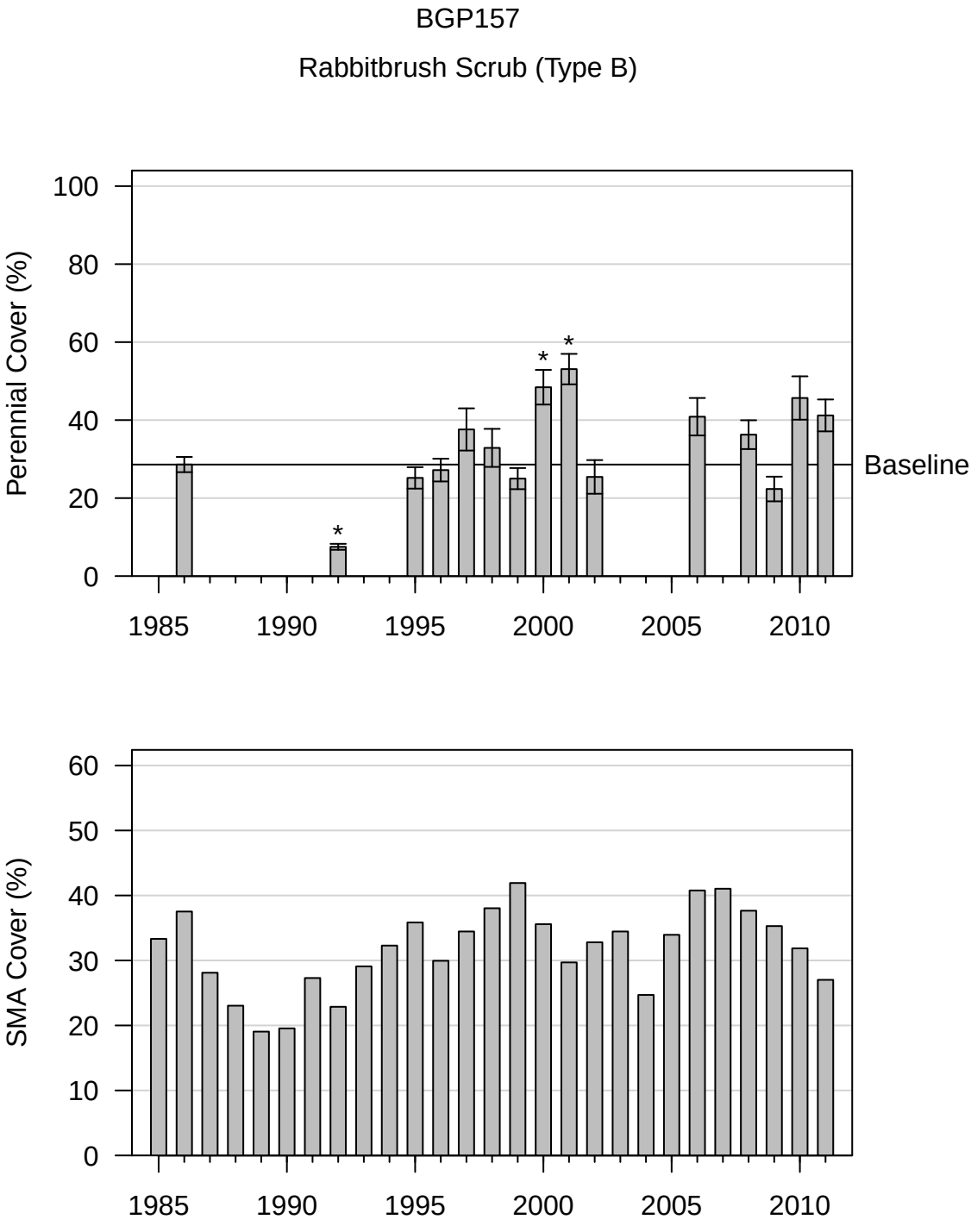


Figure 10: 2011 Wellfield

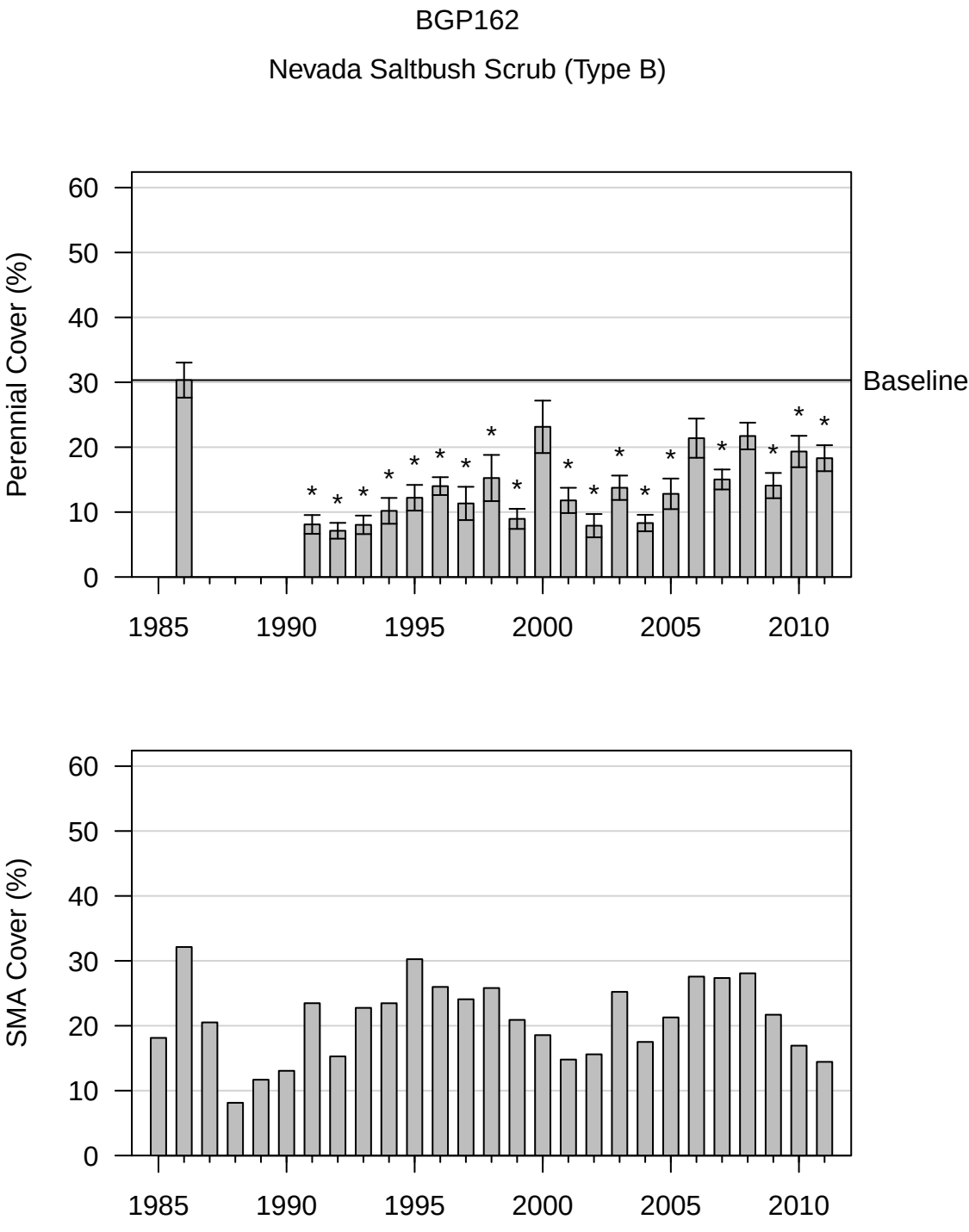


Figure 11: 2011 Wellfield

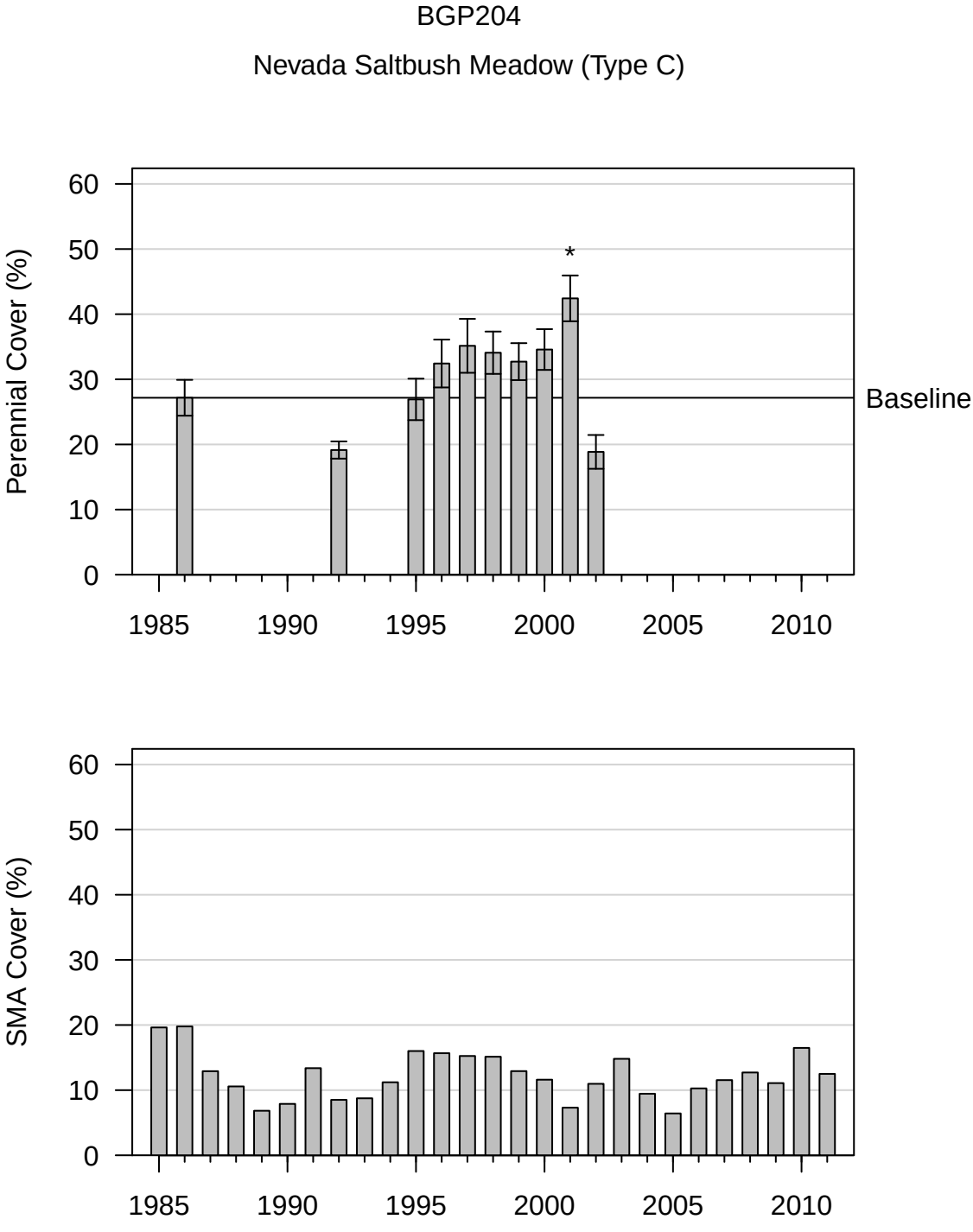


Figure 12: 2002 Control

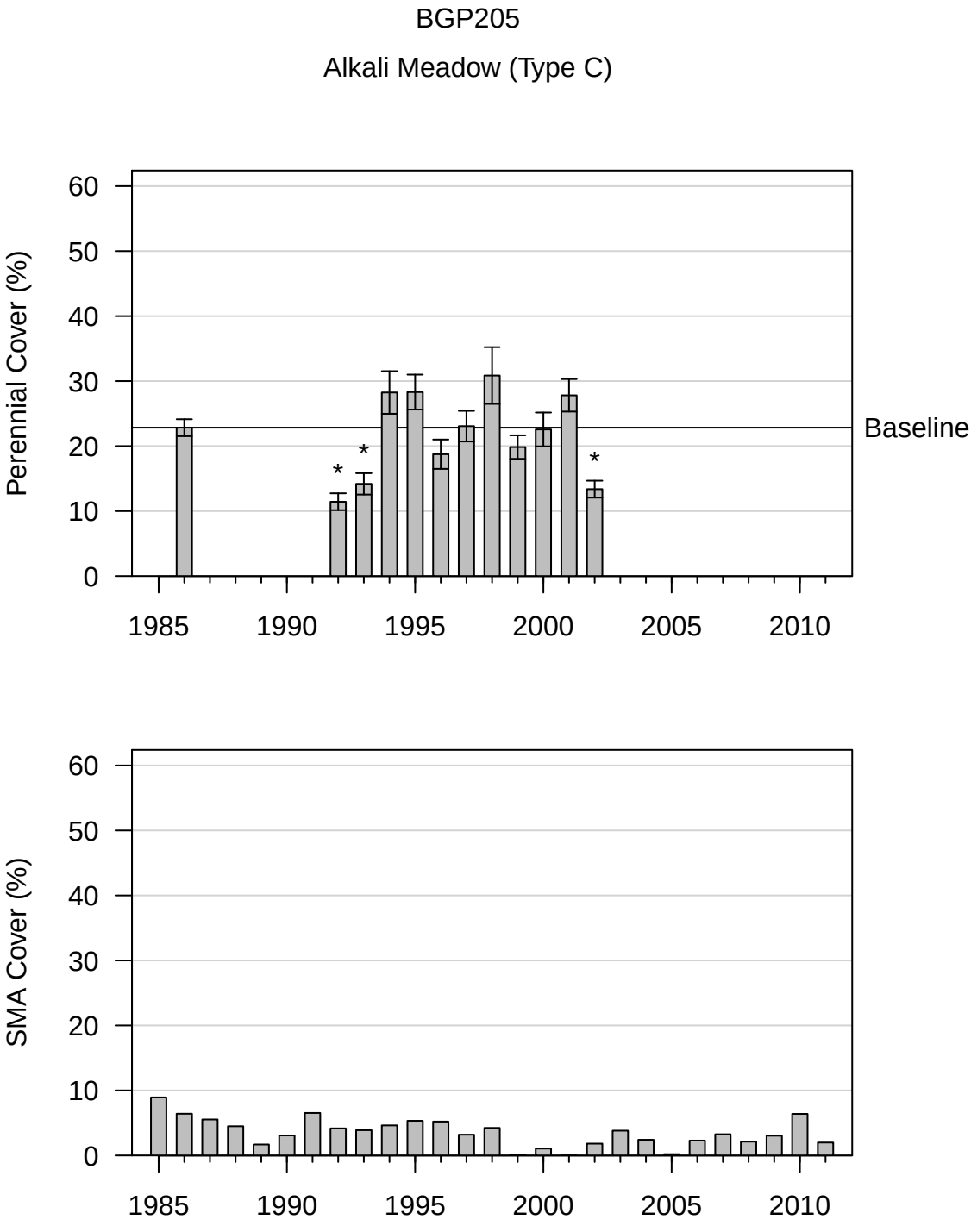


Figure 13: 2002 Control

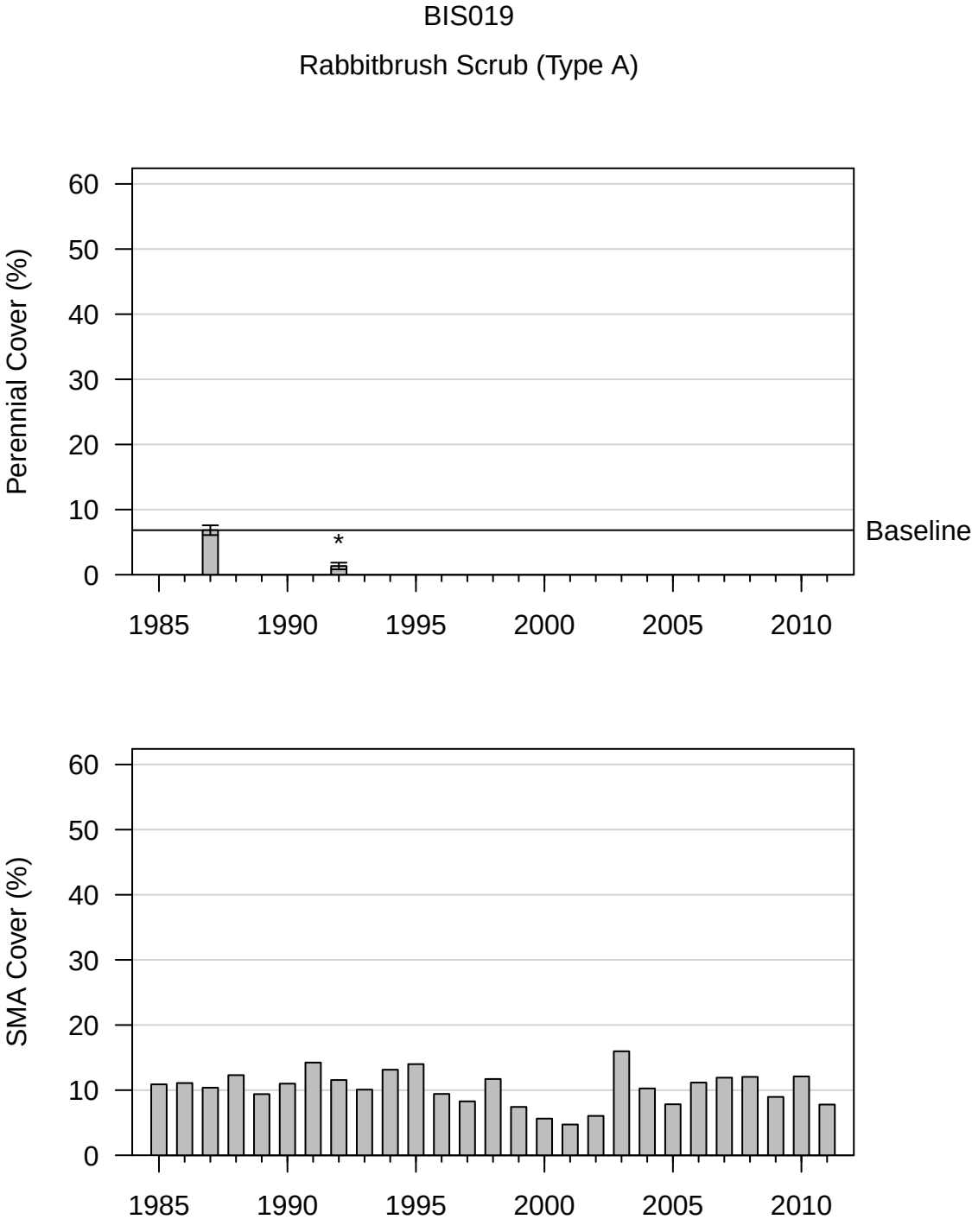


Figure 14: 1992 Control

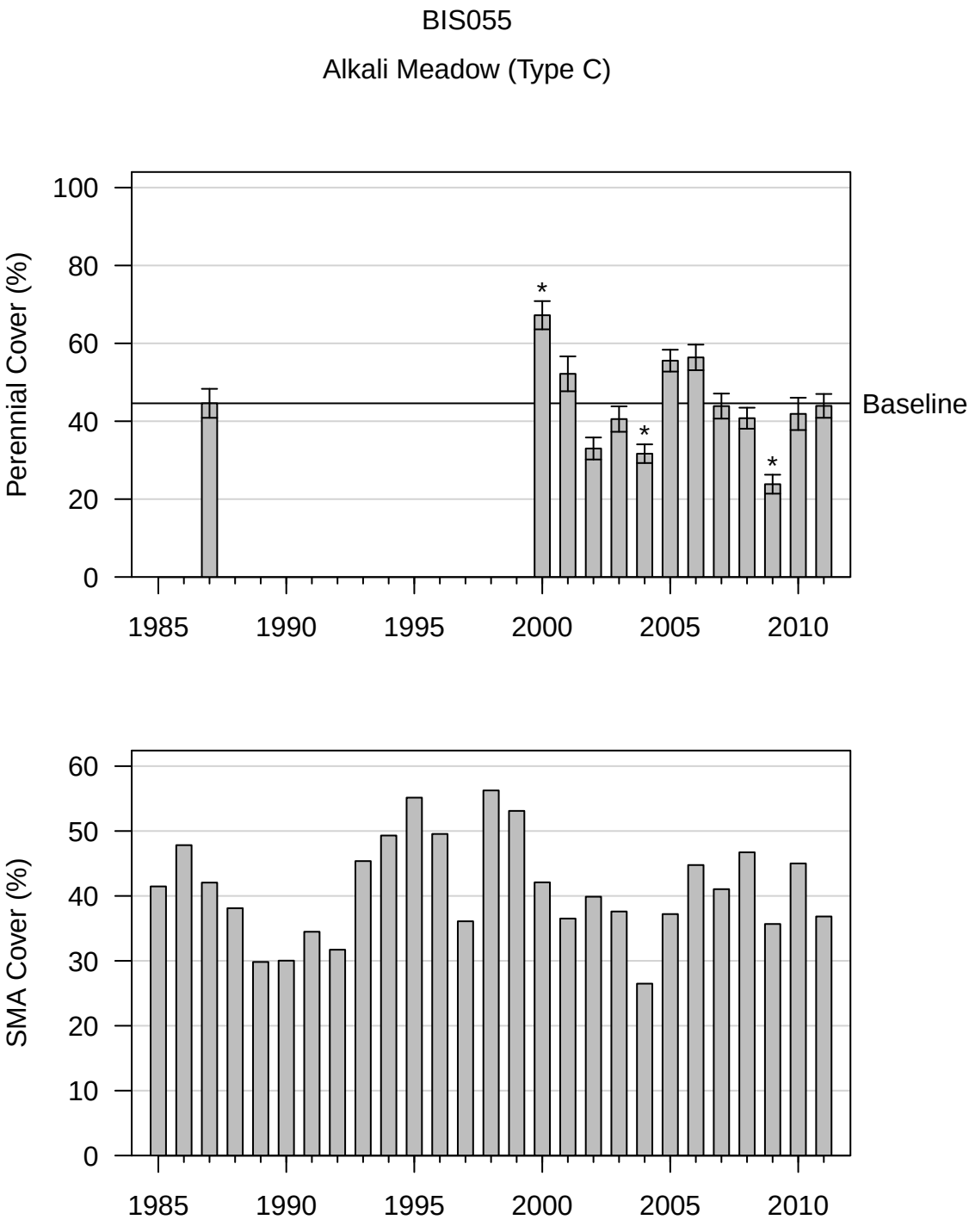


Figure 15: 2011 Control

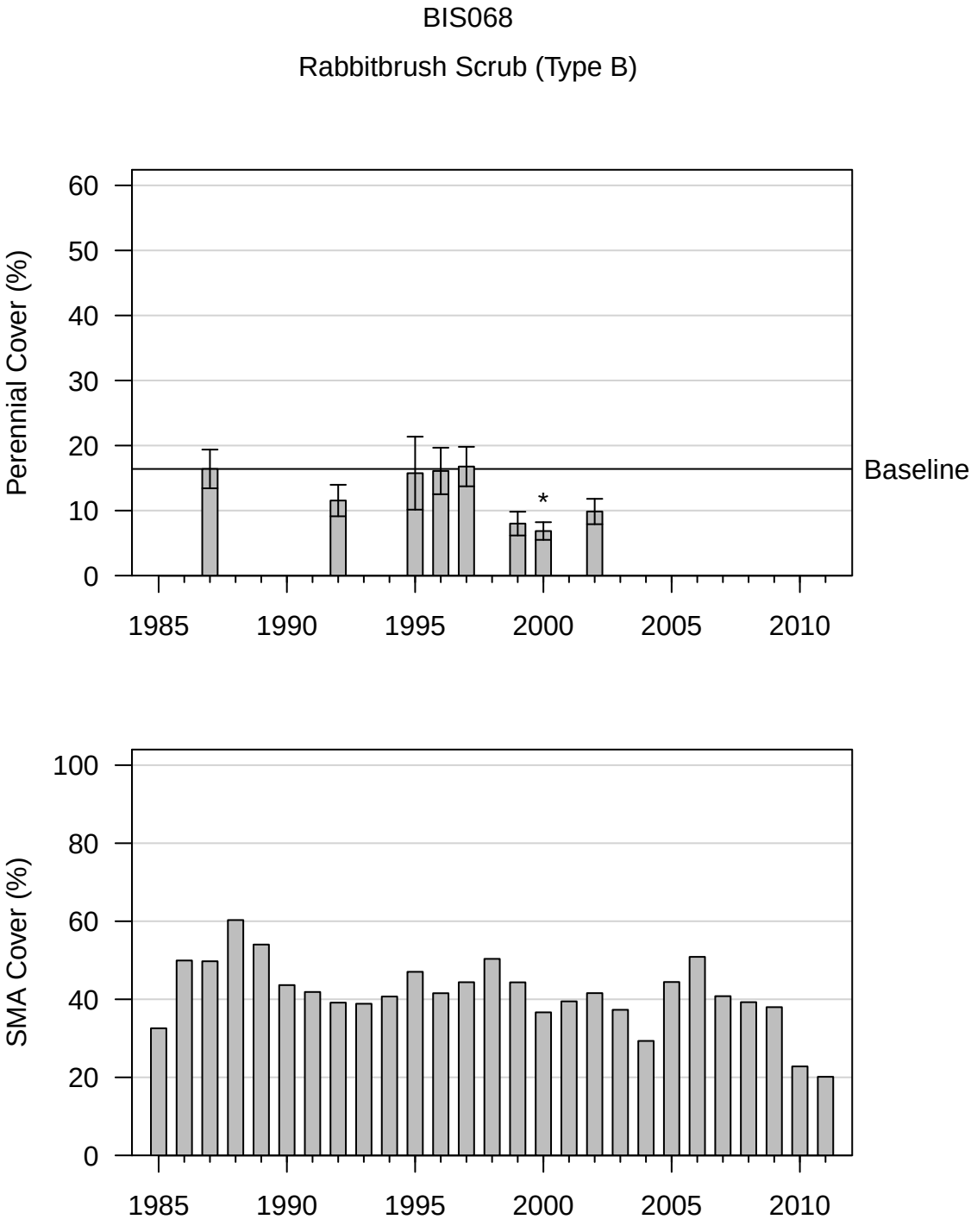


Figure 16: 2002 Control

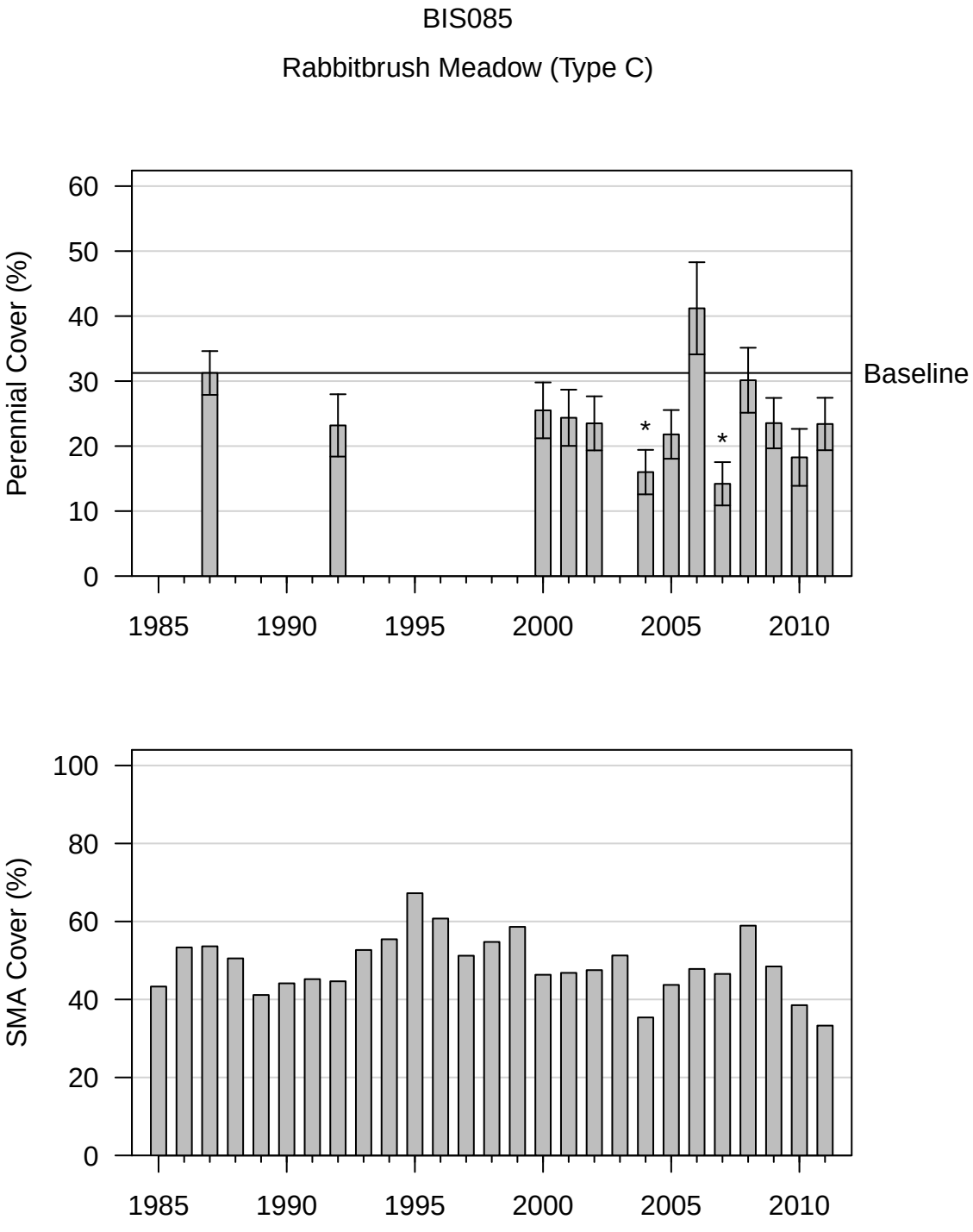


Figure 17: 2011 Wellfield

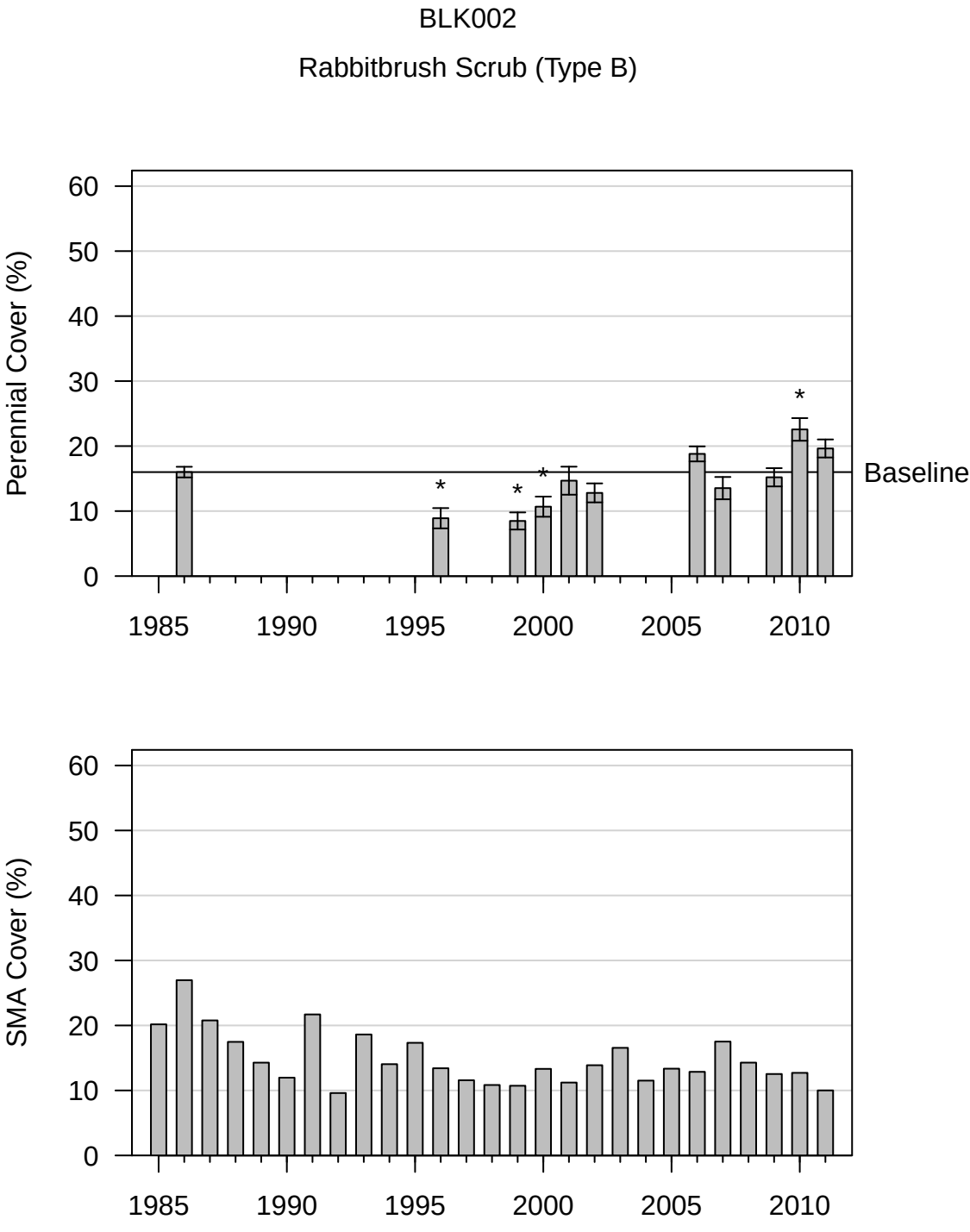


Figure 18: 2011 Wellfield

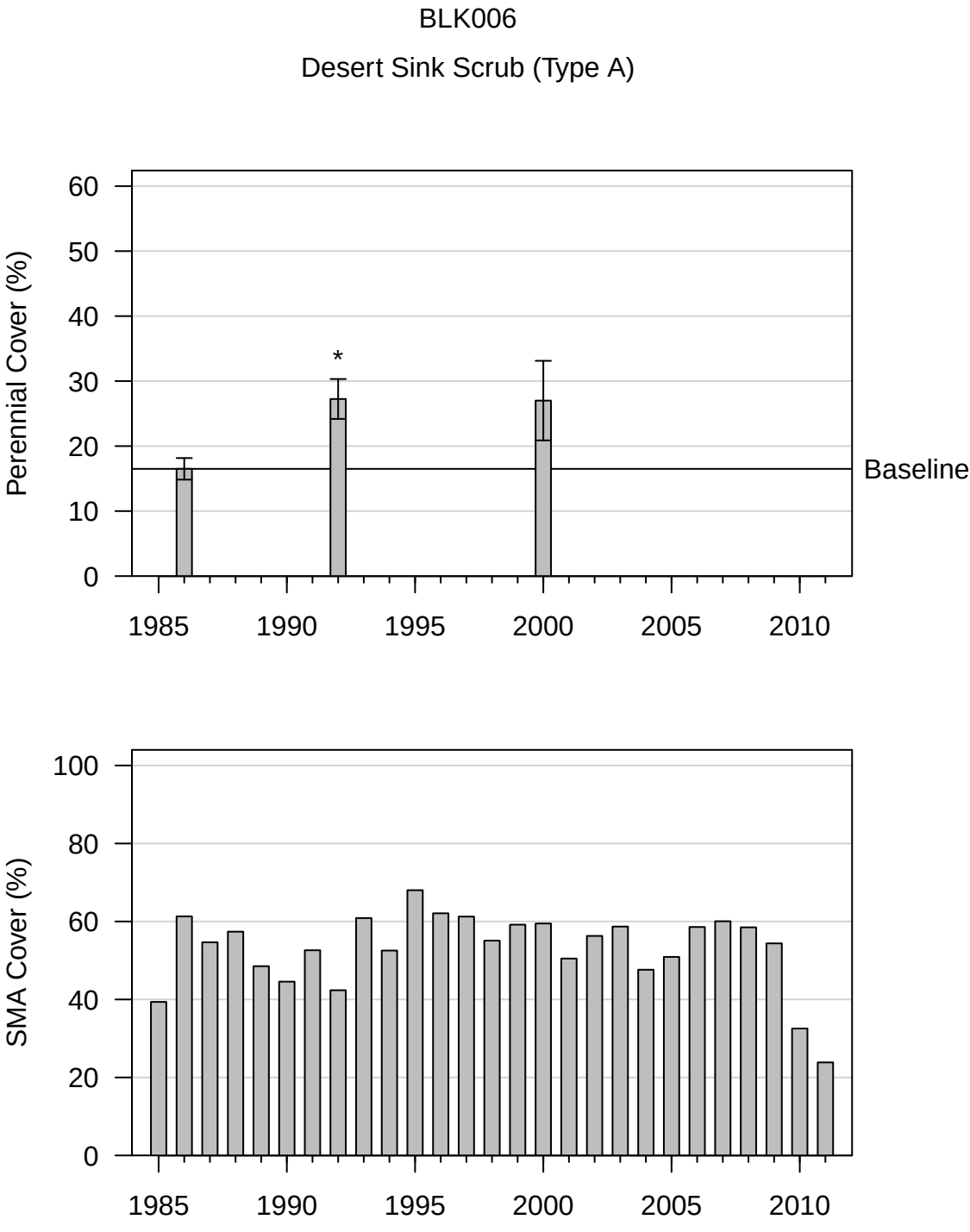


Figure 19: 2000 Wellfield

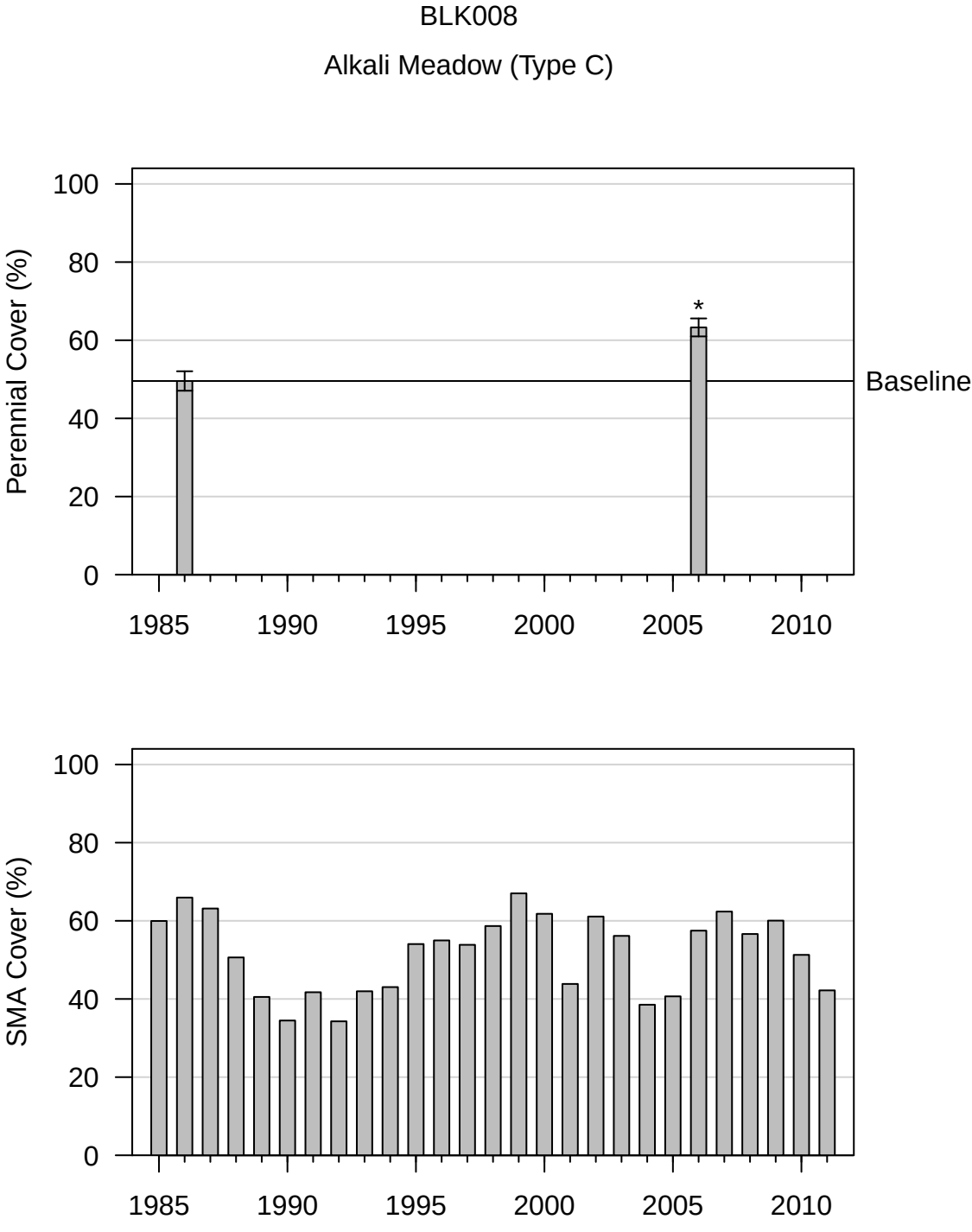


Figure 20: 2006 Wellfield

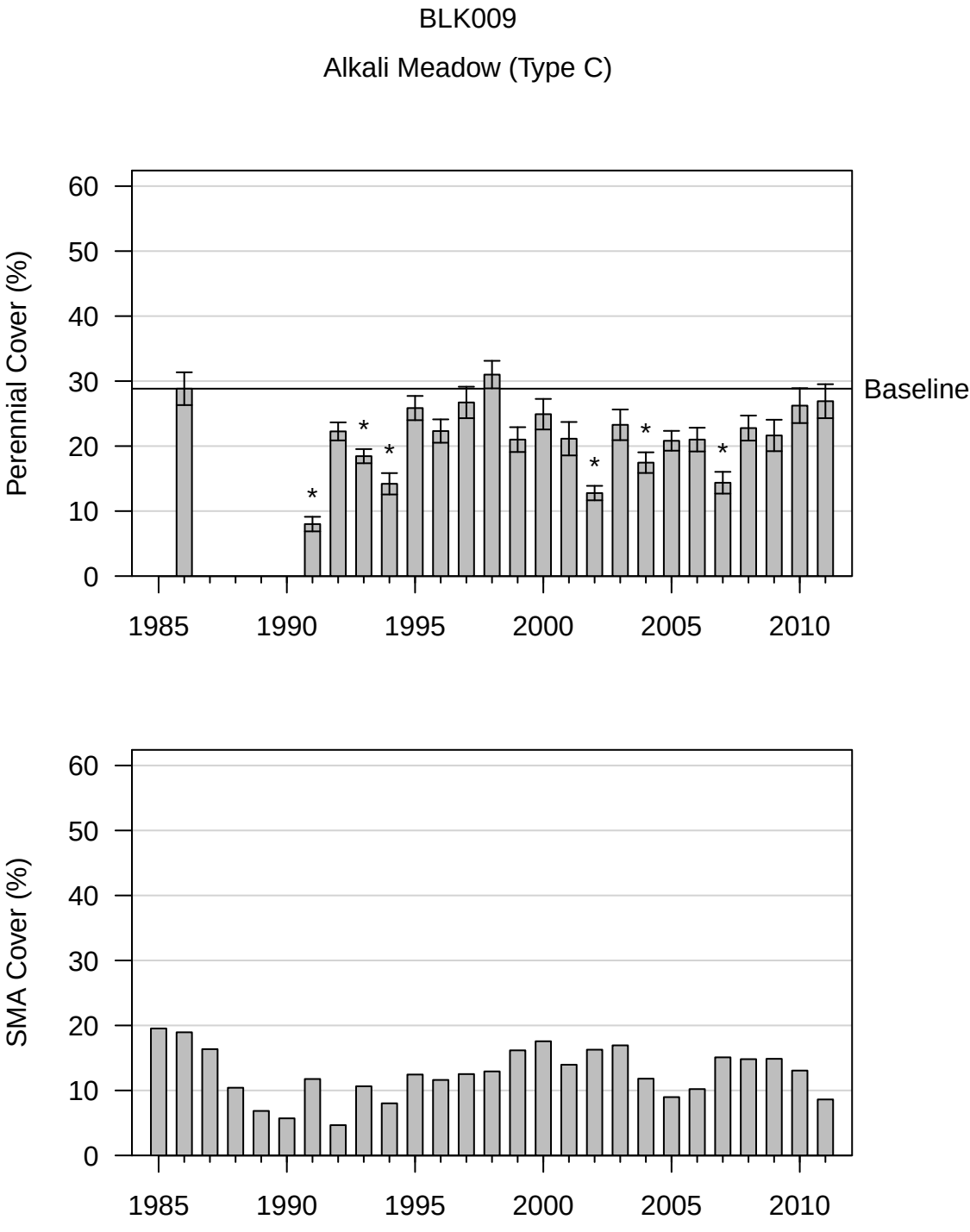


Figure 21: 2011 Wellfield

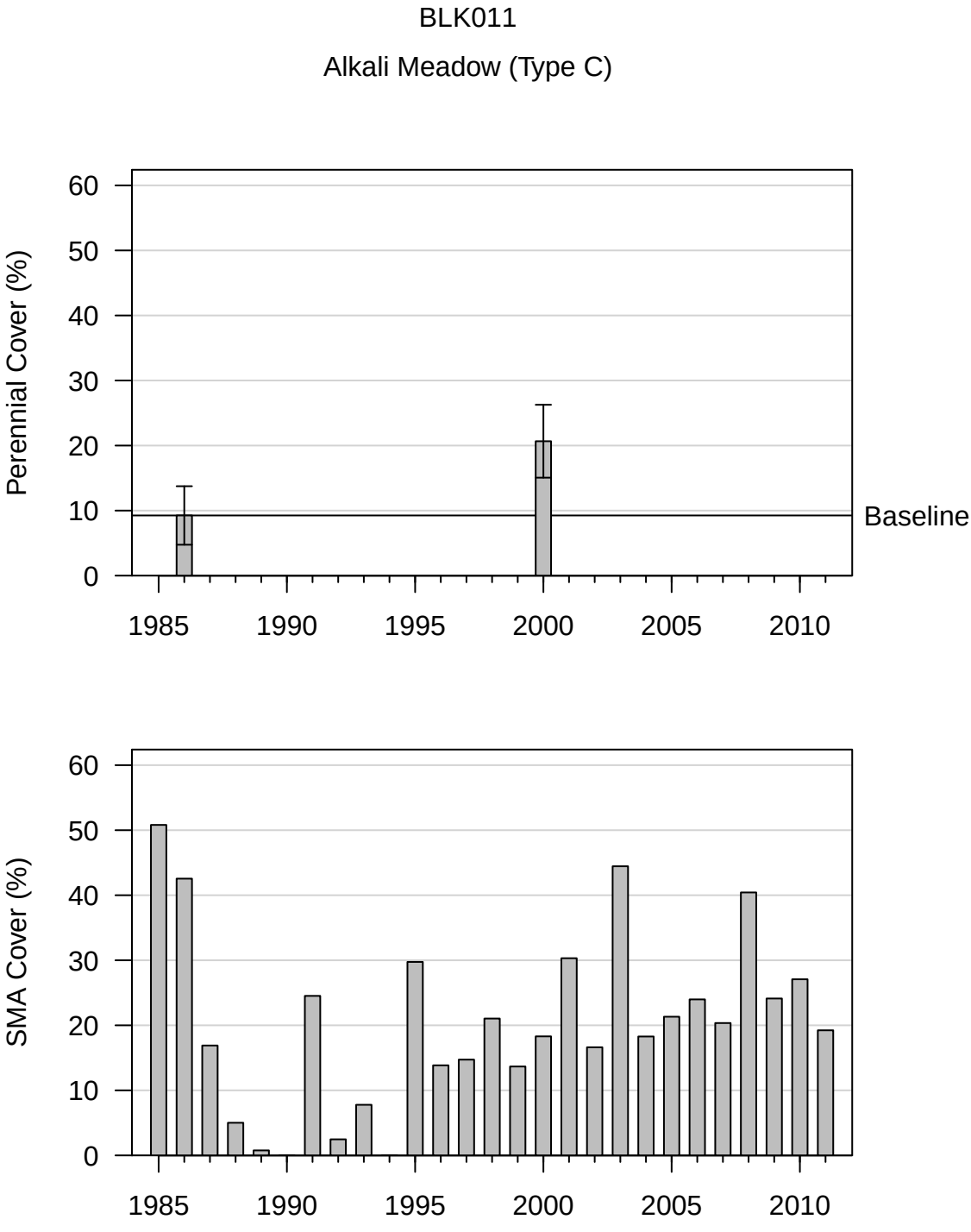


Figure 22: 2000 Wellfield

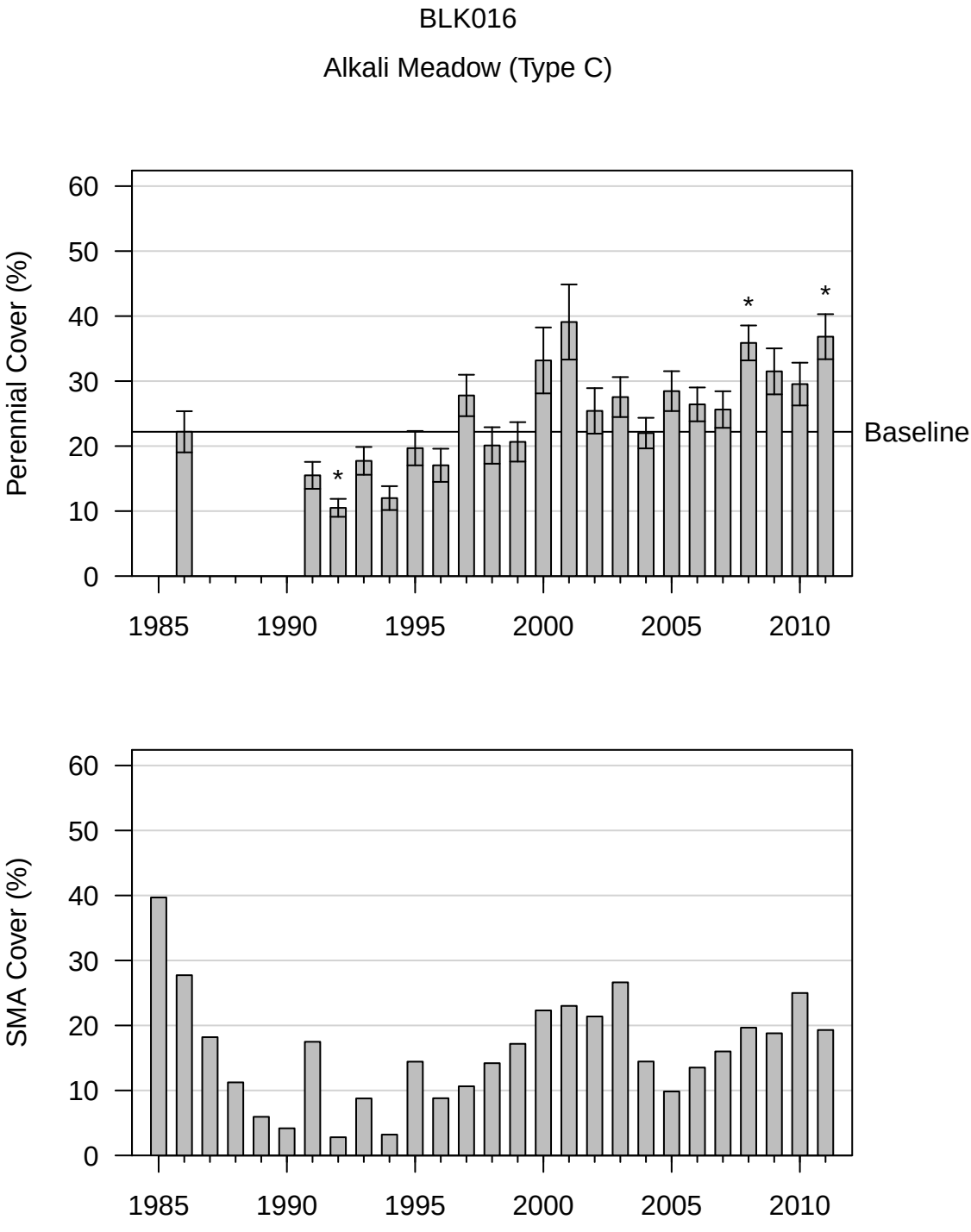


Figure 23: 2011 Wellfield

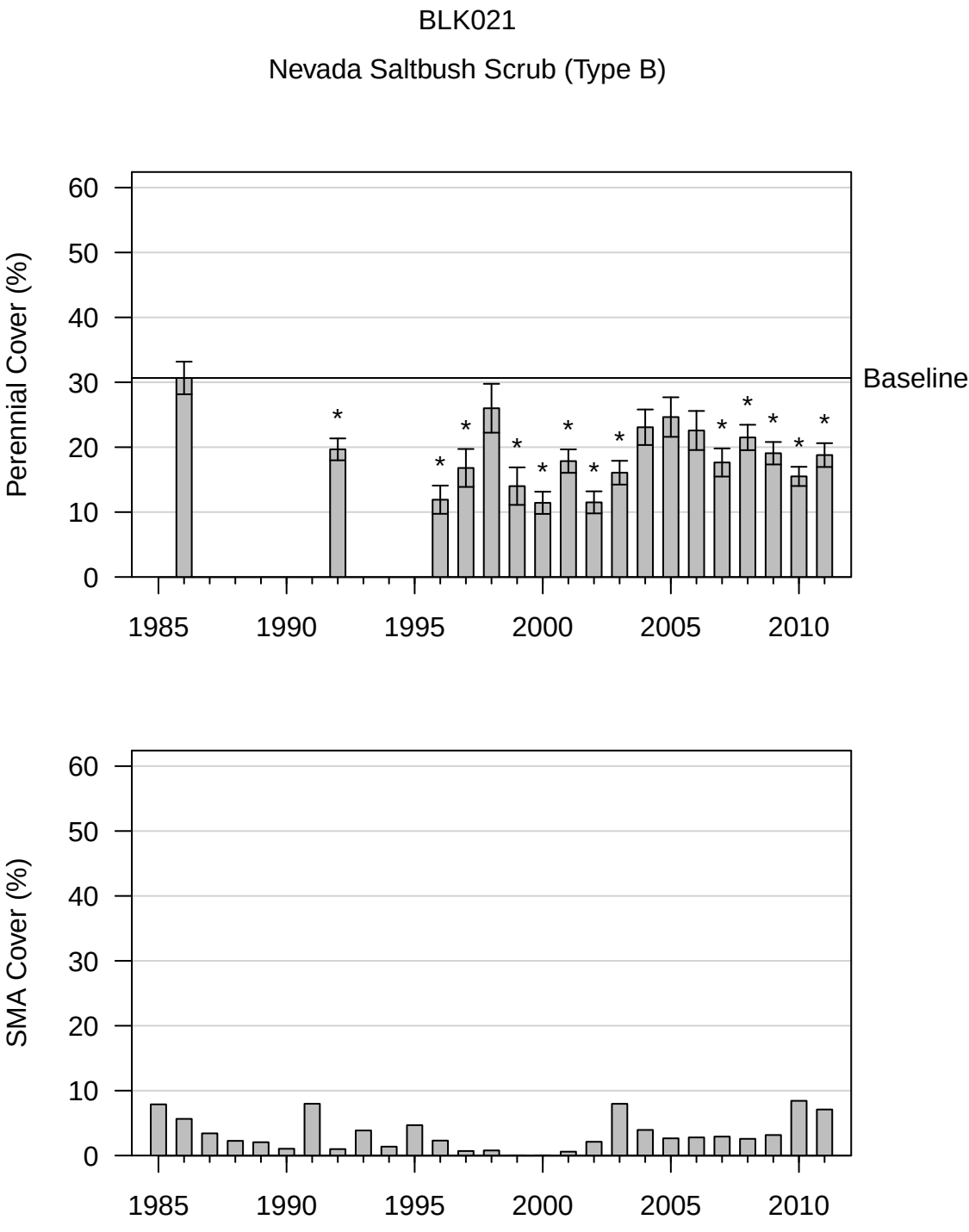


Figure 24: 2011 Wellfield

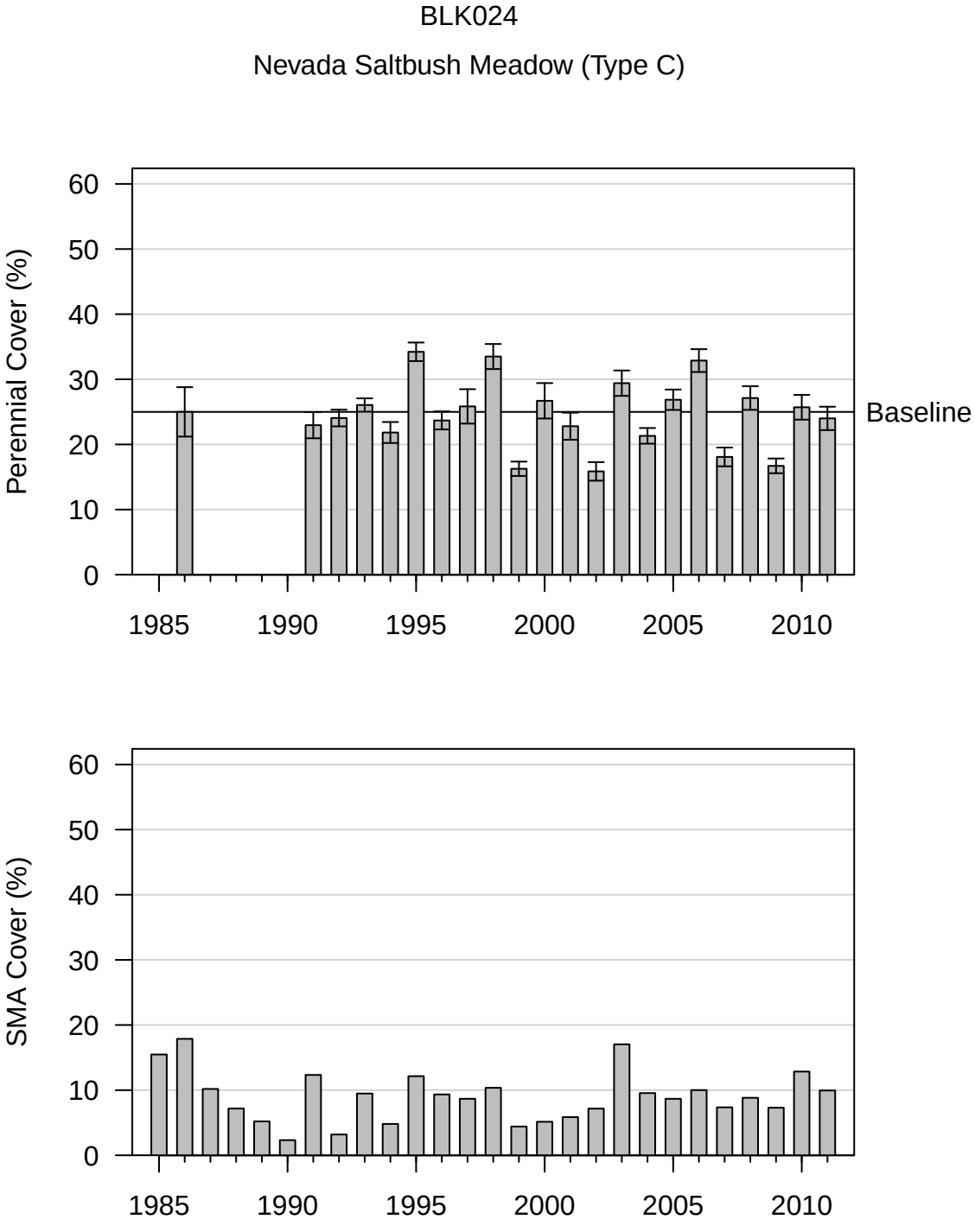


Figure 25: 2011 Wellfield

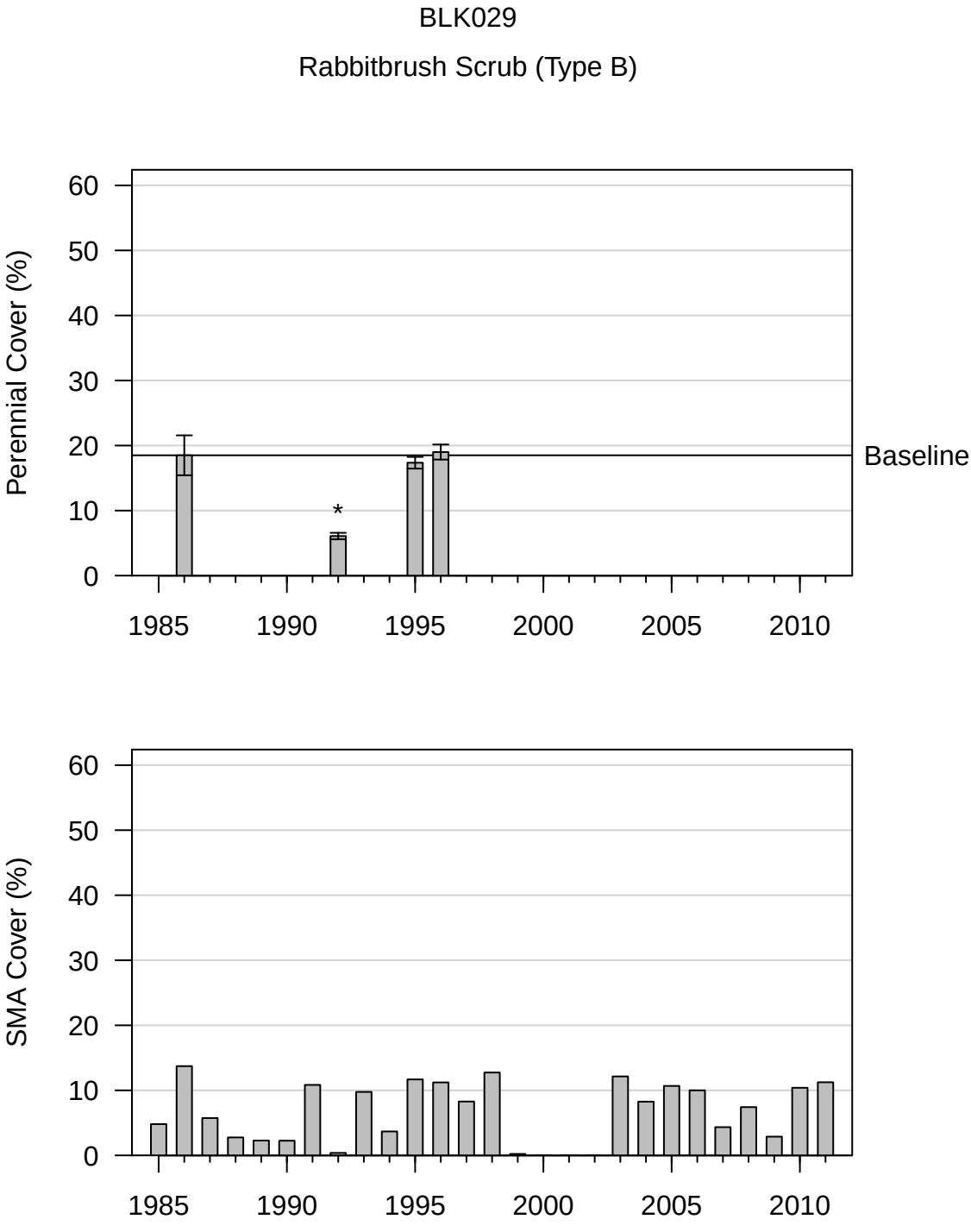


Figure 26: 1996 Control

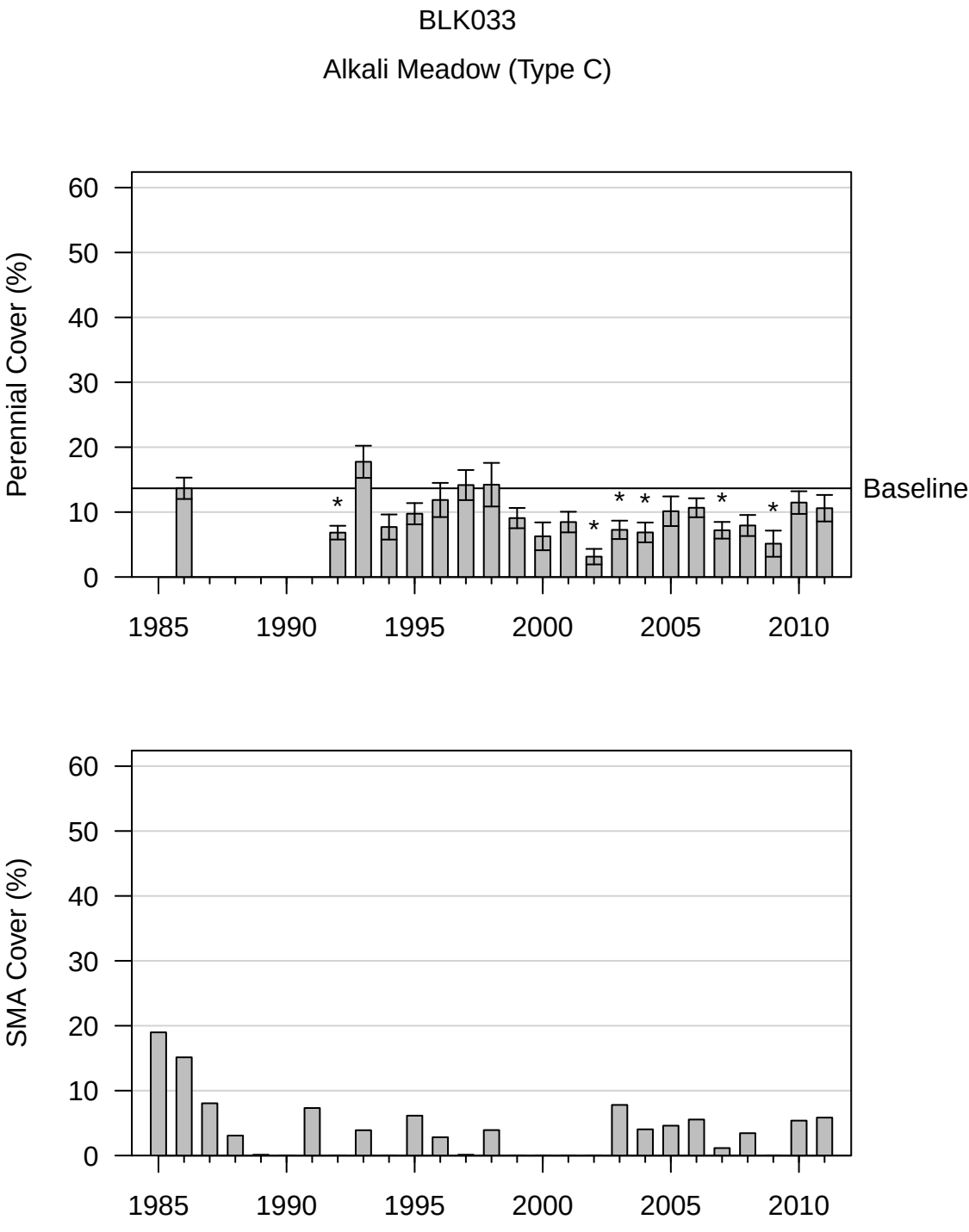


Figure 27: 2011 Wellfield

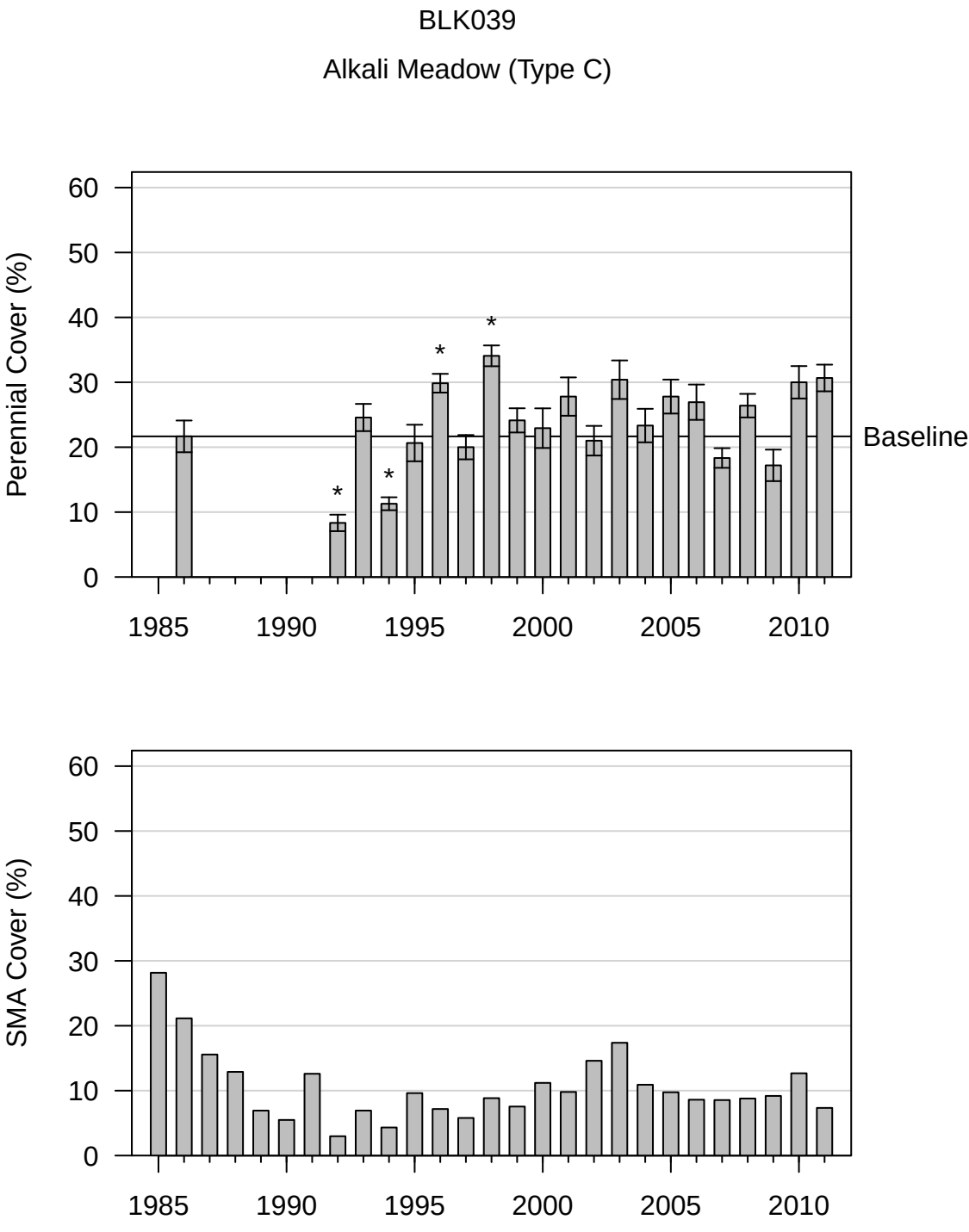


Figure 28: 2011 Wellfield

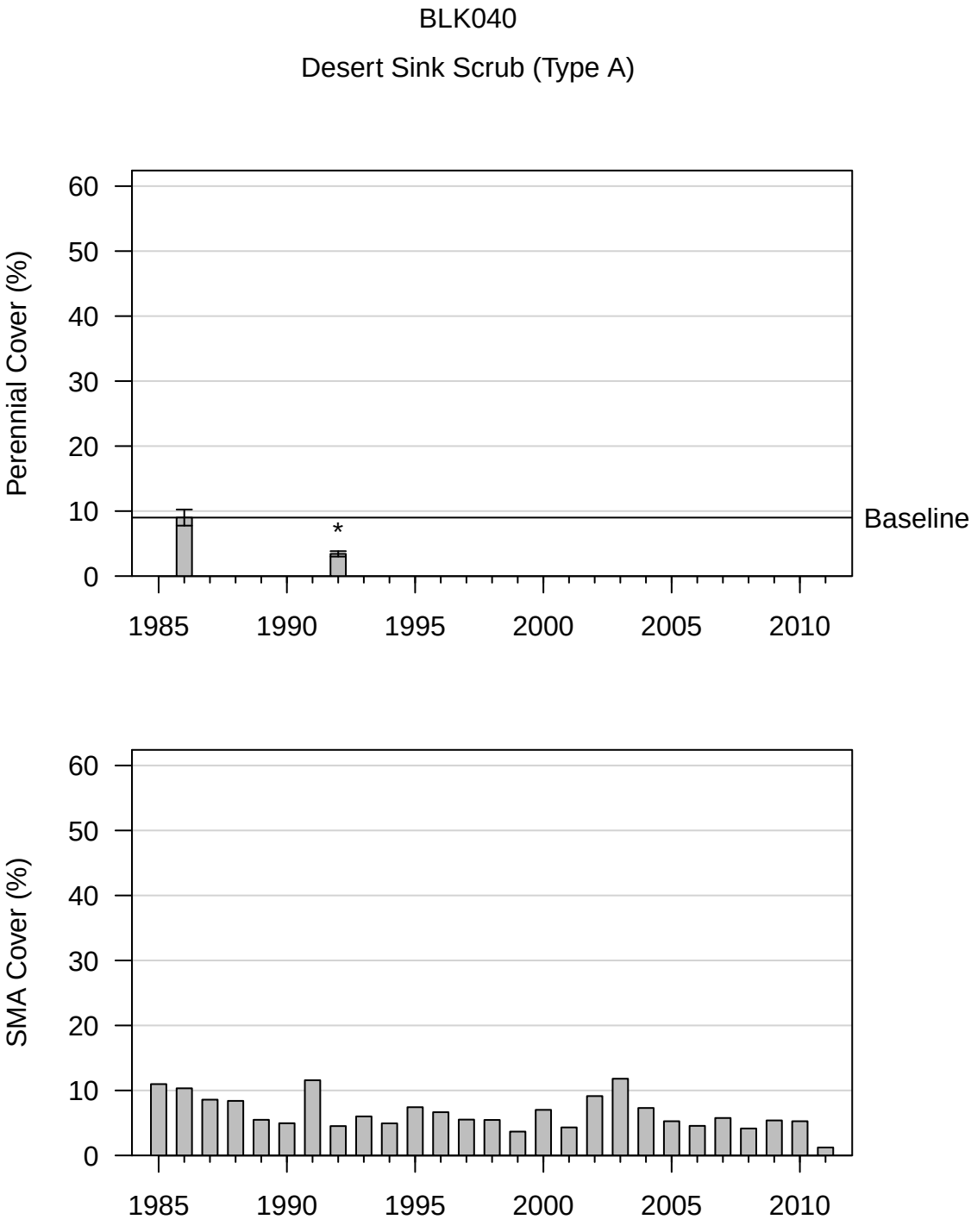


Figure 29: 1992 Wellfield

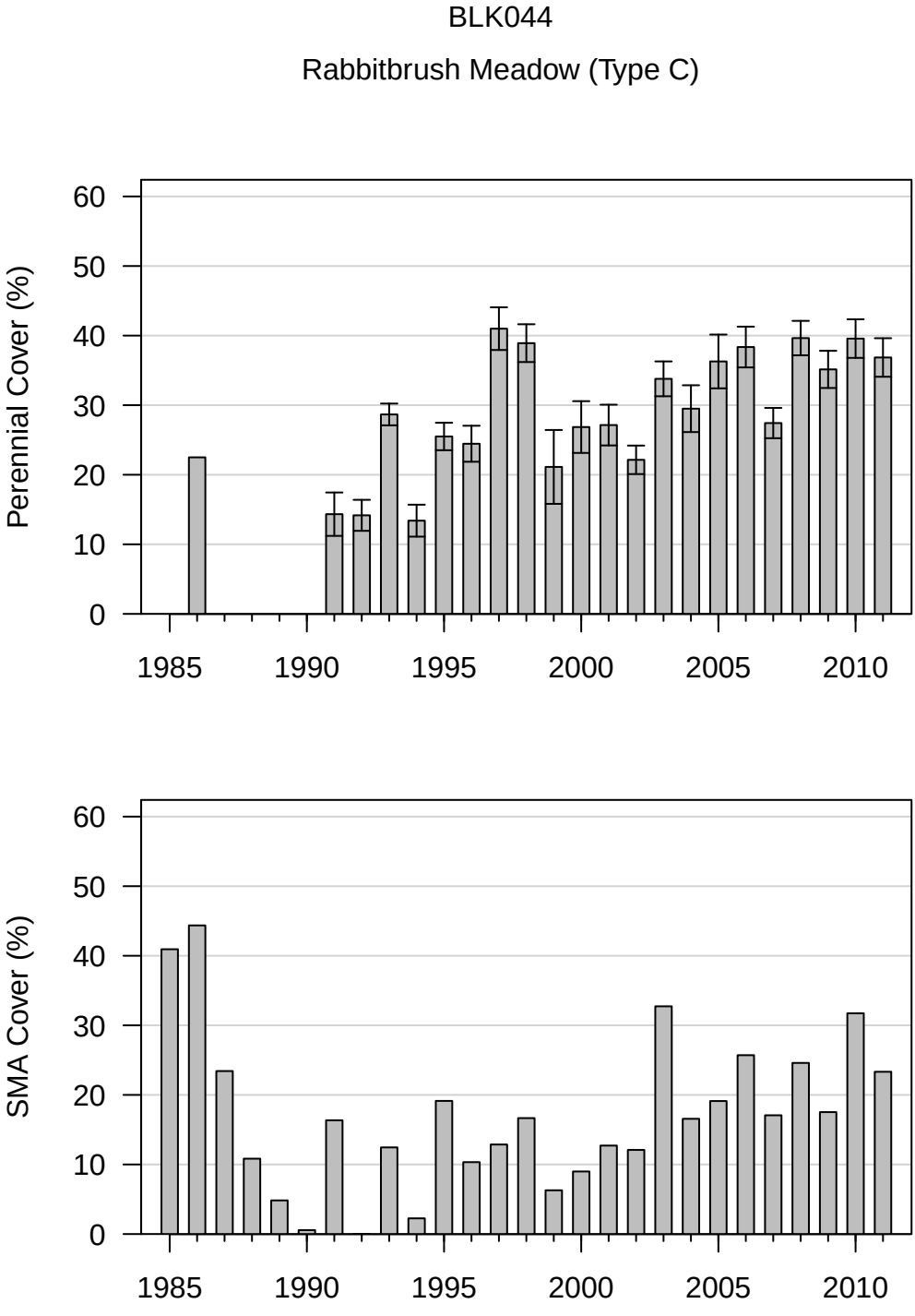


Figure 30: 2011 Wellfield

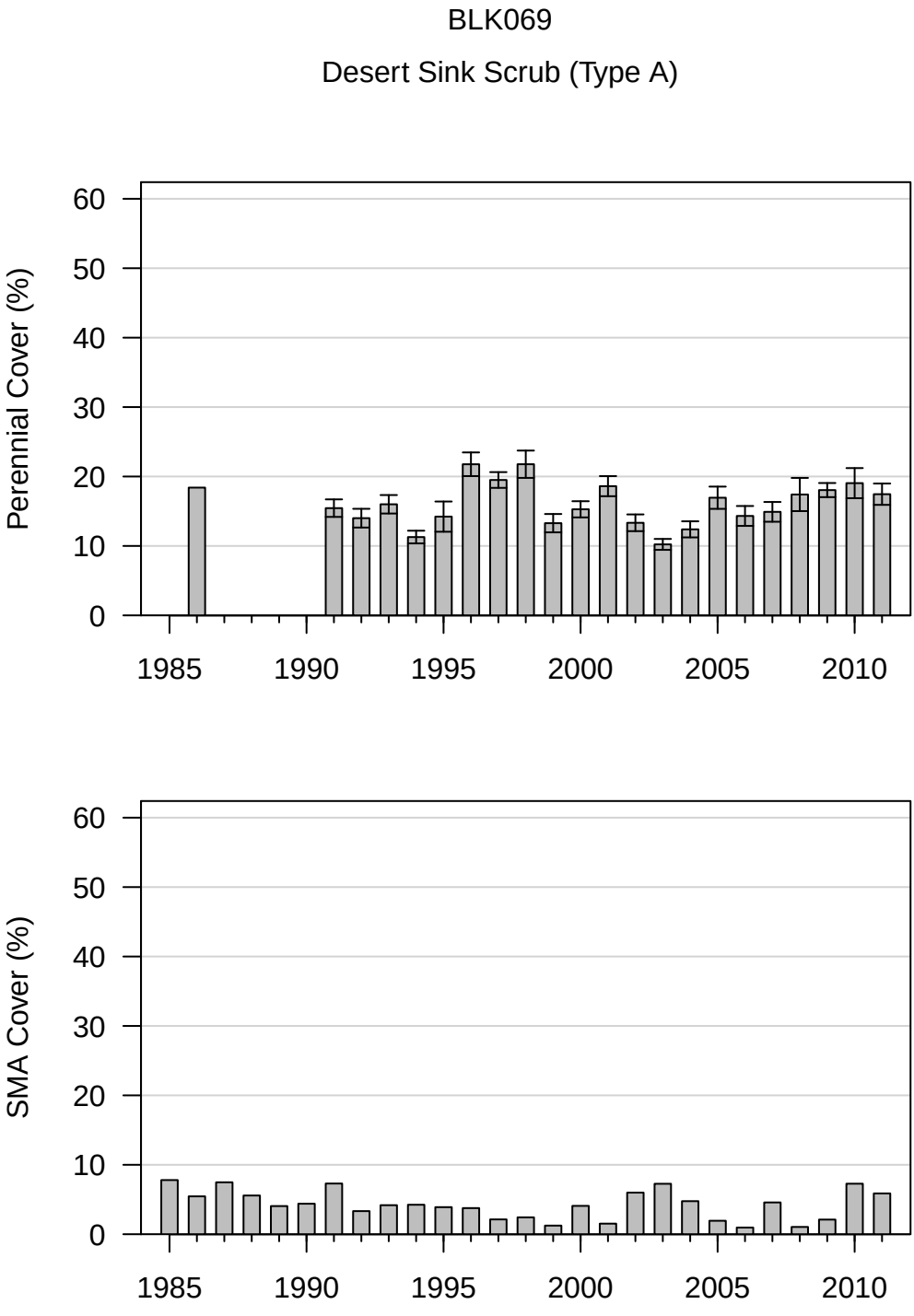


Figure 31: 2011 Wellfield

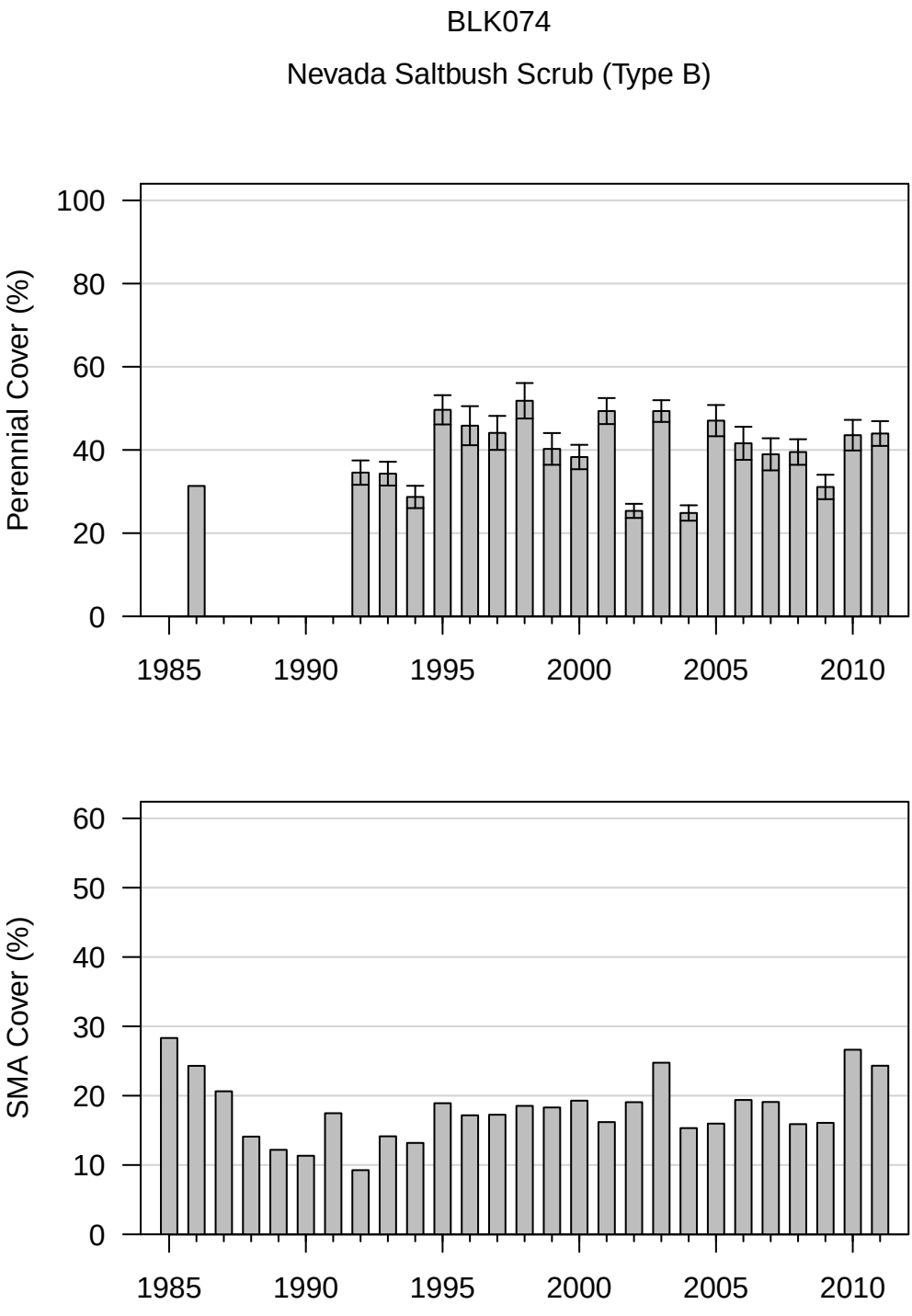


Figure 32: 2011 Wellfield

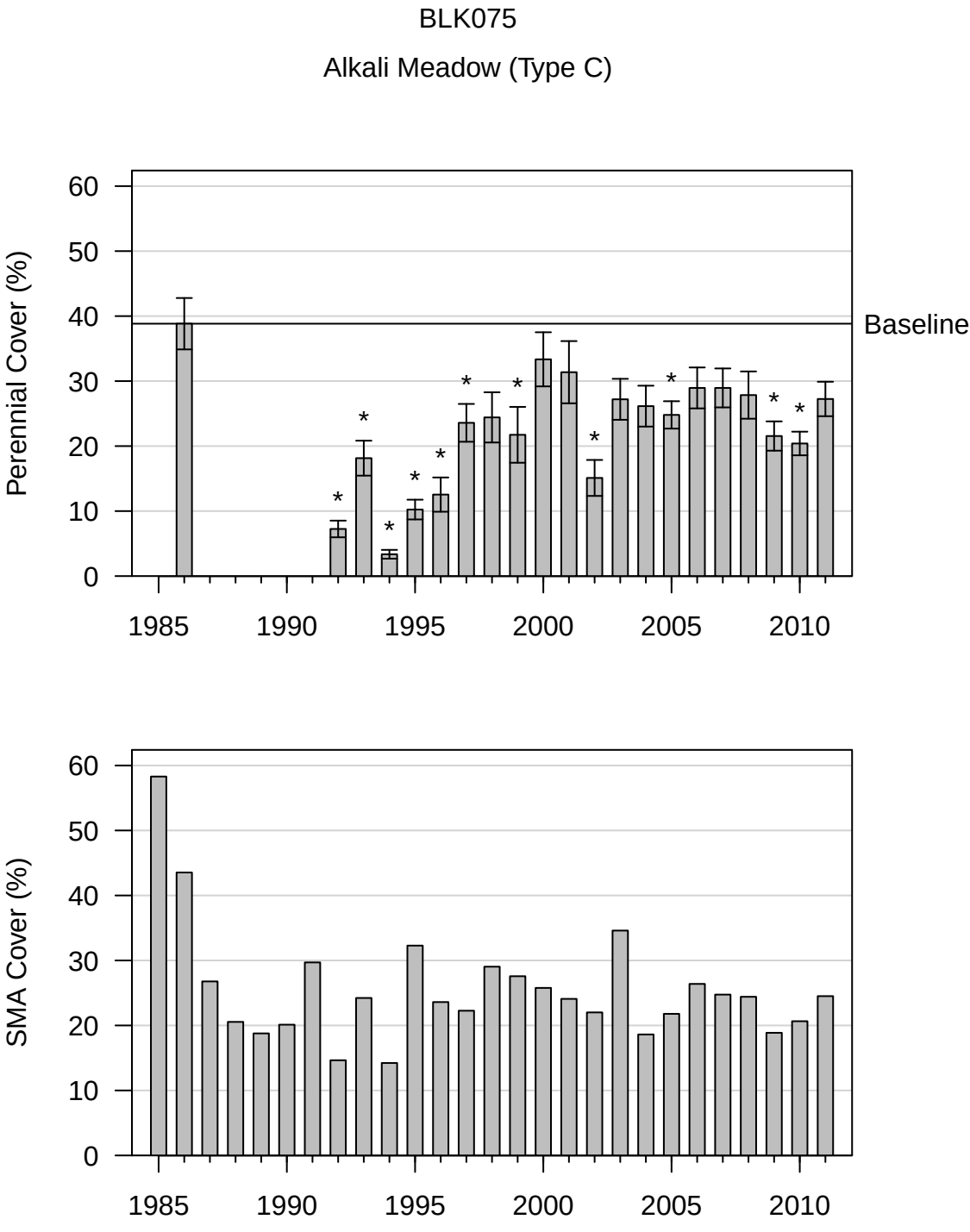


Figure 33: 2011 Wellfield

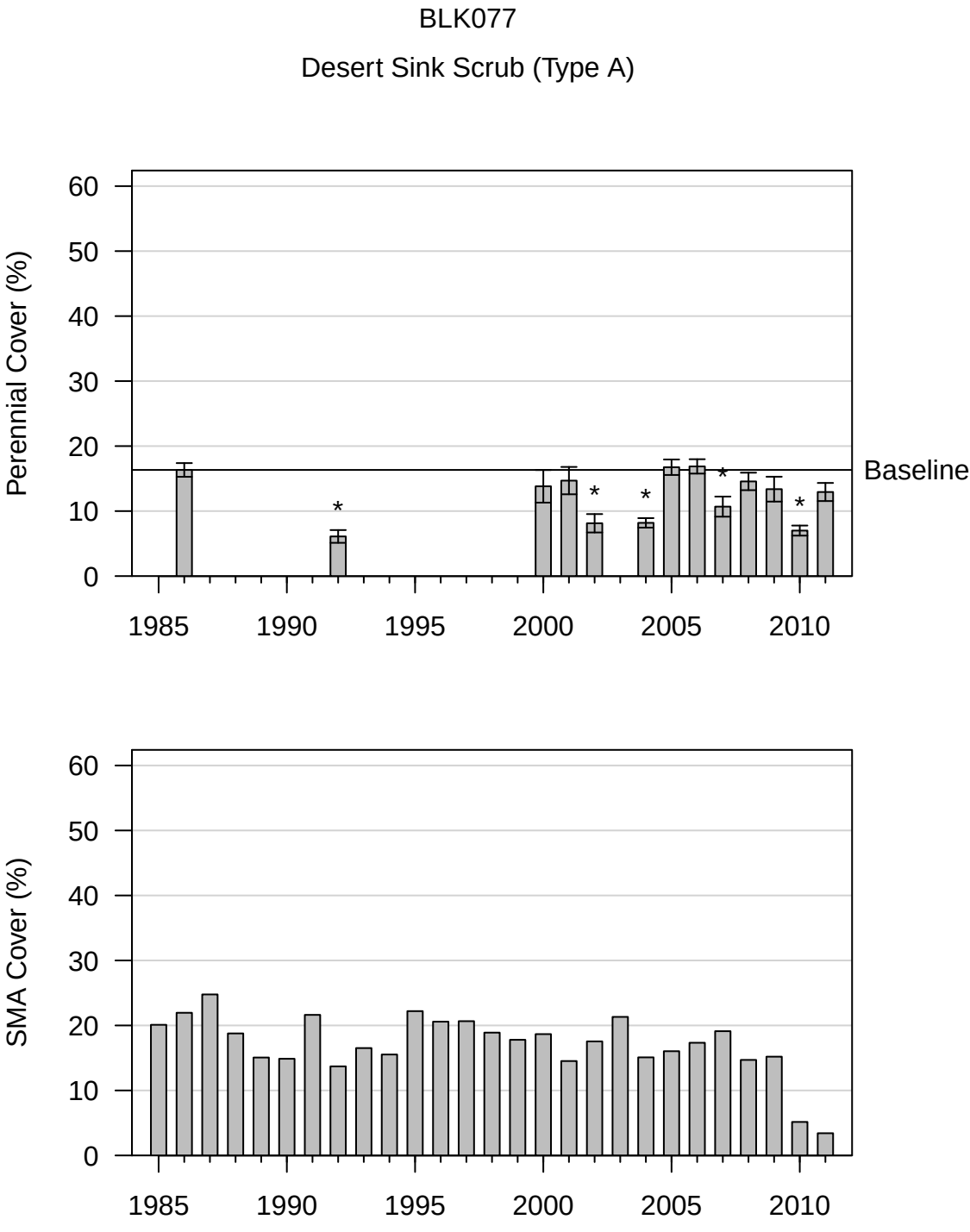


Figure 34: 2011 Wellfield

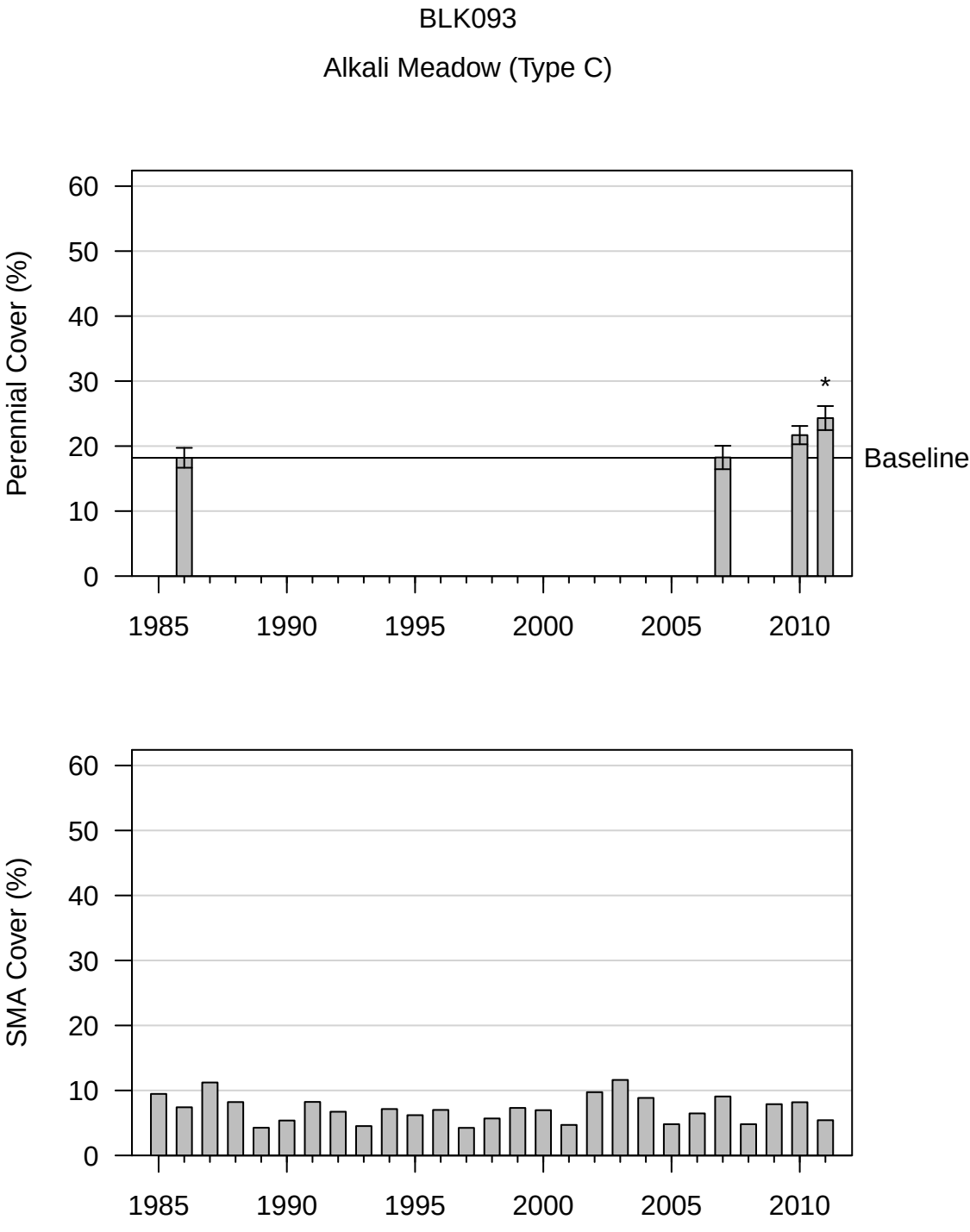


Figure 35: 2011 Wellfield

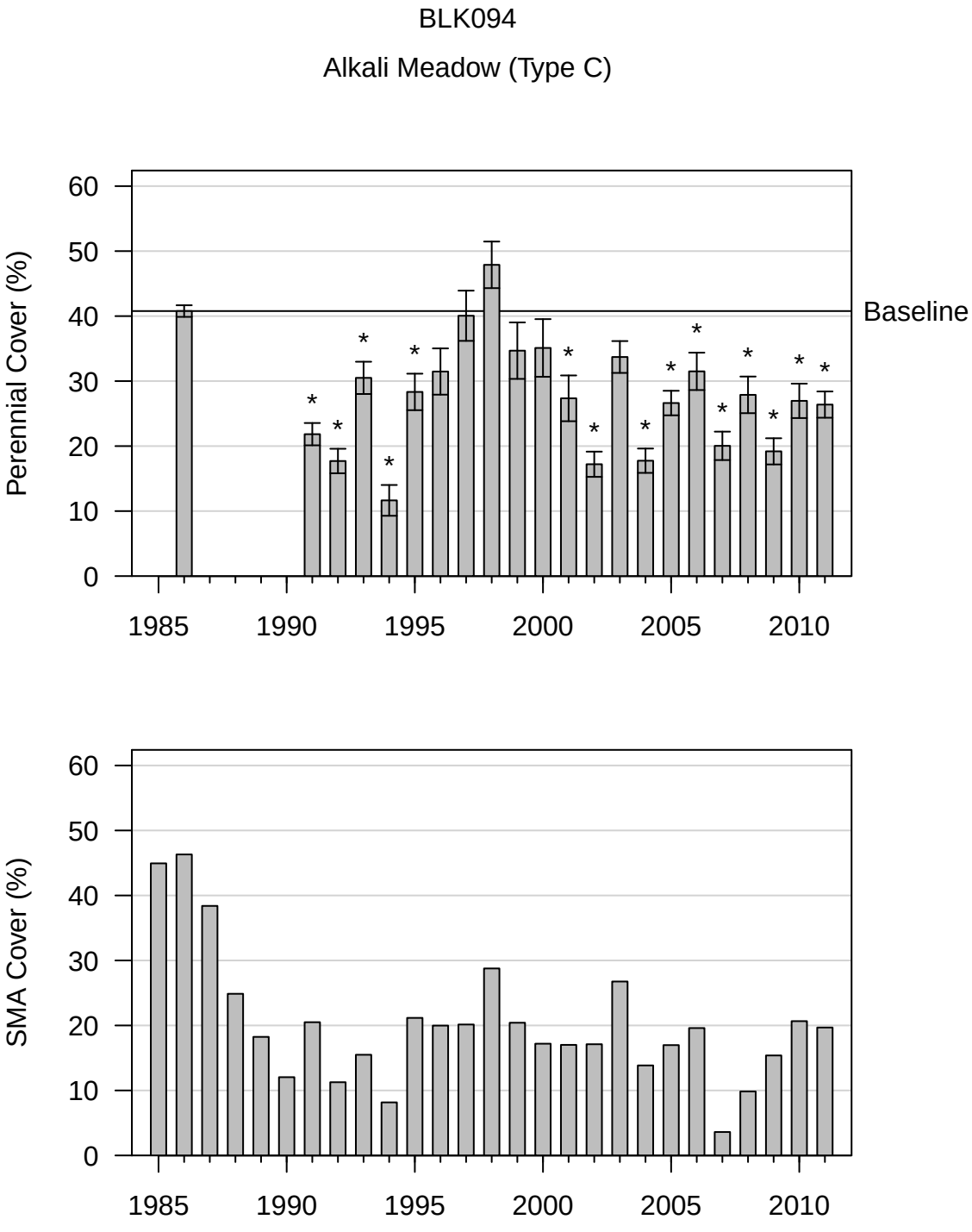


Figure 36: 2011 Wellfield

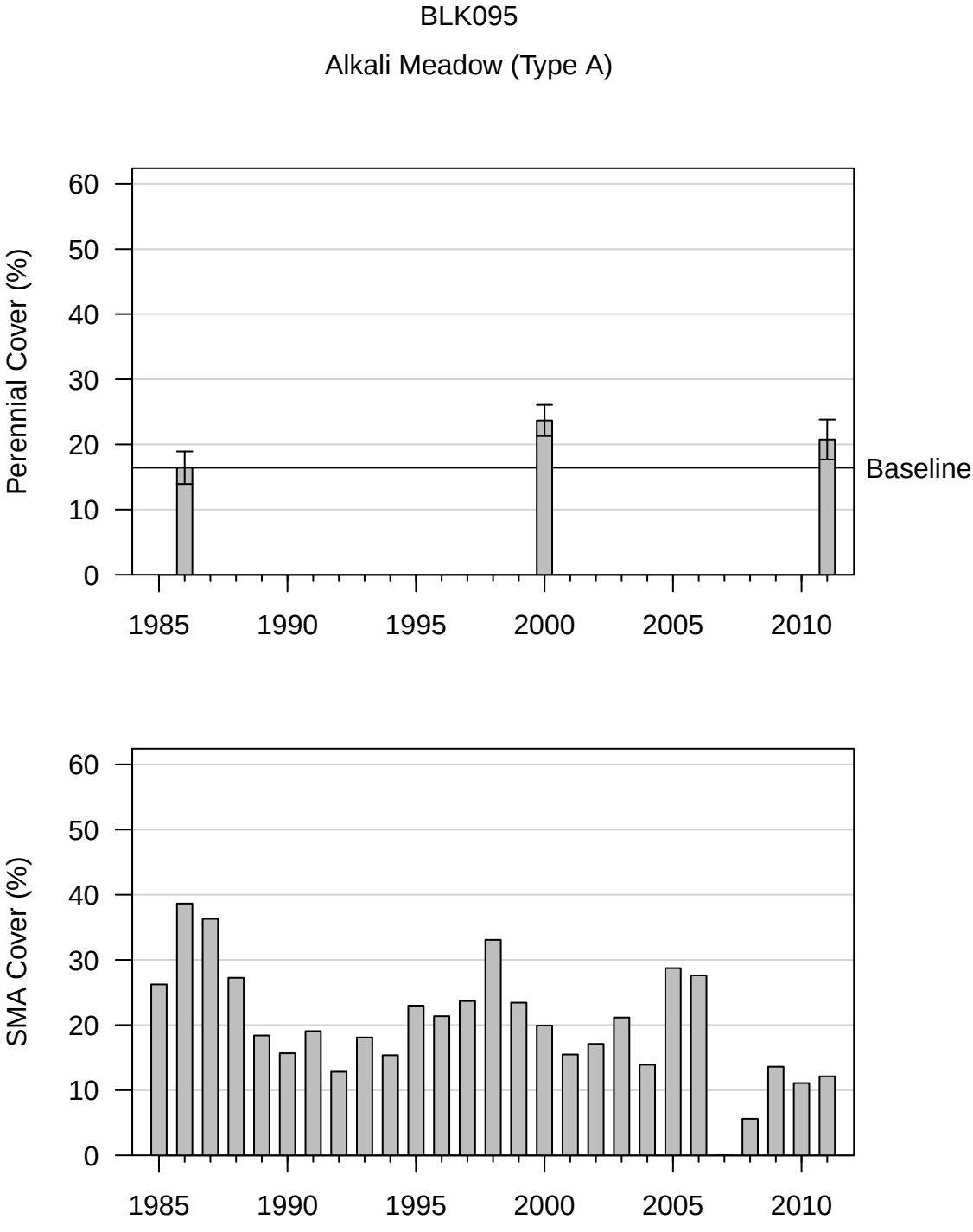


Figure 37: 2011 Wellfield

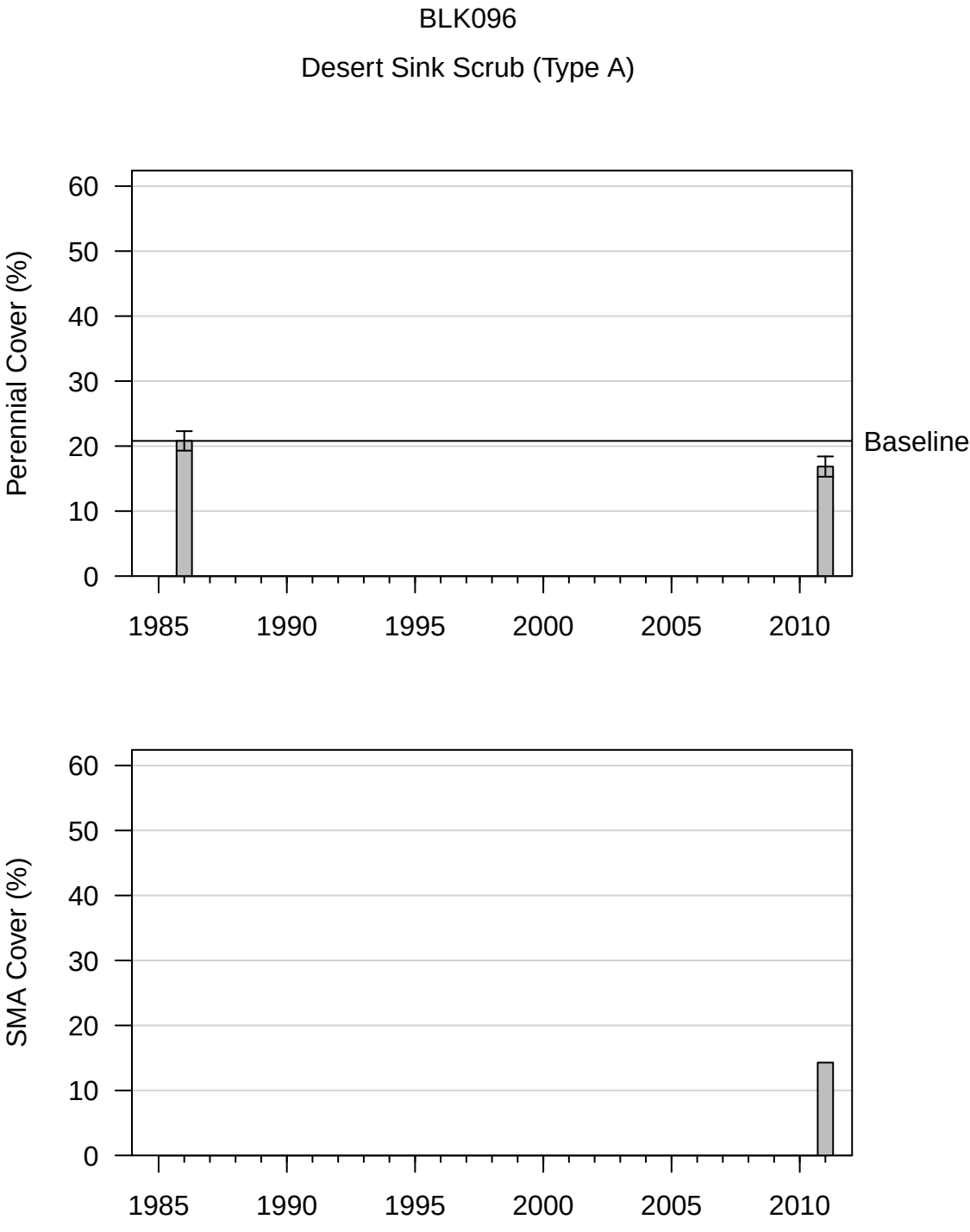


Figure 38: 2011 Wellfield

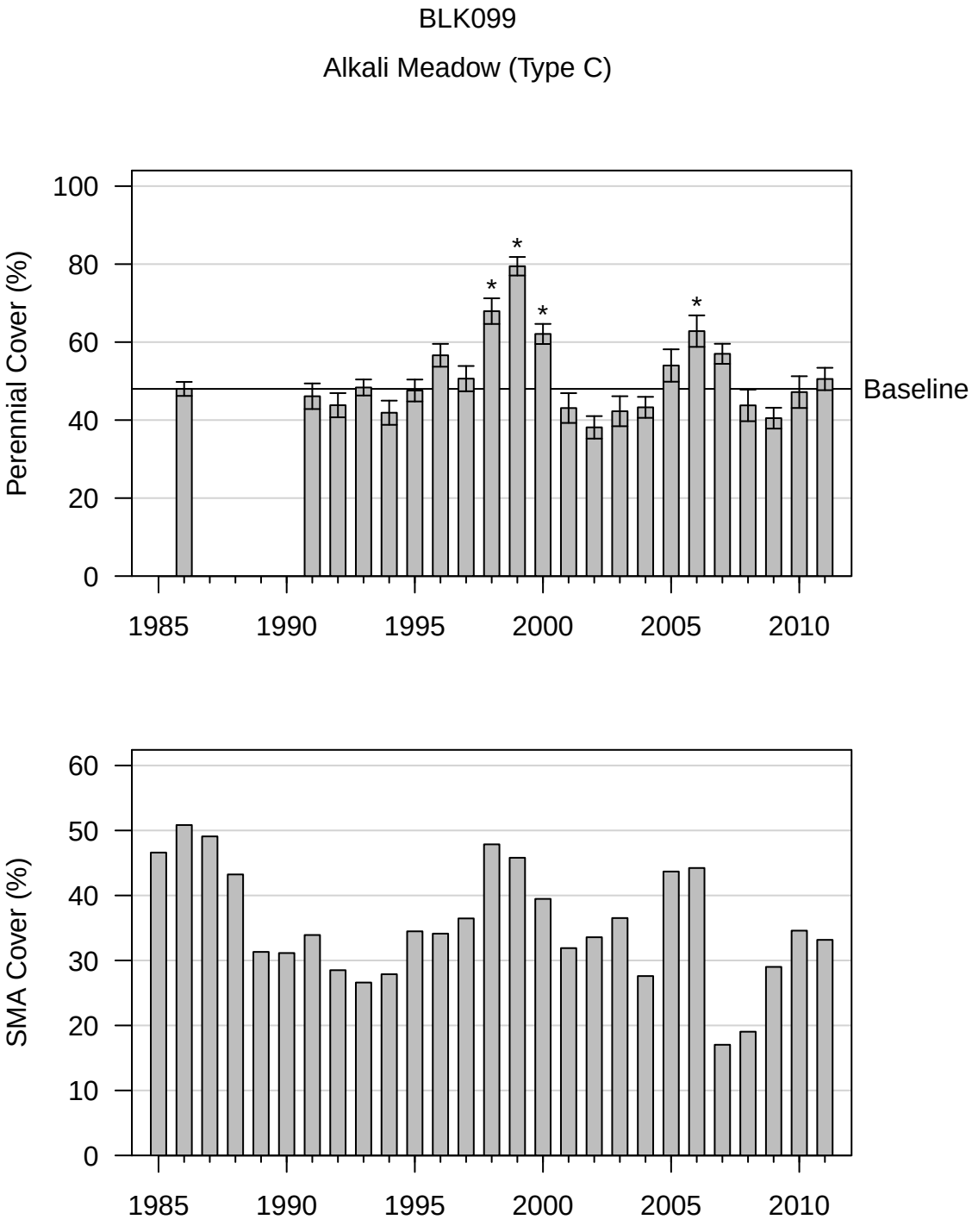


Figure 39: 2011 Wellfield

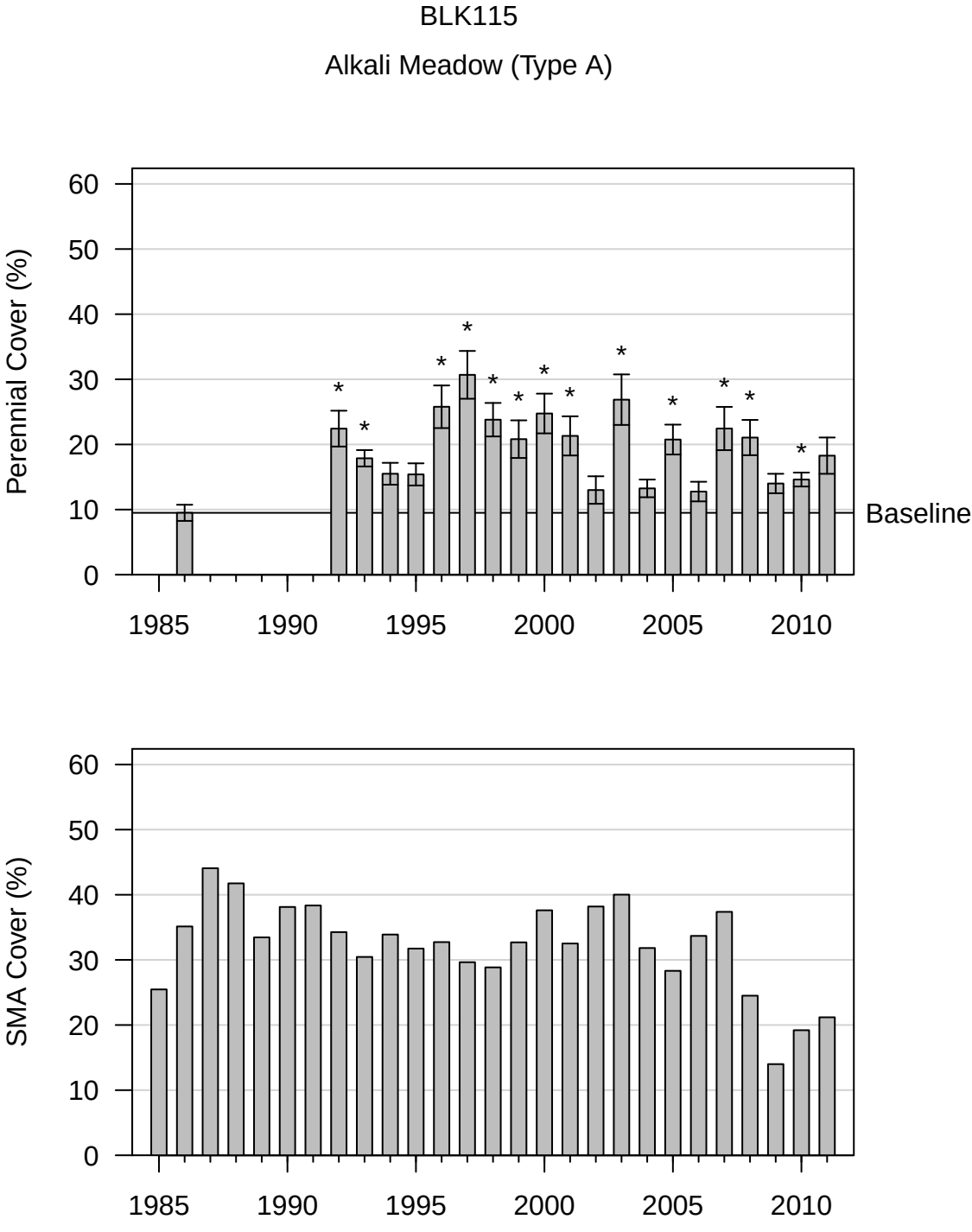


Figure 40: 2011 Control

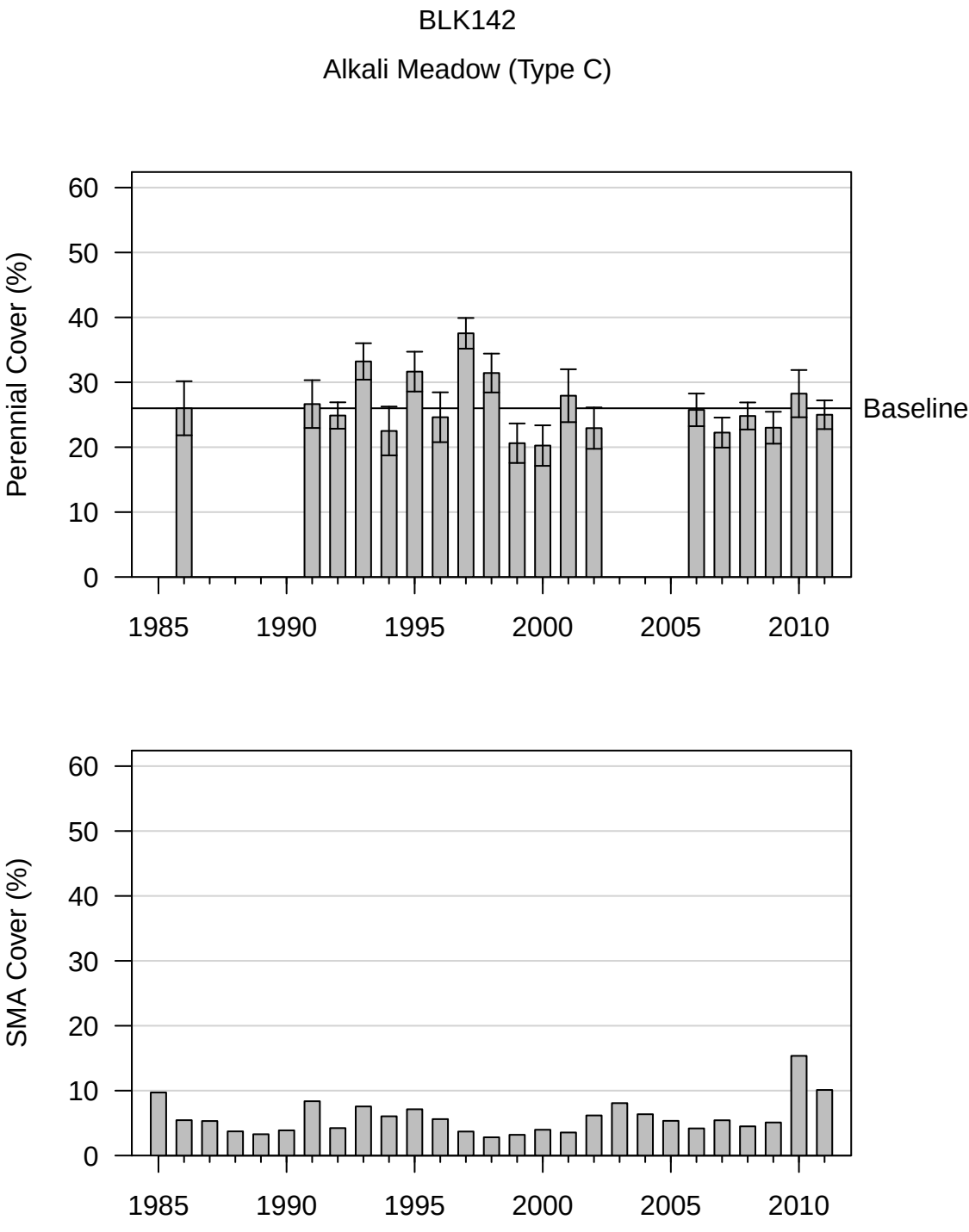


Figure 41: 2011 Wellfield

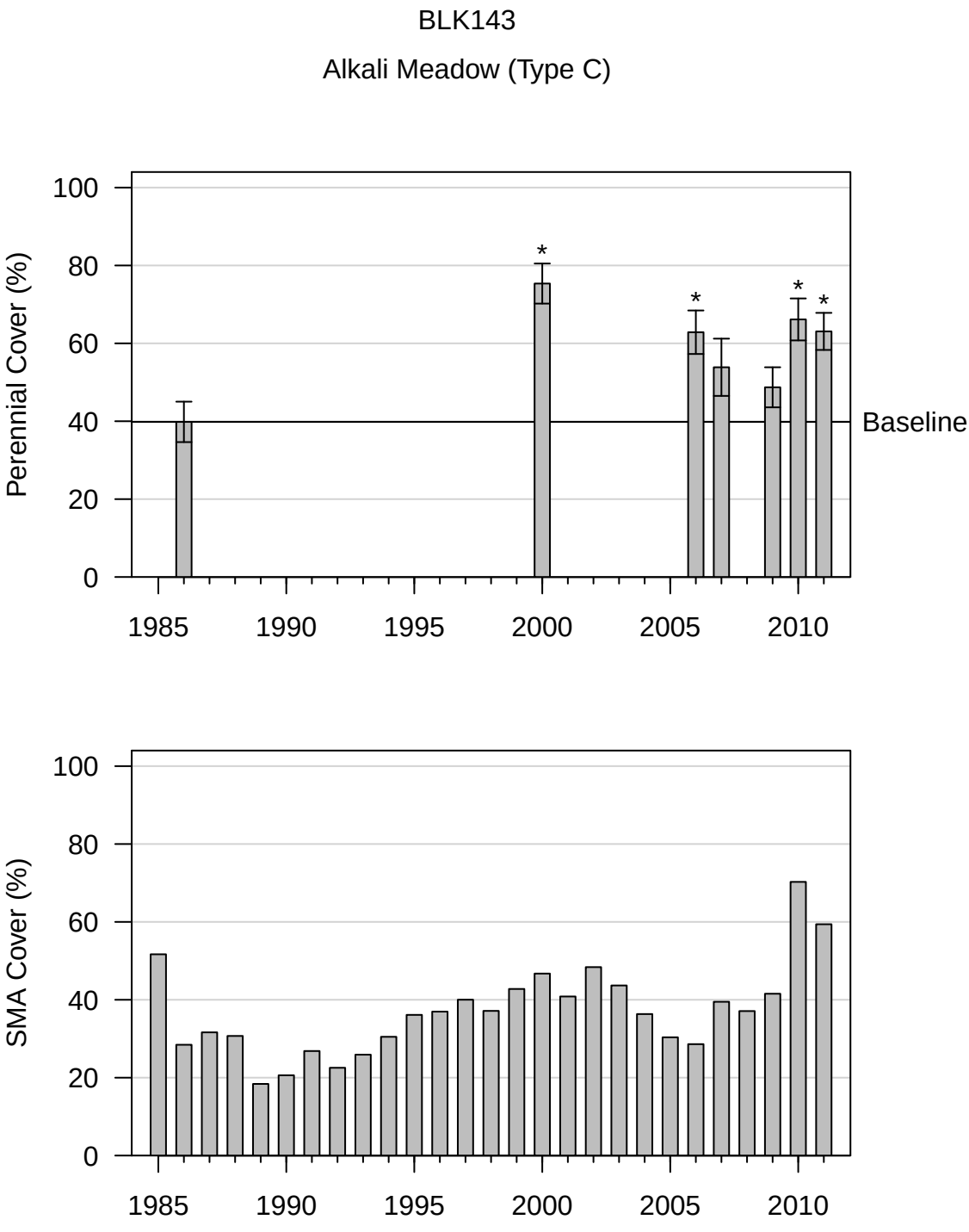


Figure 42: 2011 Wellfield

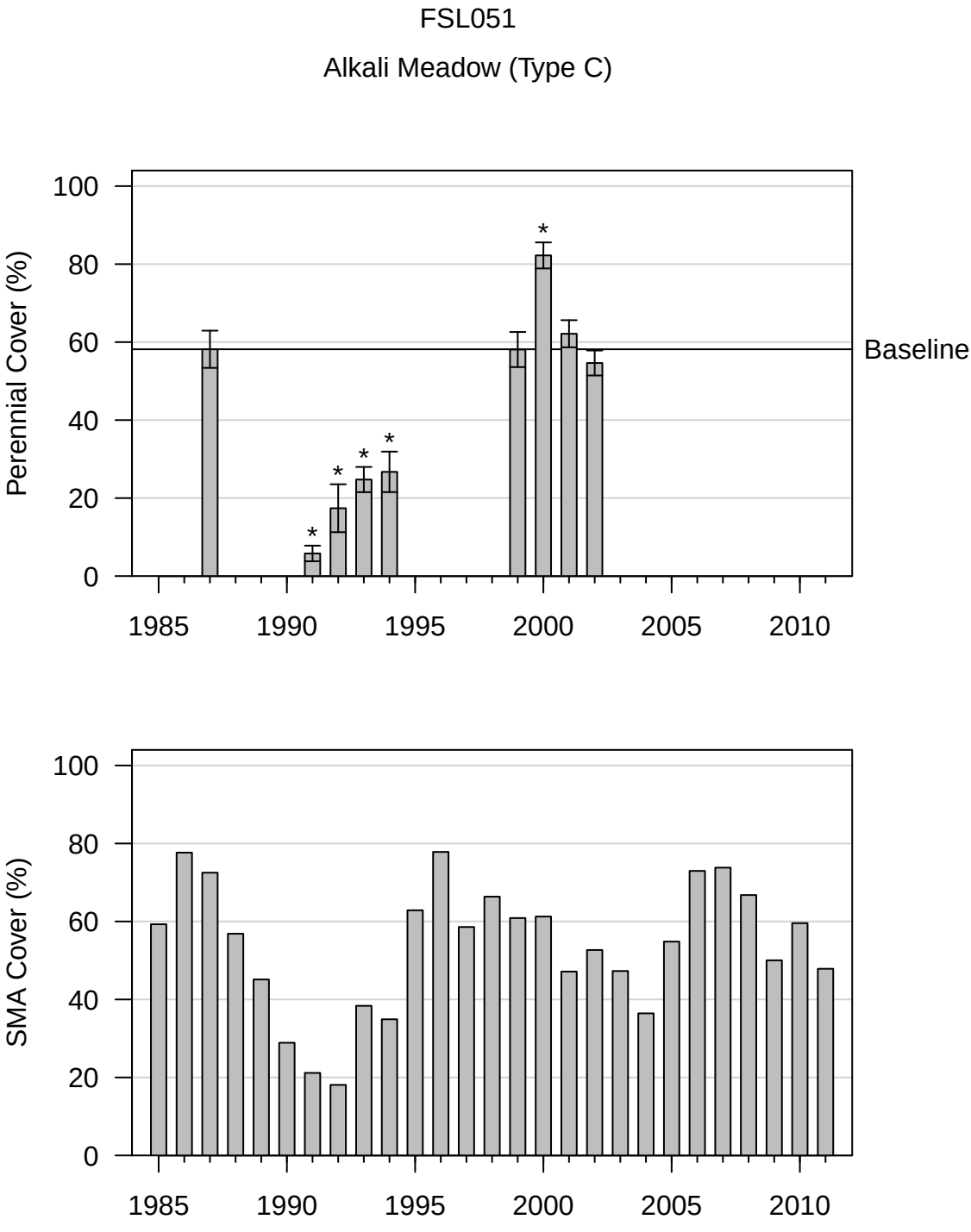


Figure 43: 2002 Wellfield

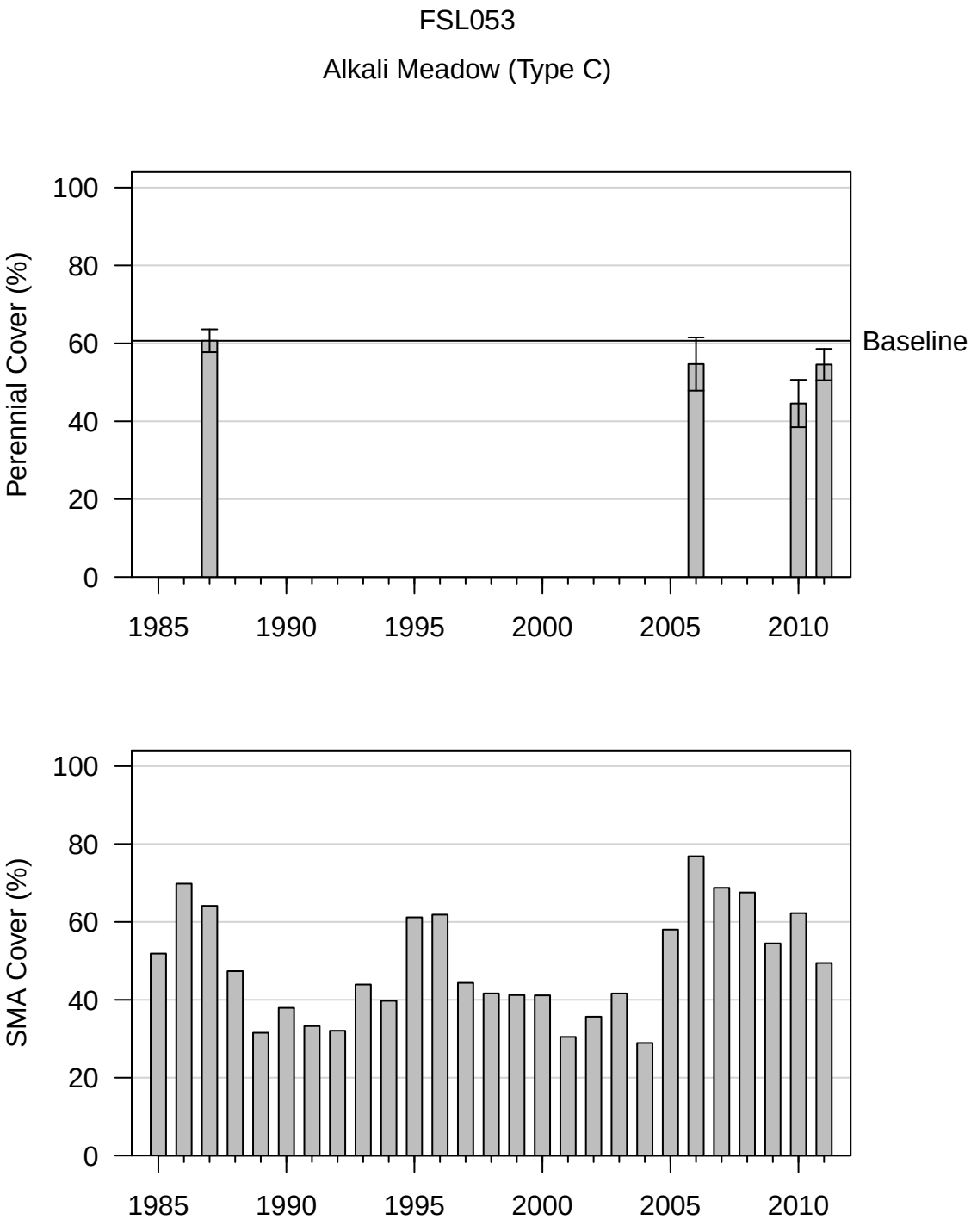


Figure 44: 2011 Wellfield

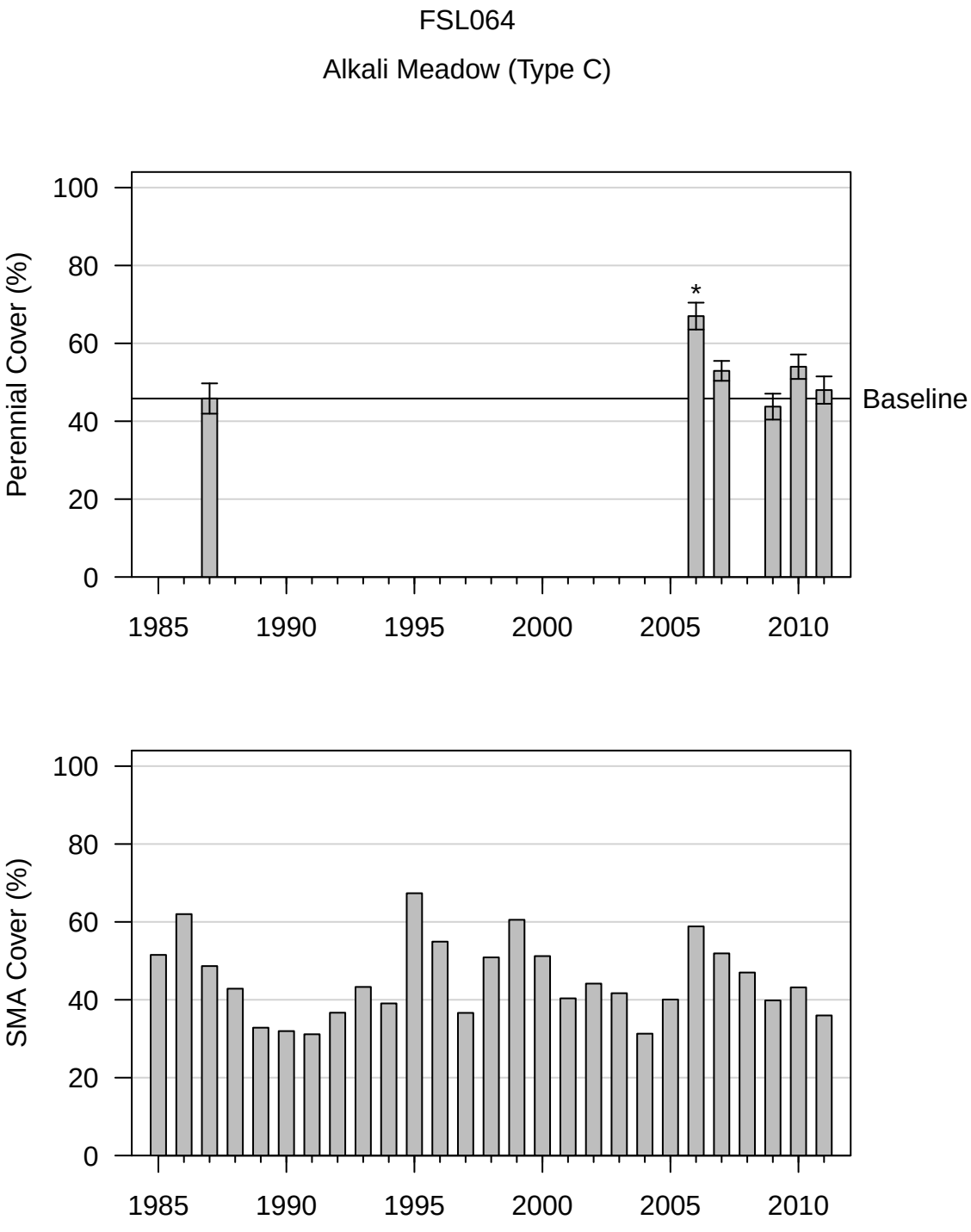


Figure 45: 2011 Wellfield

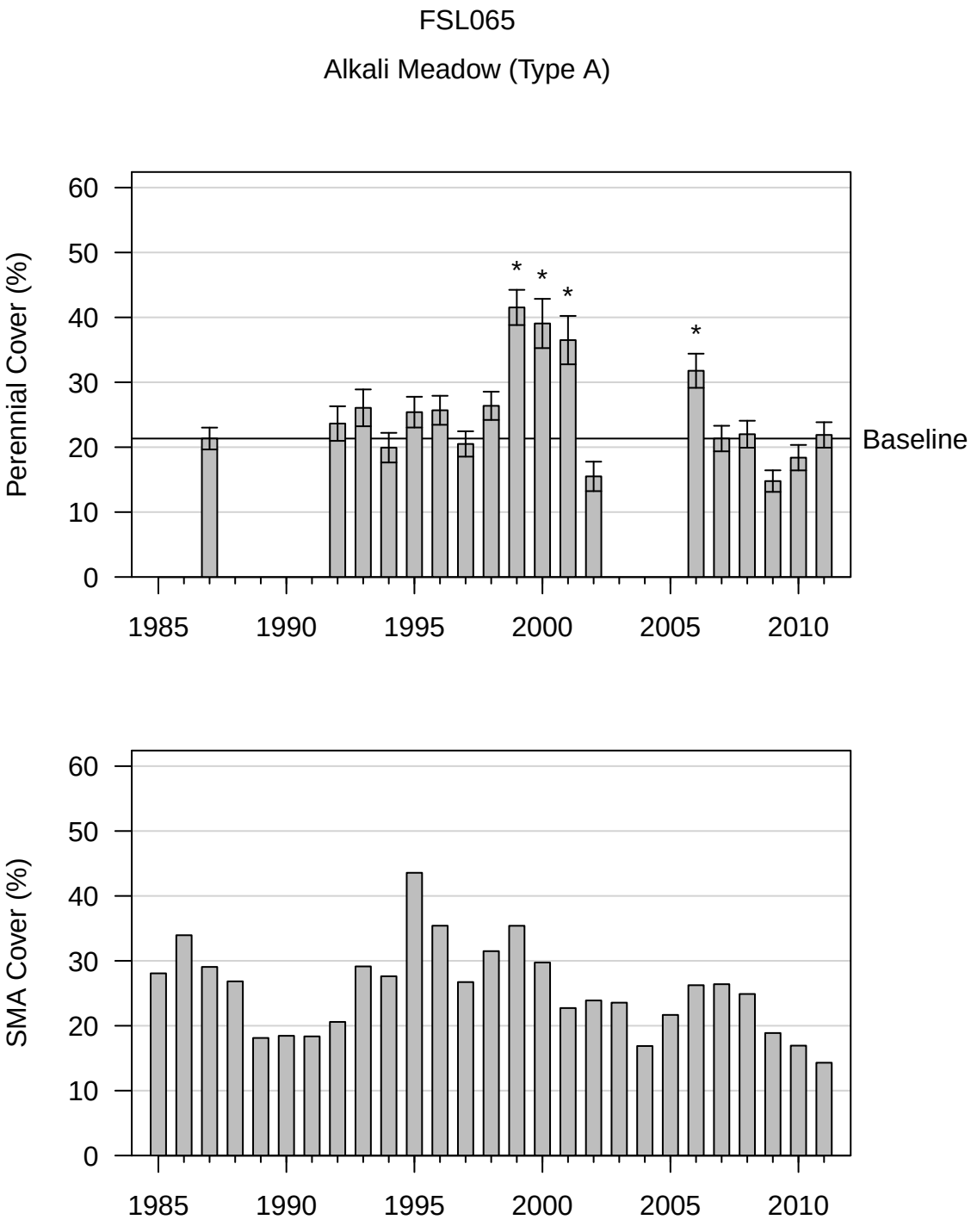


Figure 46: 2011 Wellfield

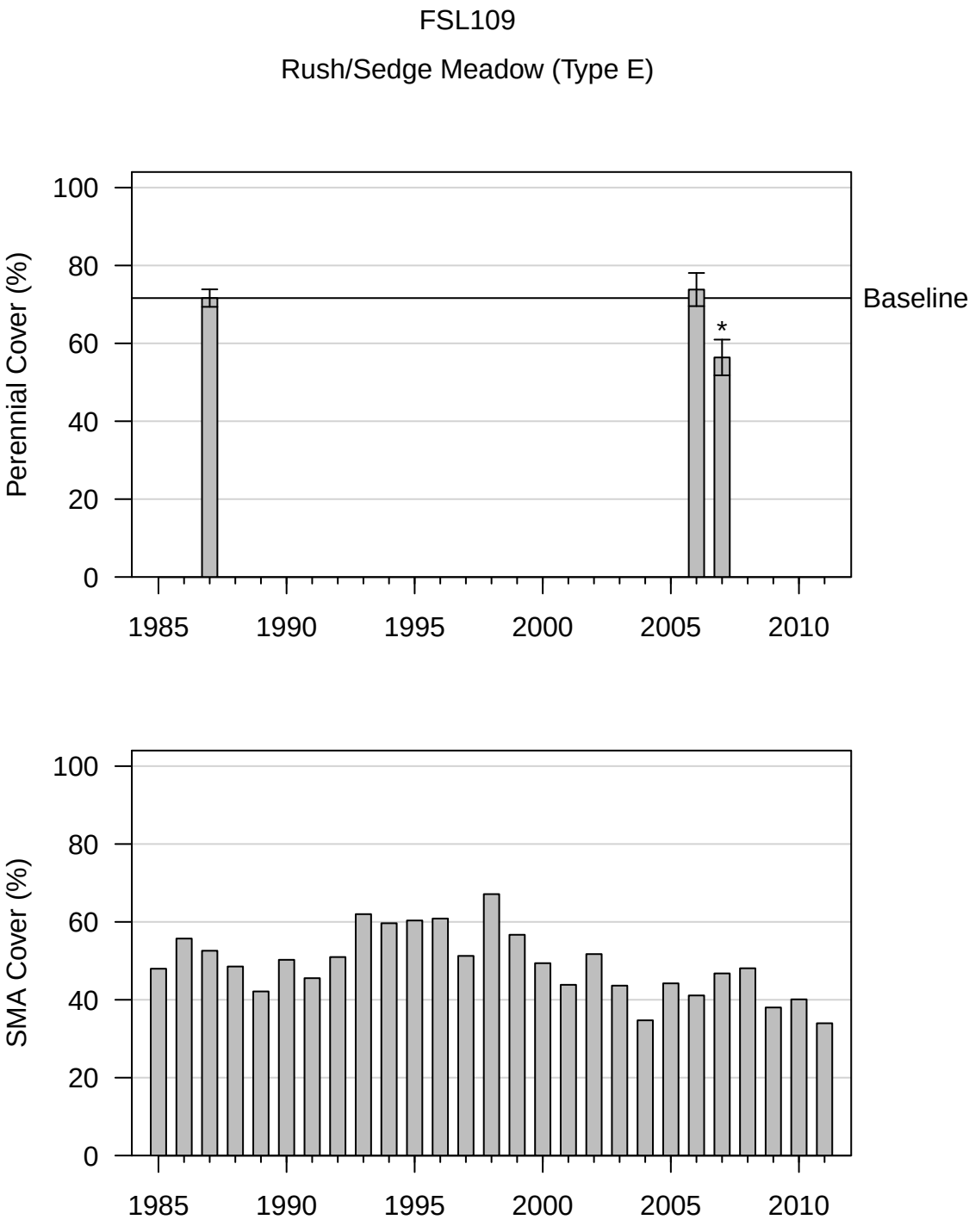


Figure 47: 2007 Control

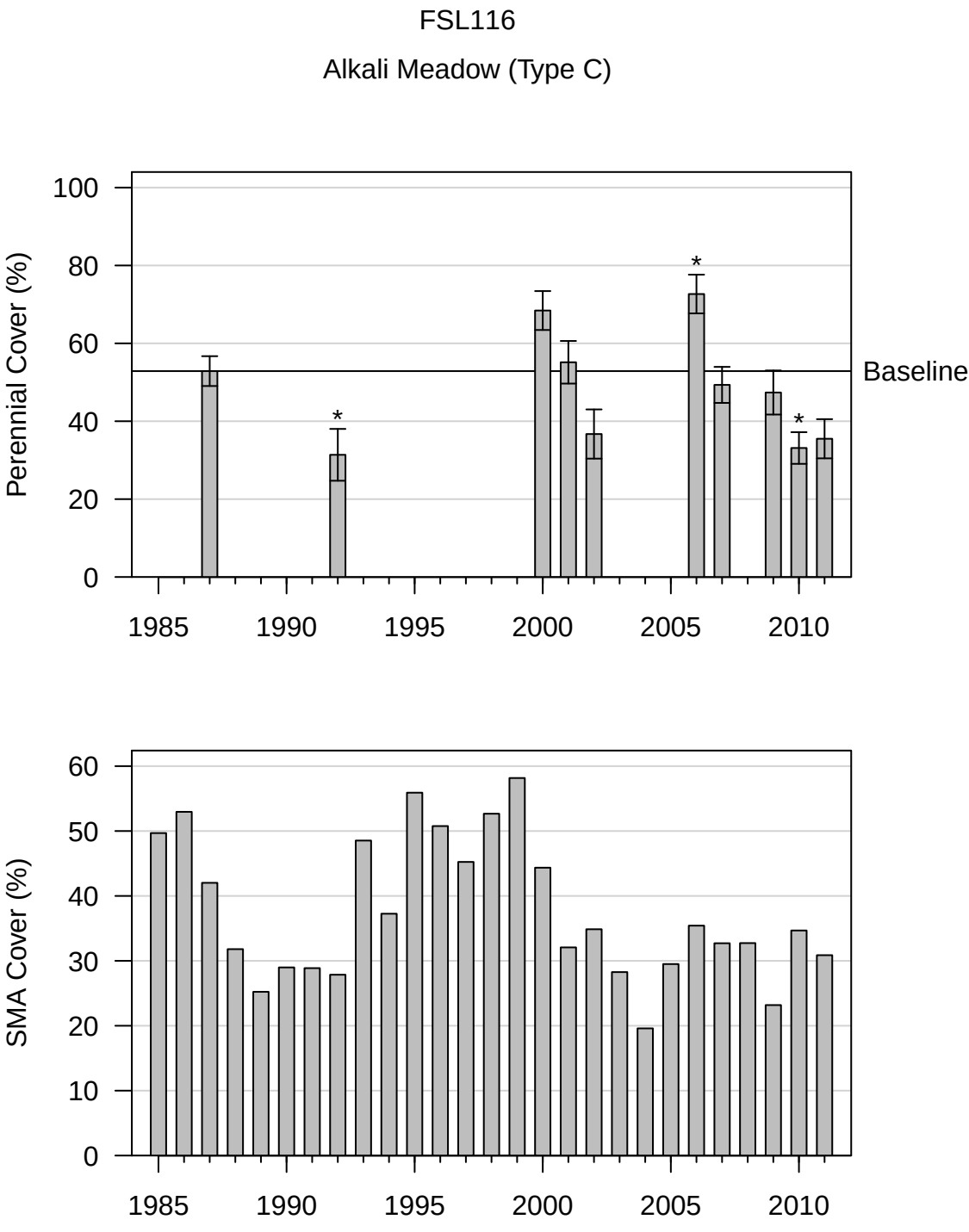


Figure 48: 2011 Wellfield

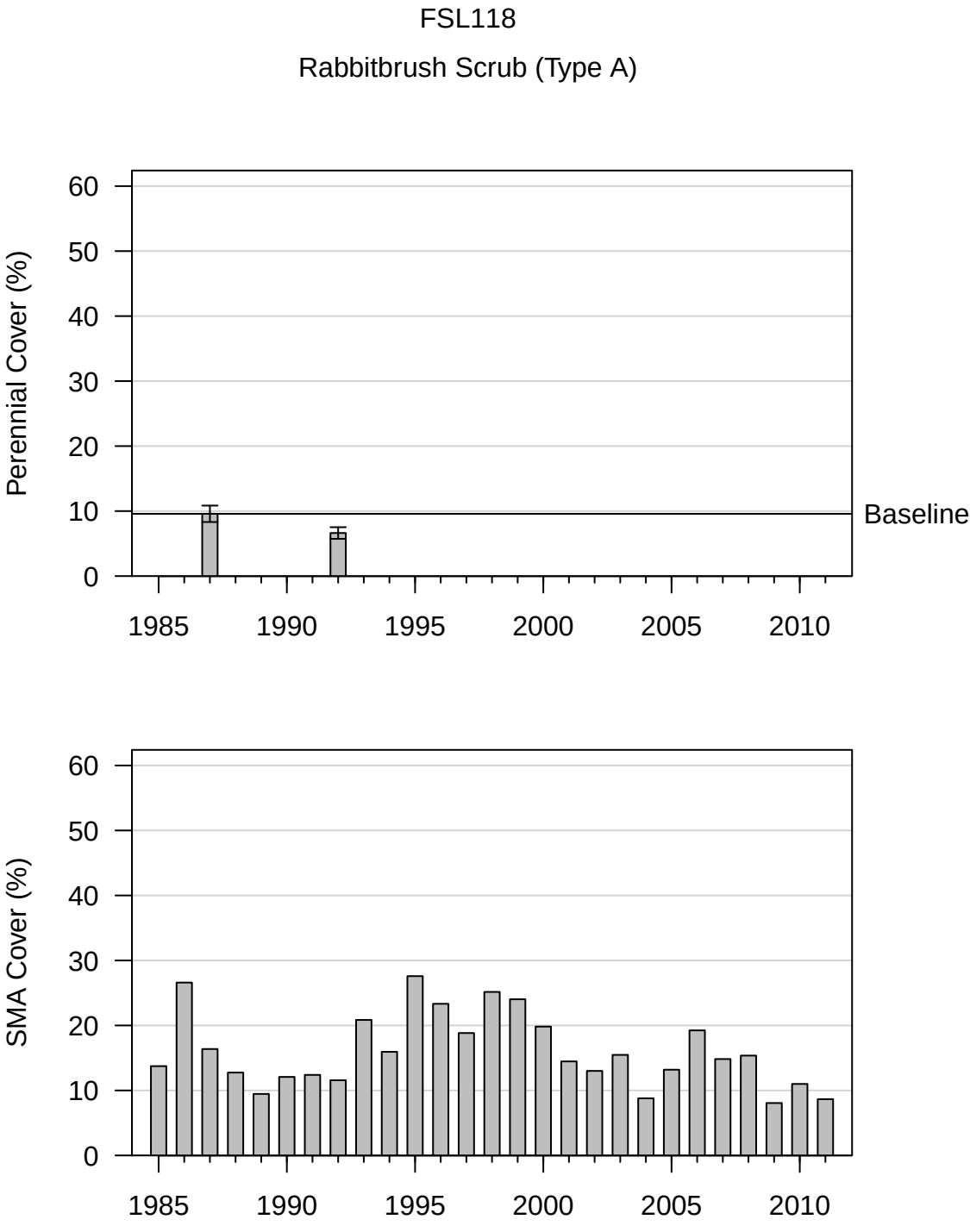
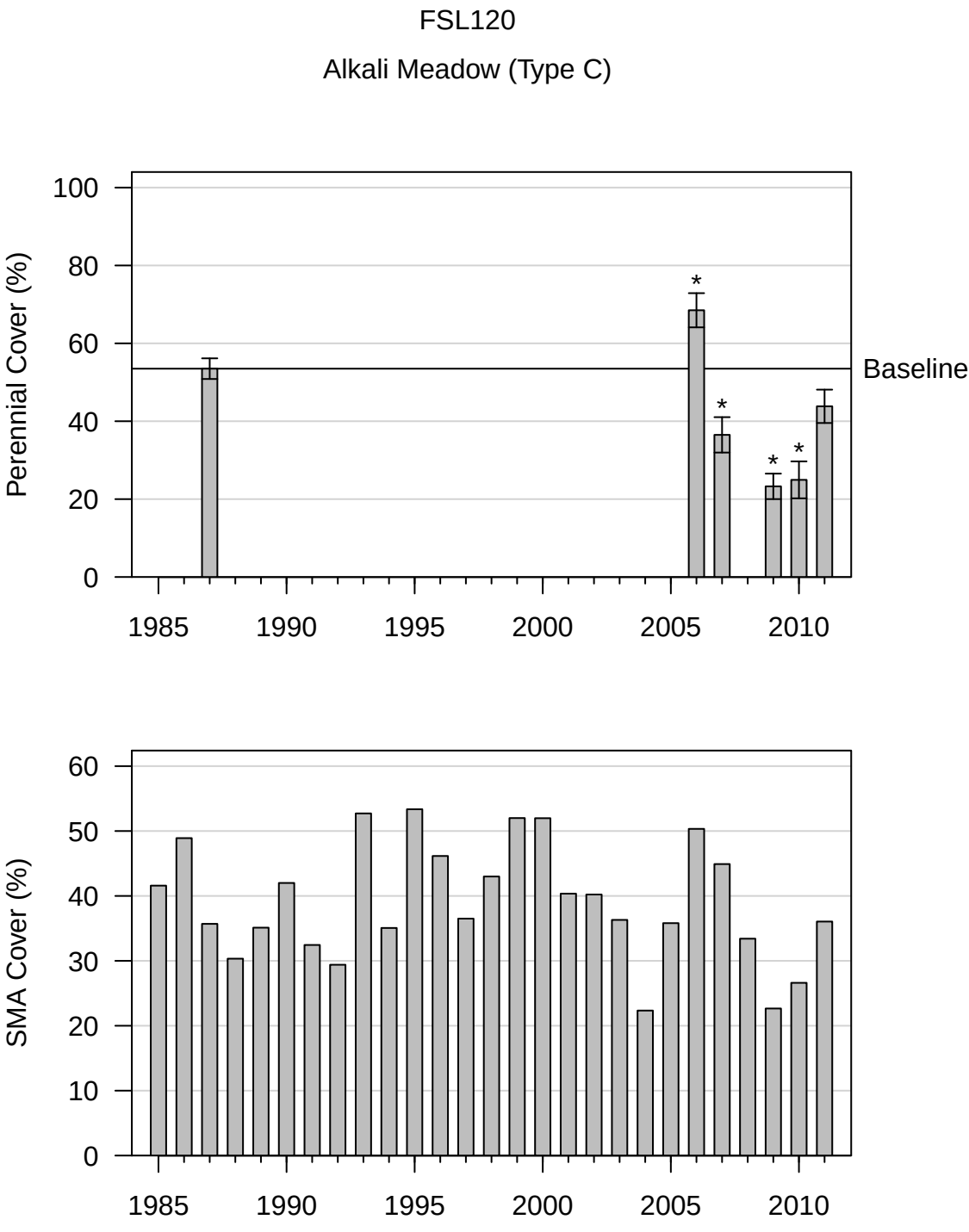


Figure 49: 1992 Wellfield



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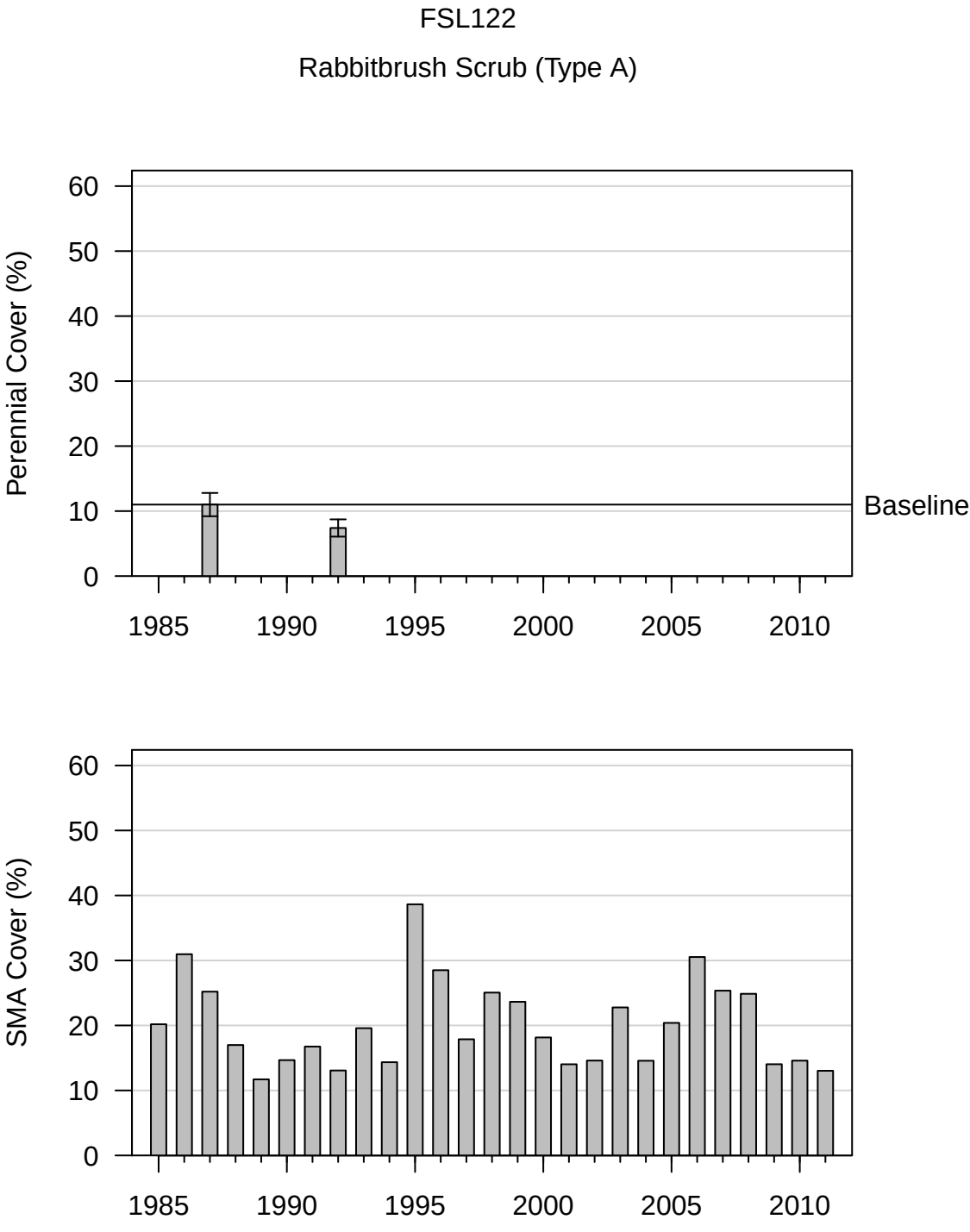


Figure 51: 1992 Wellfield

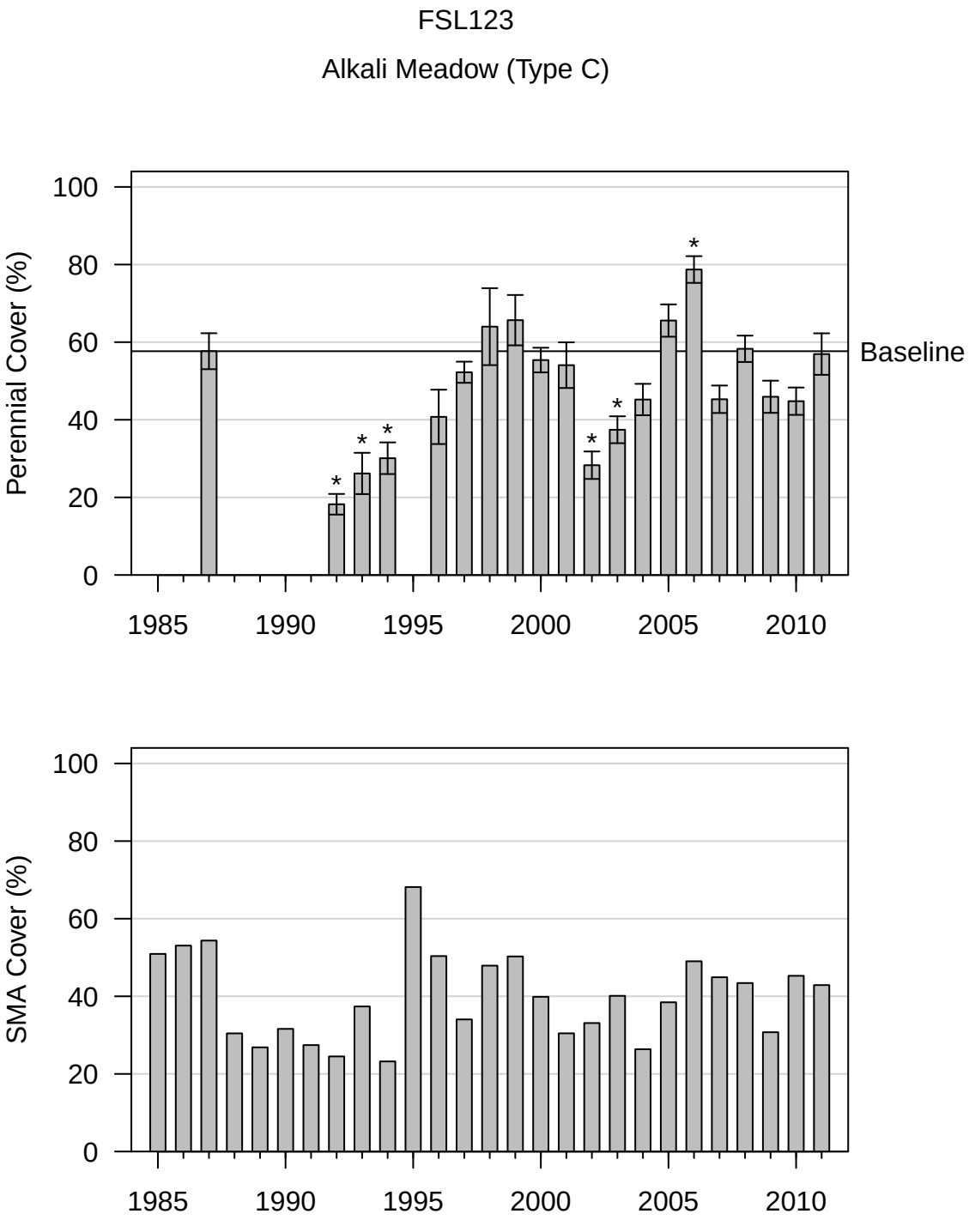


Figure 52: 2011 Wellfield

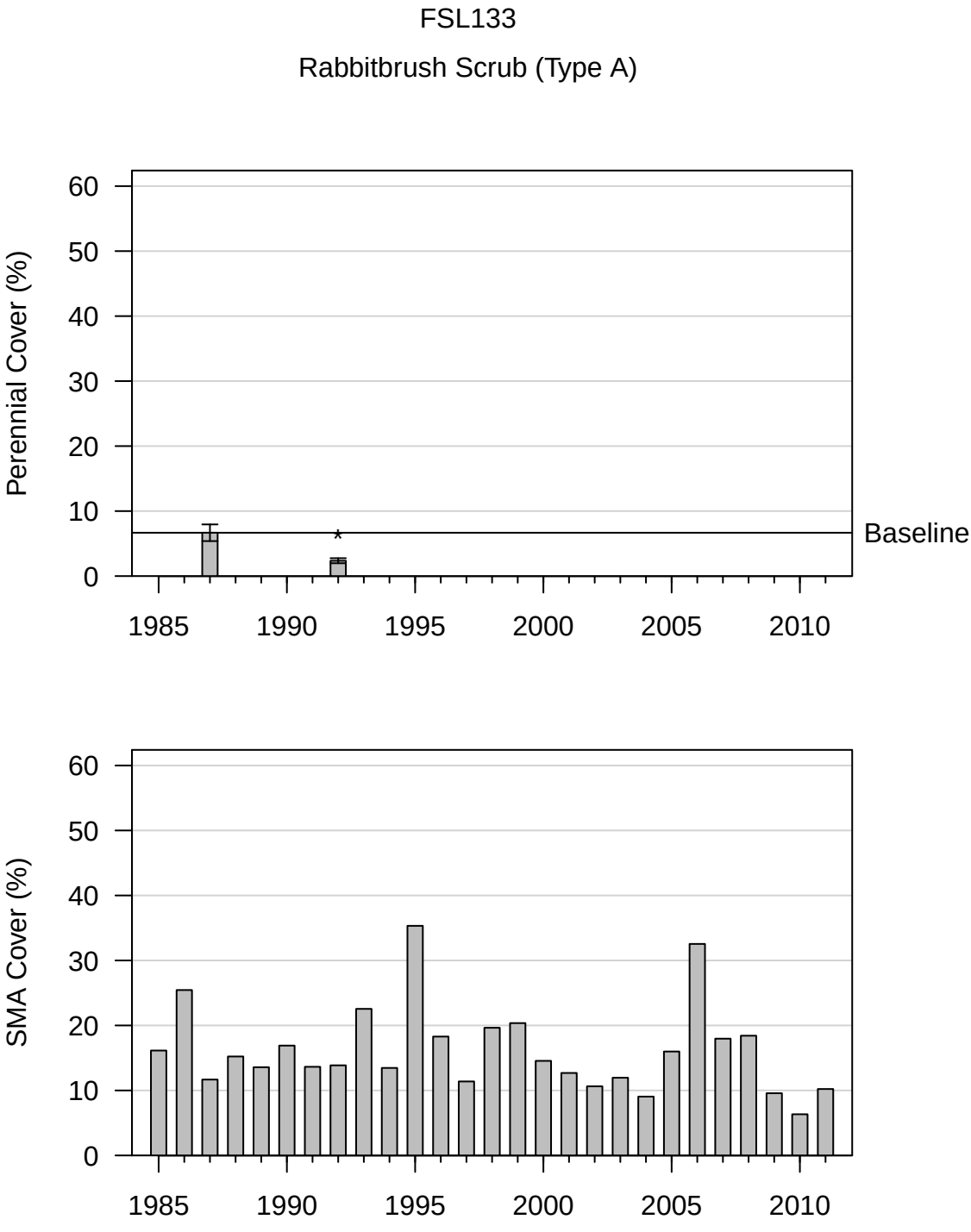


Figure 53: 1992 Wellfield

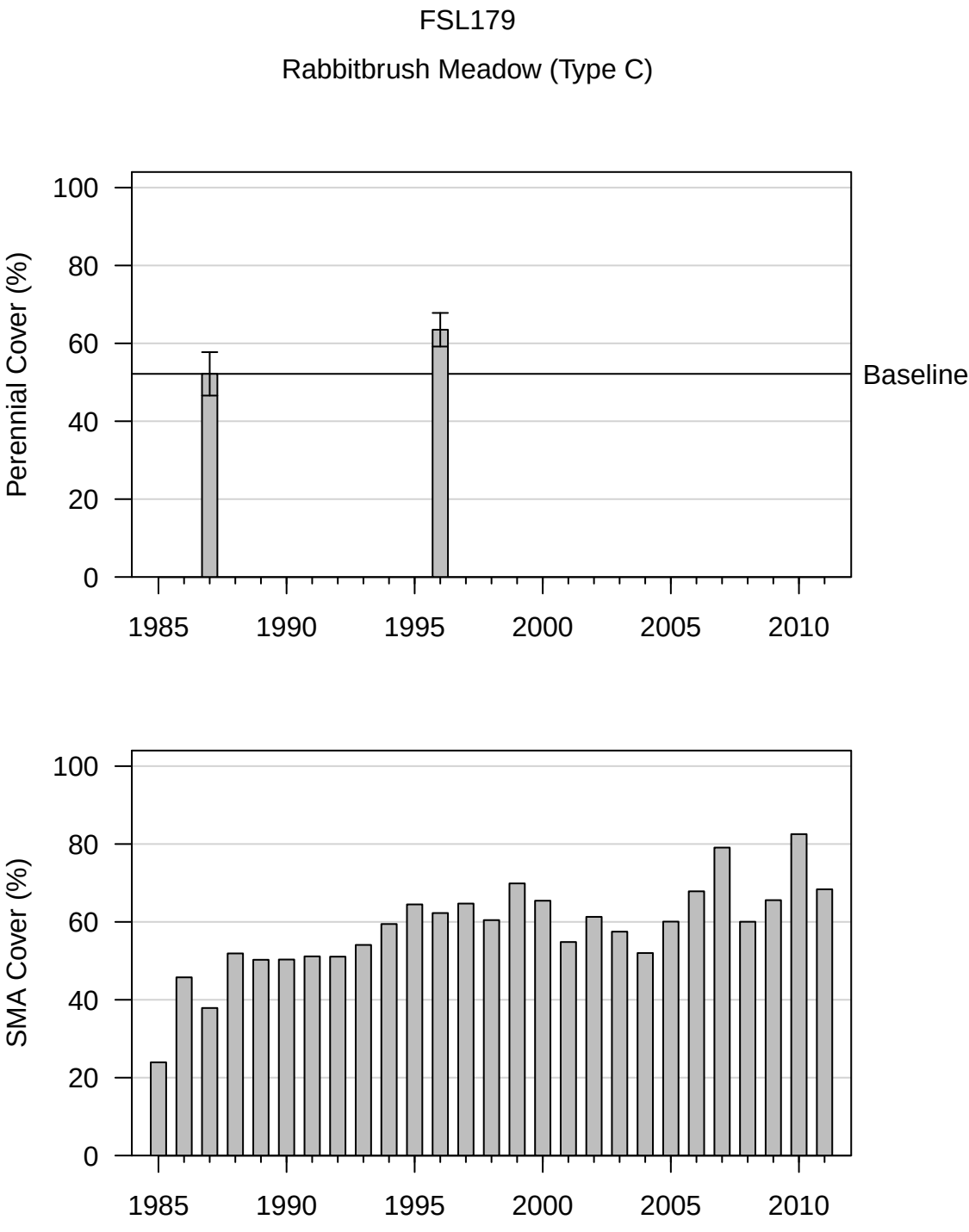


Figure 54: 1996 Control

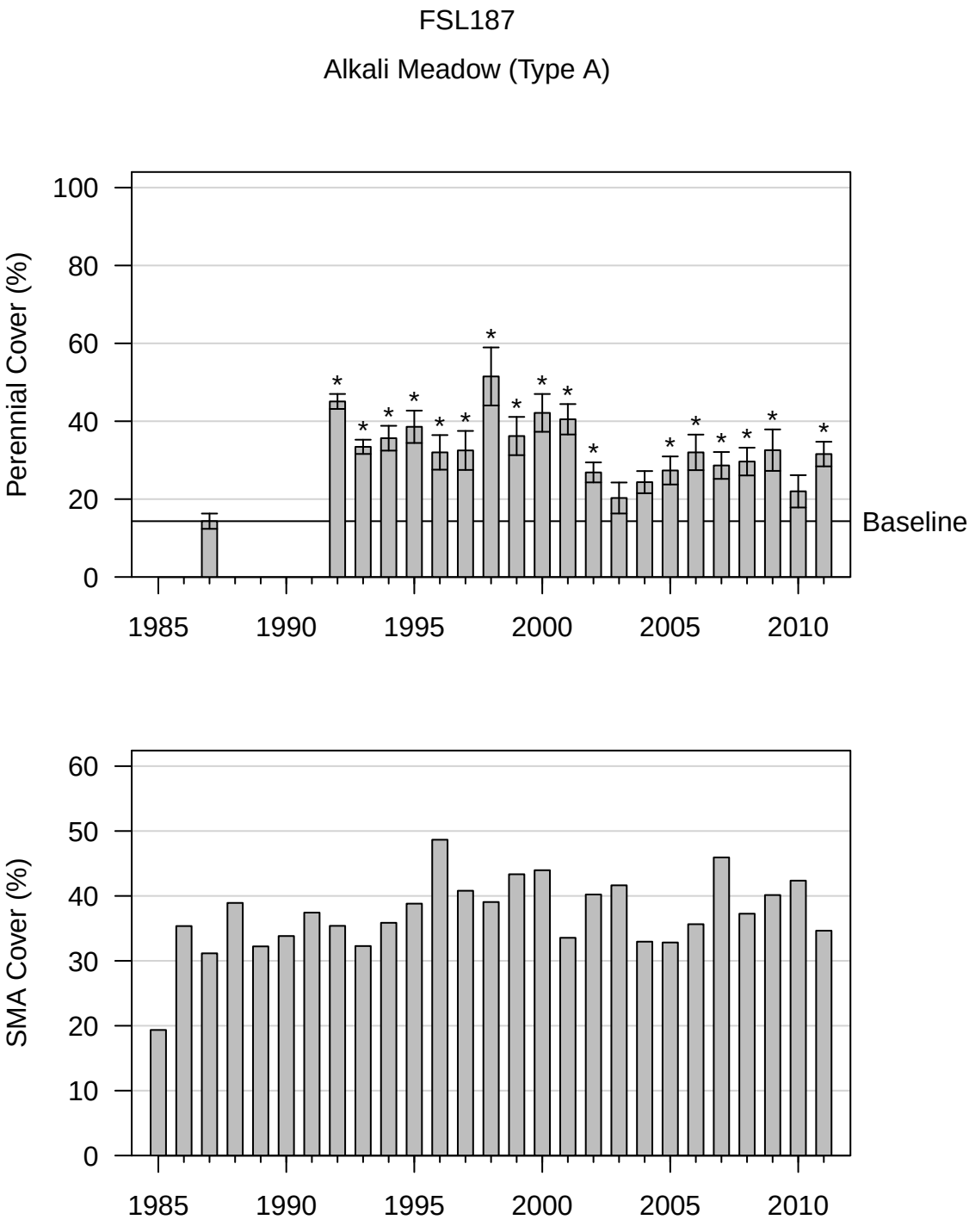


Figure 55: 2011 Control

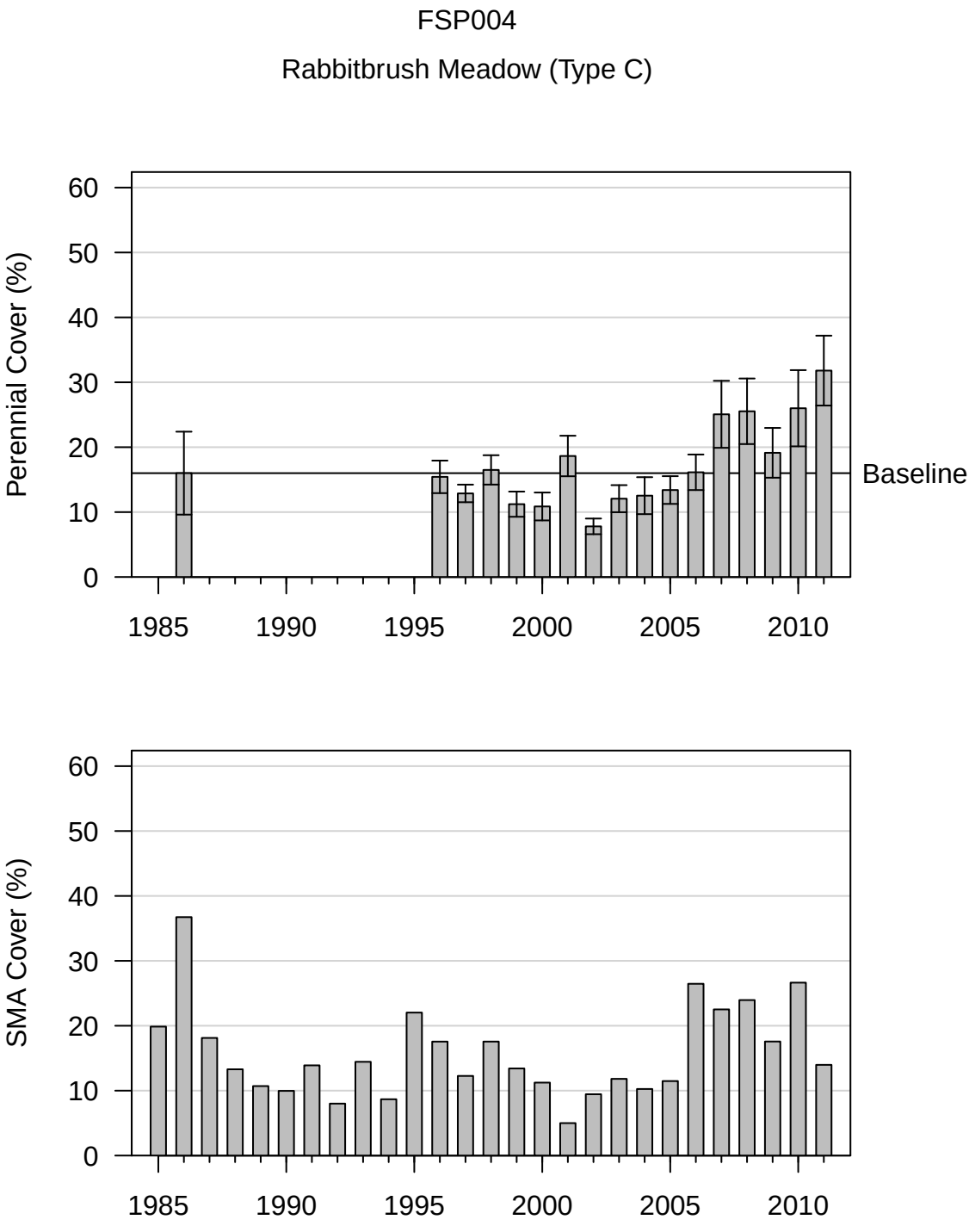


Figure 56: 2011 Wellfield

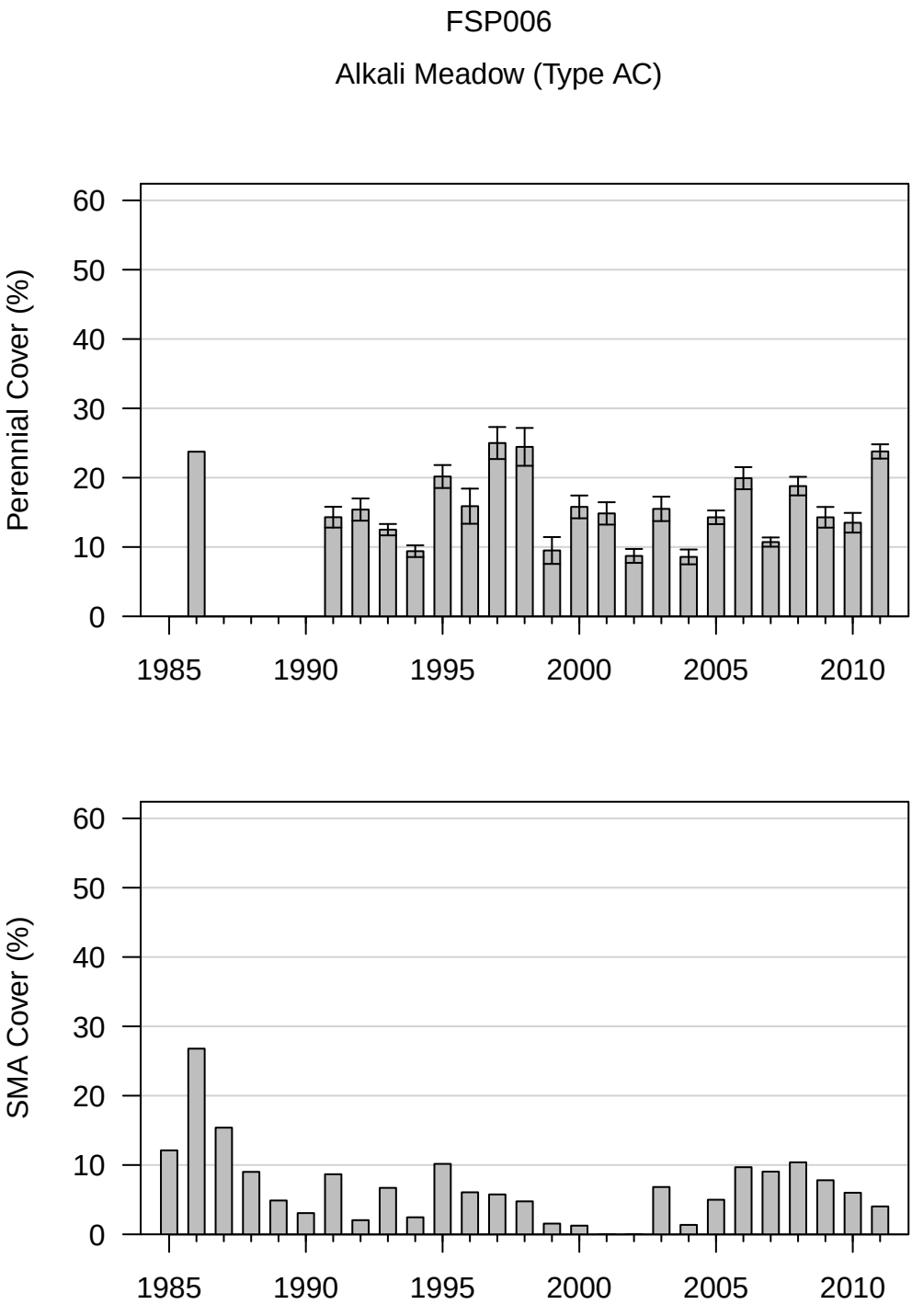


Figure 57: 2011 Wellfield

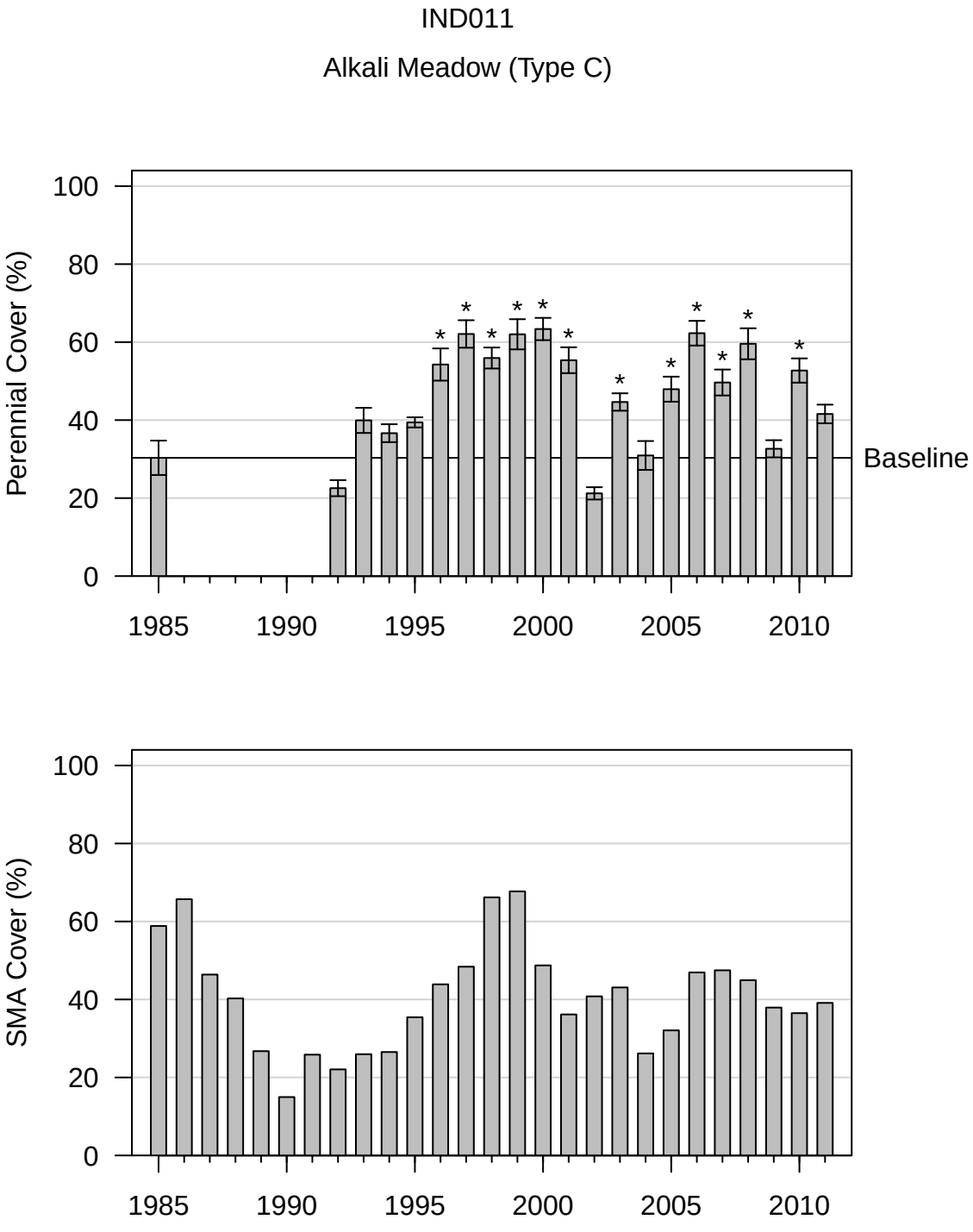


Figure 58: 2011 Wellfield

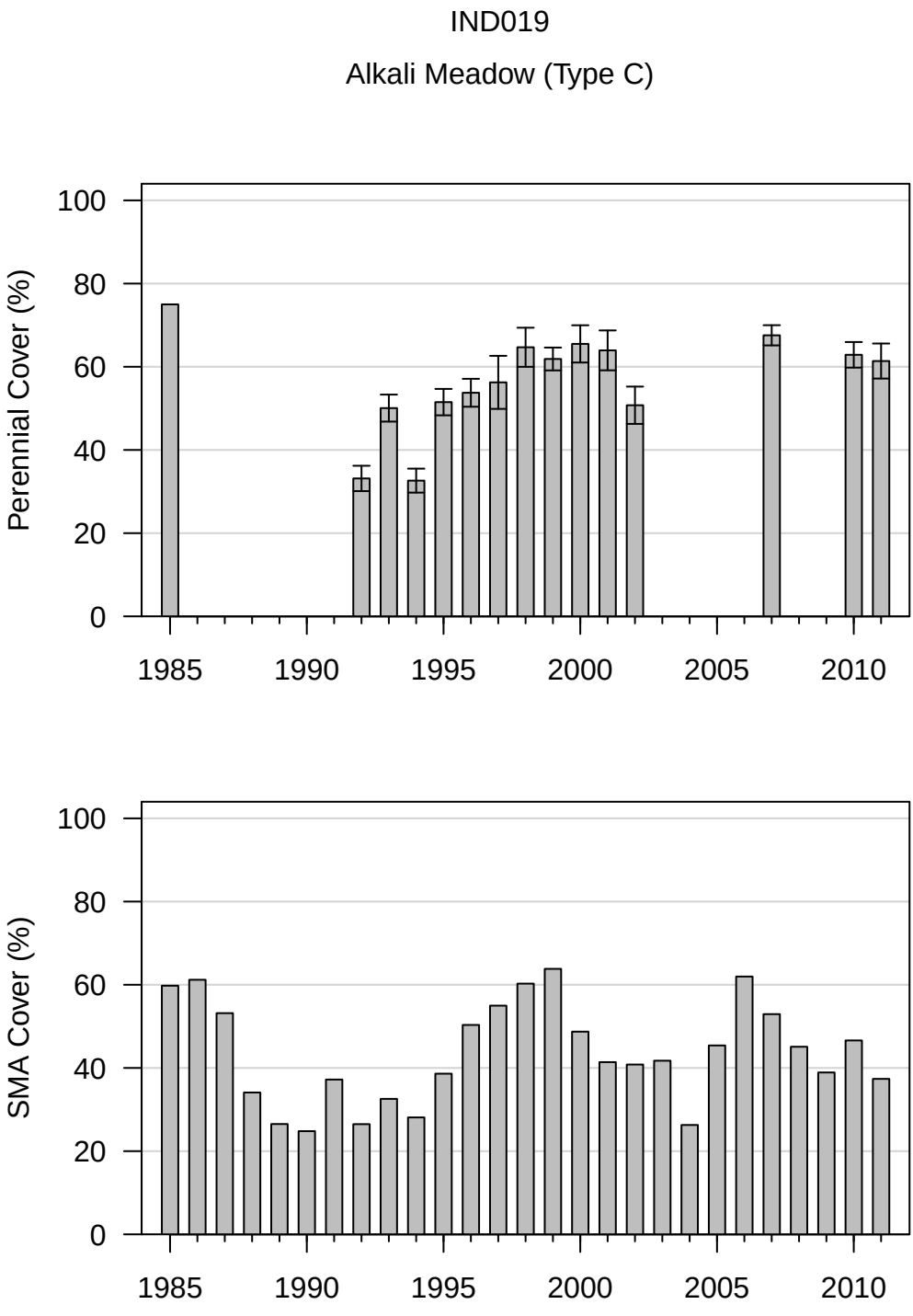


Figure 59: 2011 Wellfield

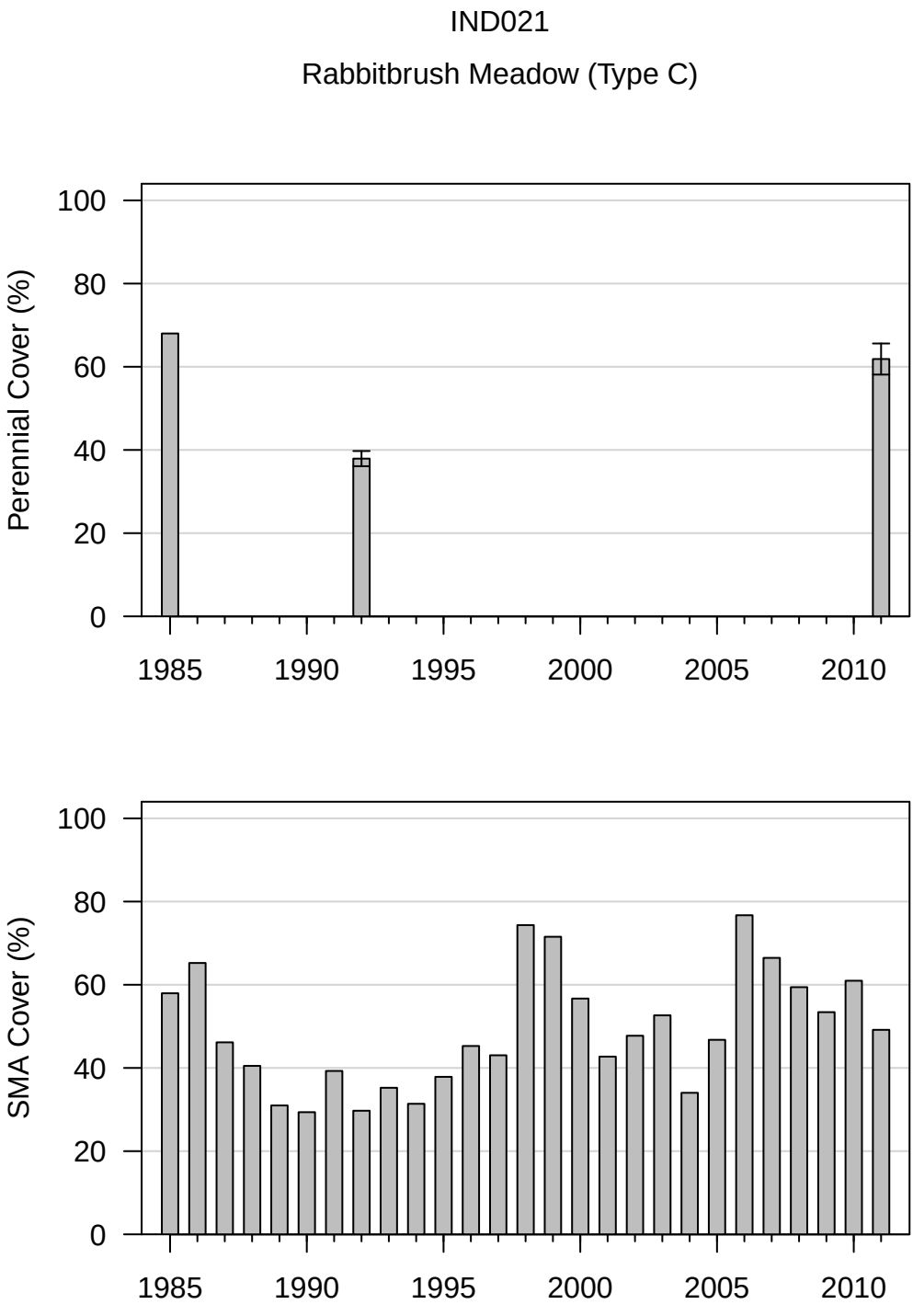


Figure 60: 2011 Wellfield

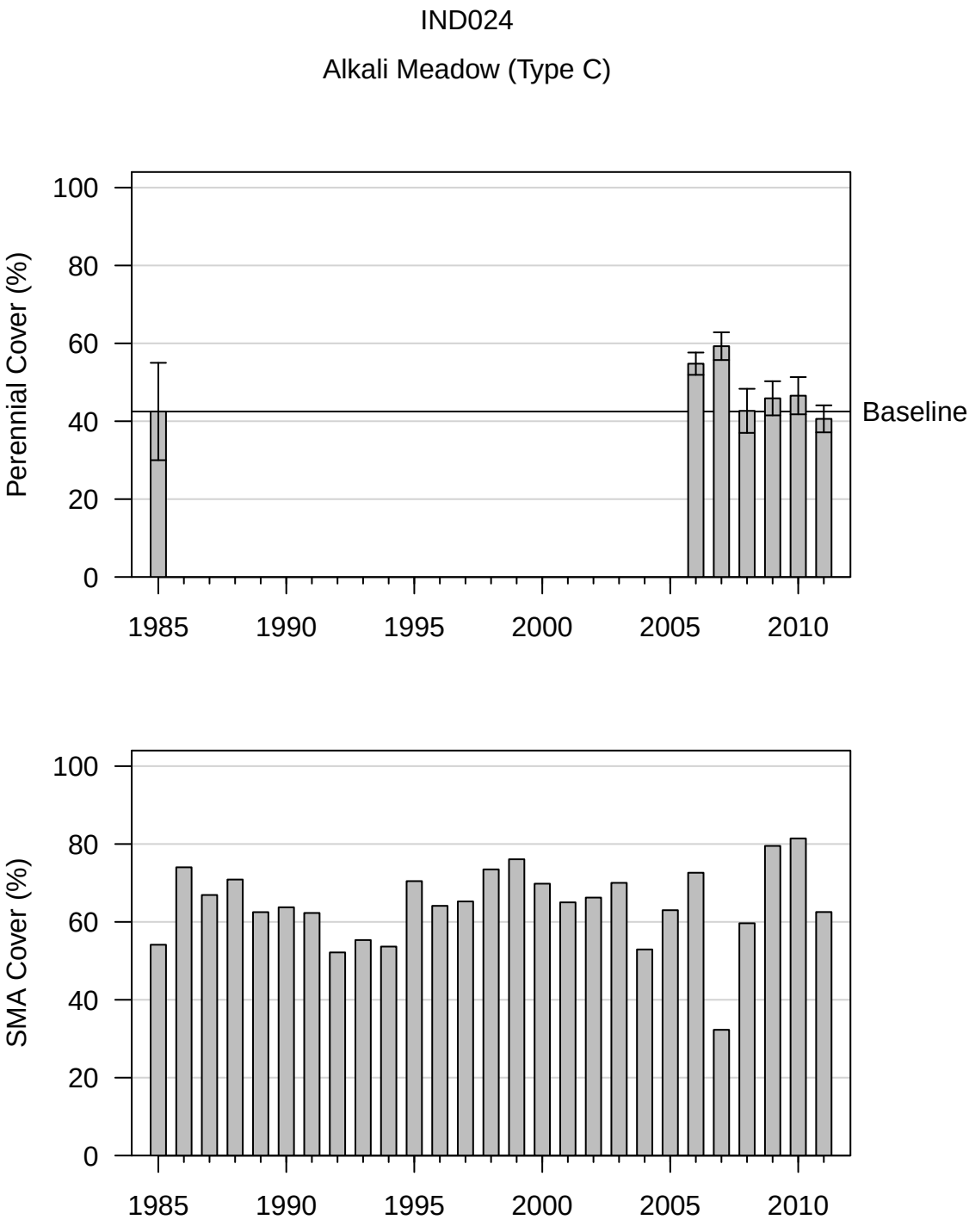


Figure 61: 2011 Wellfield

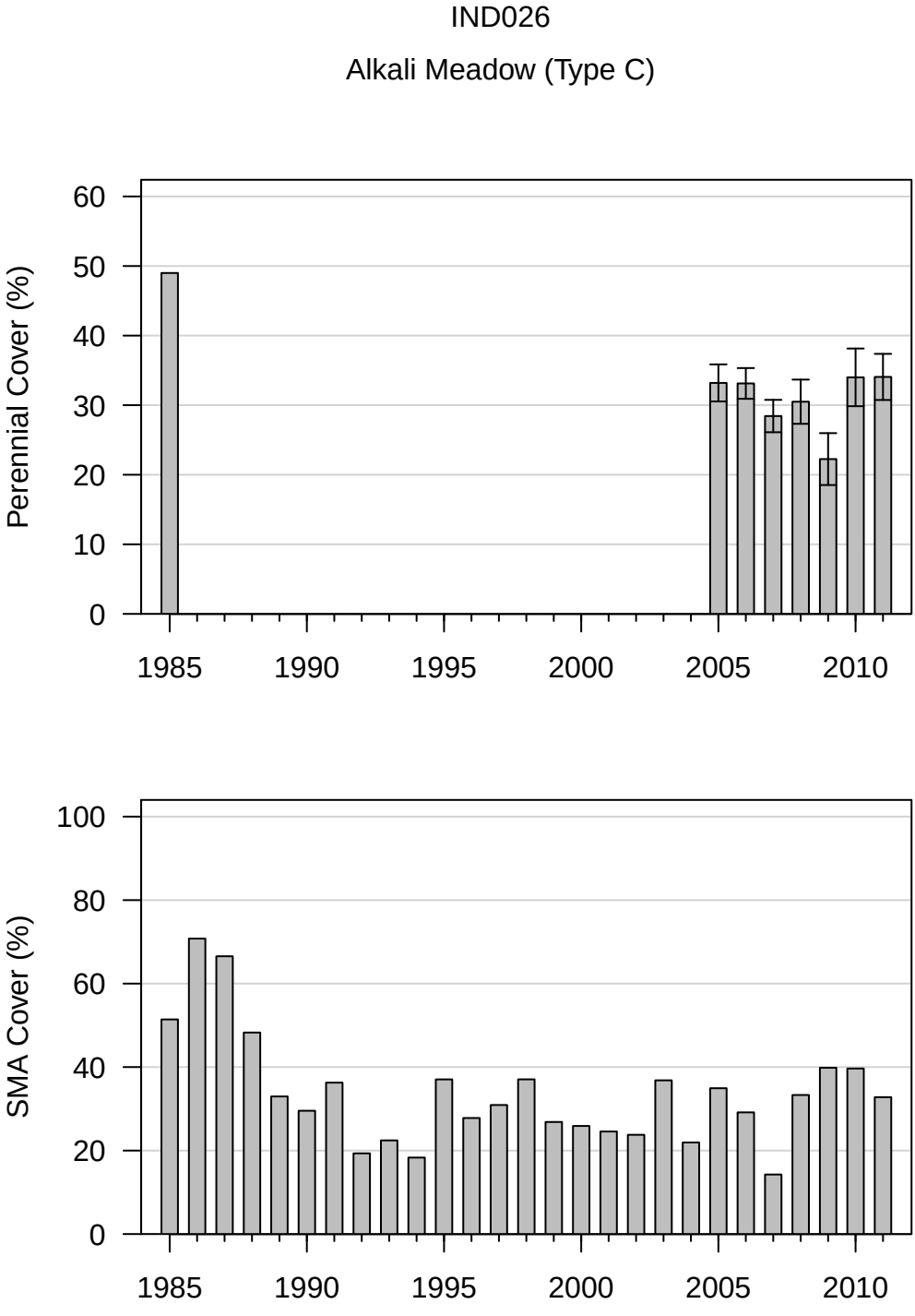


Figure 62: 2011 Wellfield

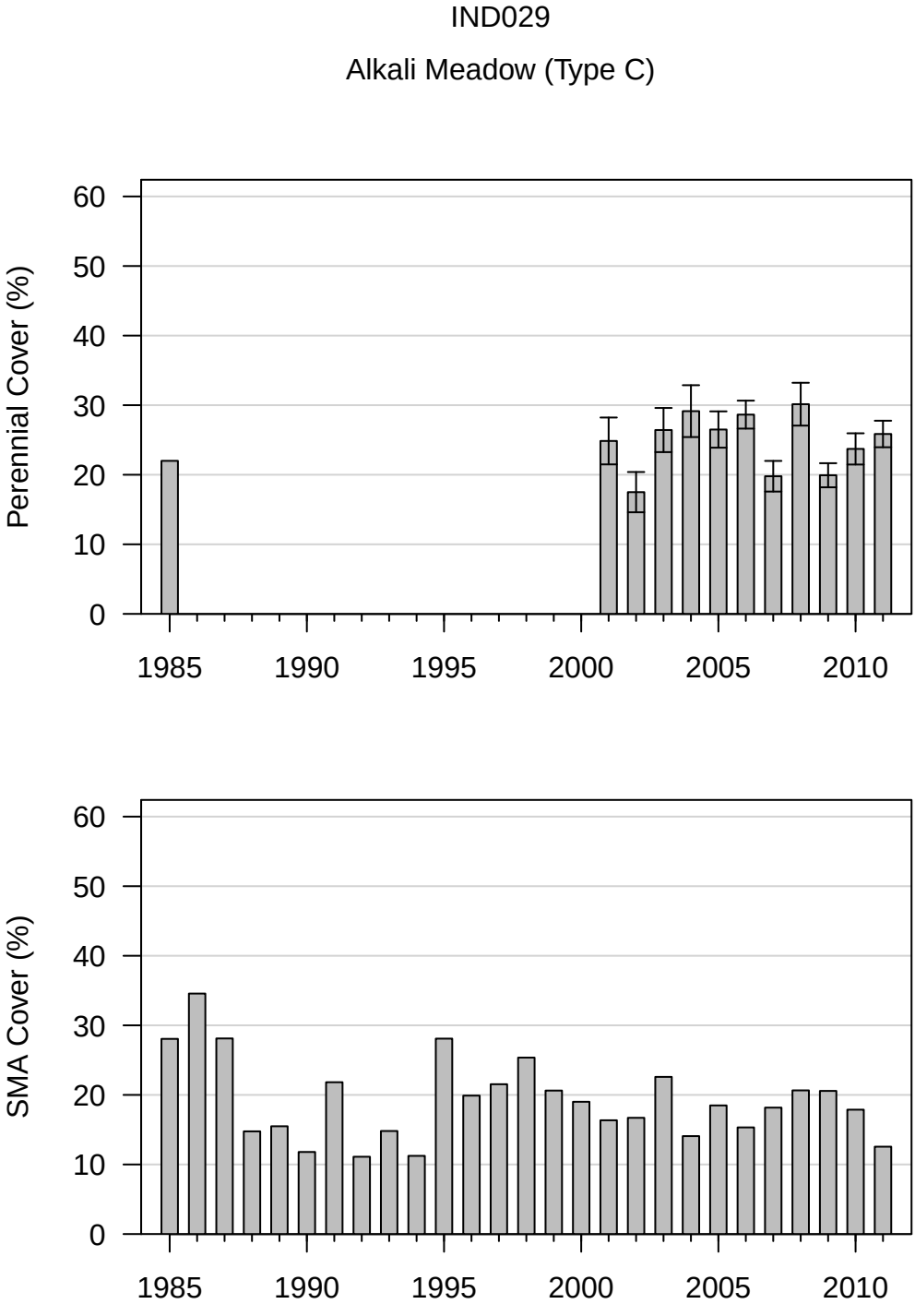


Figure 63: 2011 Wellfield

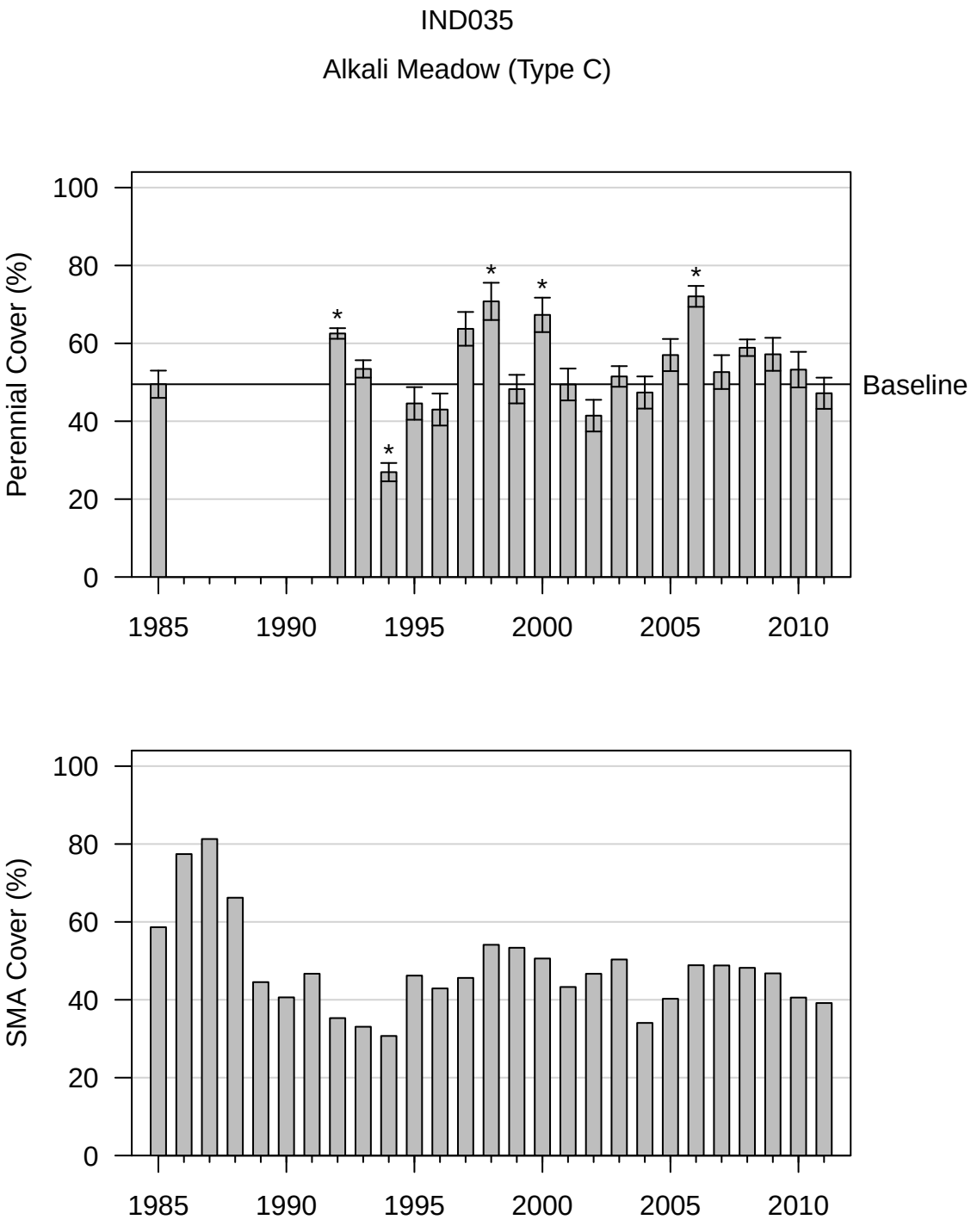


Figure 64: 2011 Wellfield

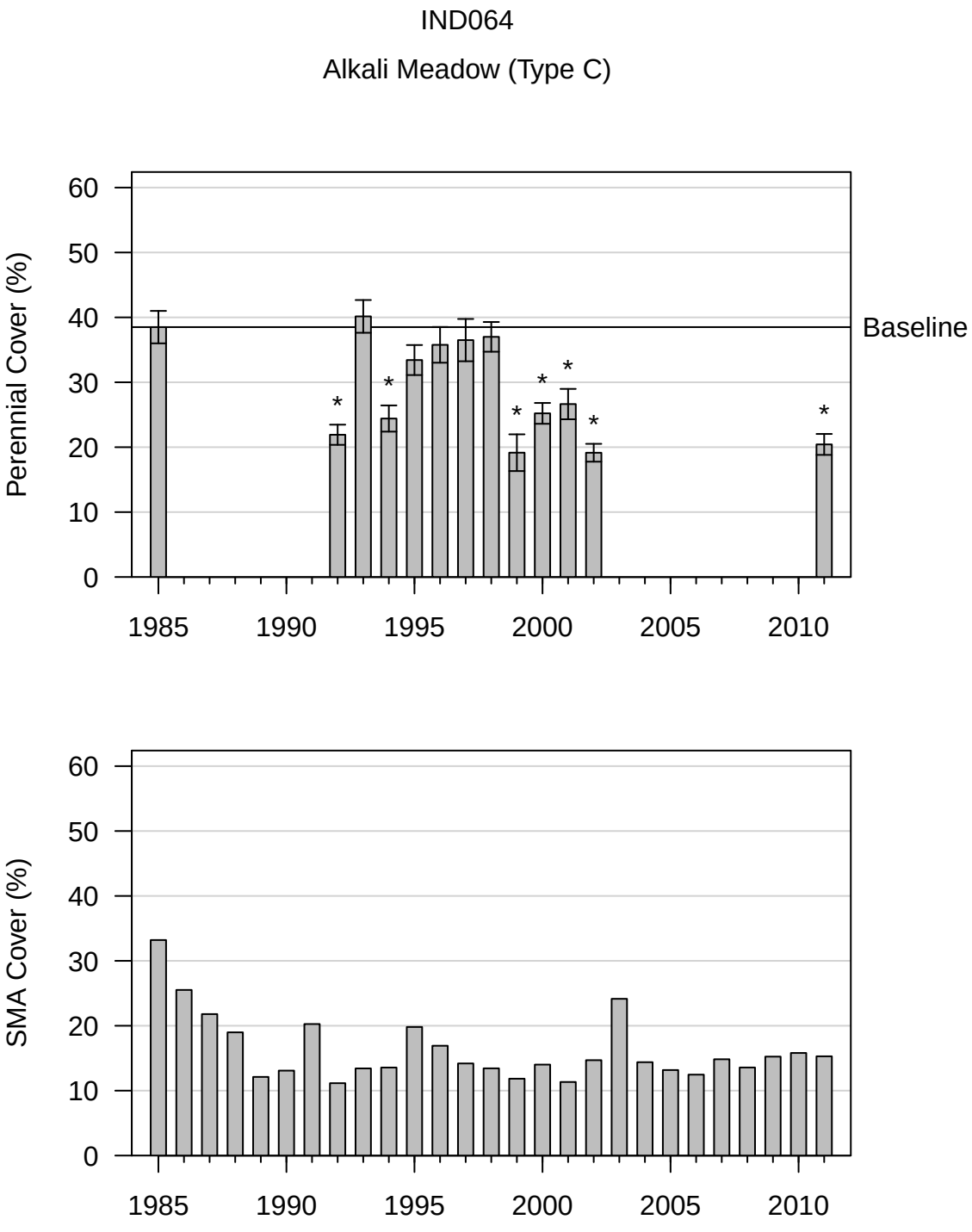


Figure 65: 2011 Control

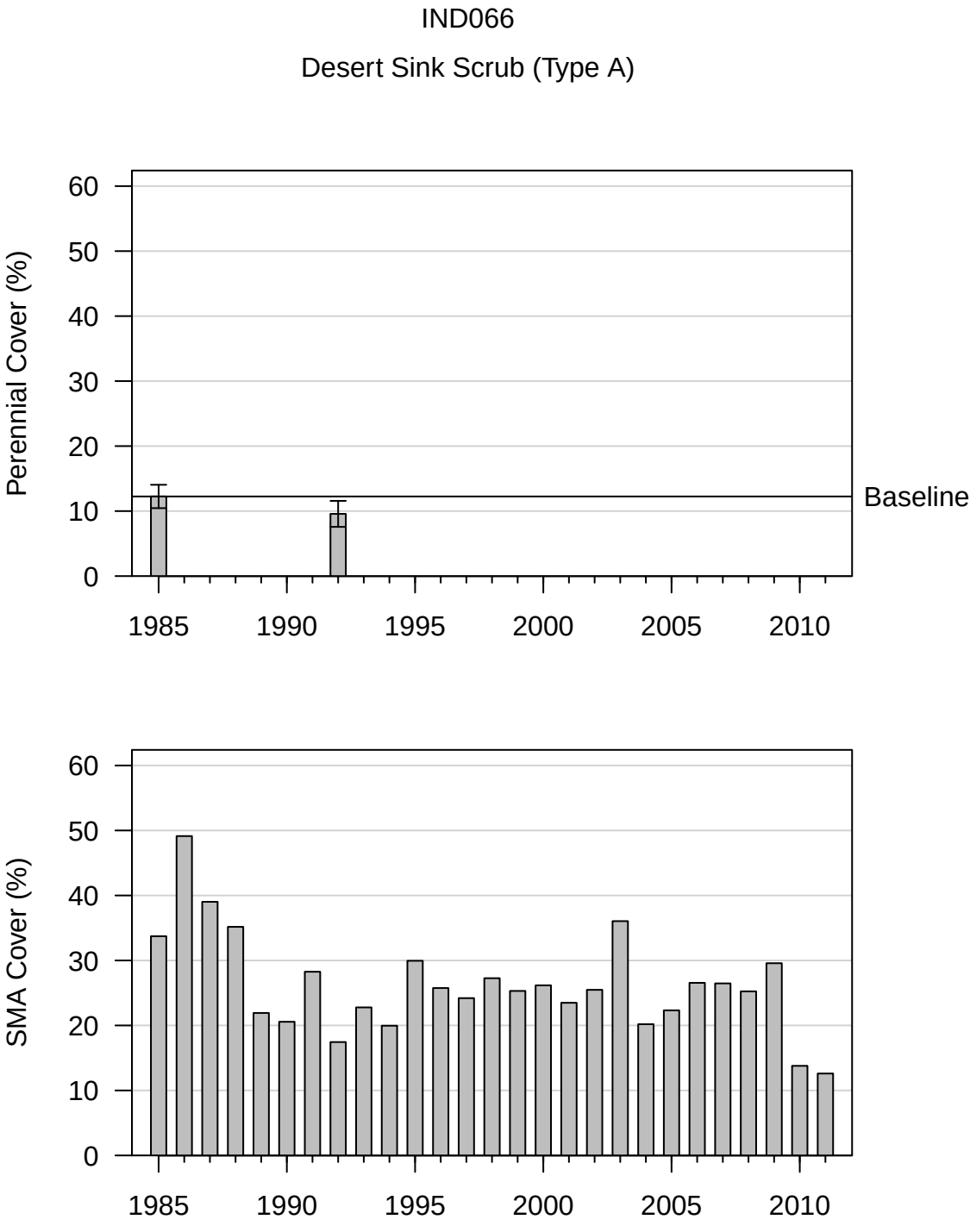


Figure 66: 1992 Control

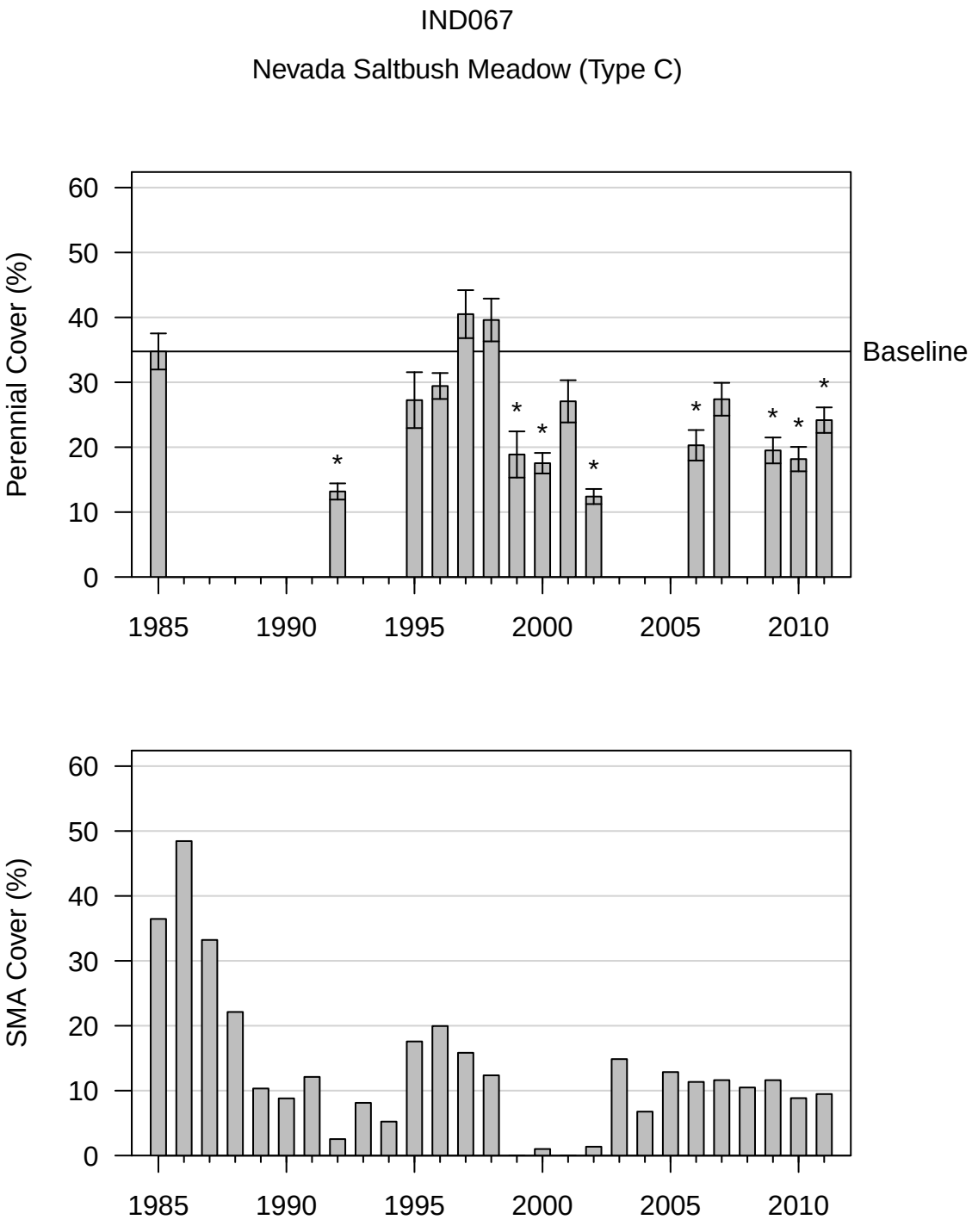


Figure 67: 2011 Control

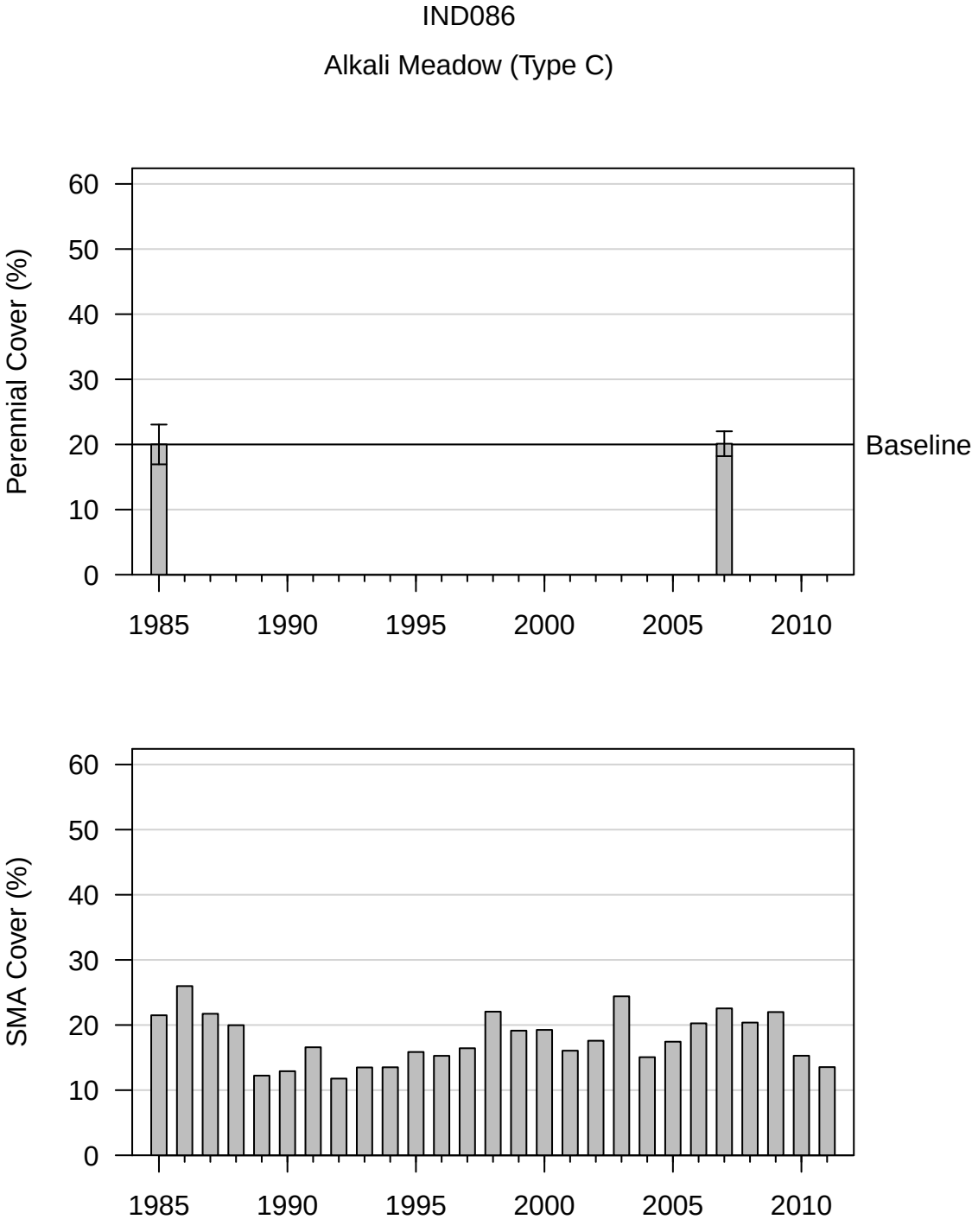


Figure 68: 2007 Control

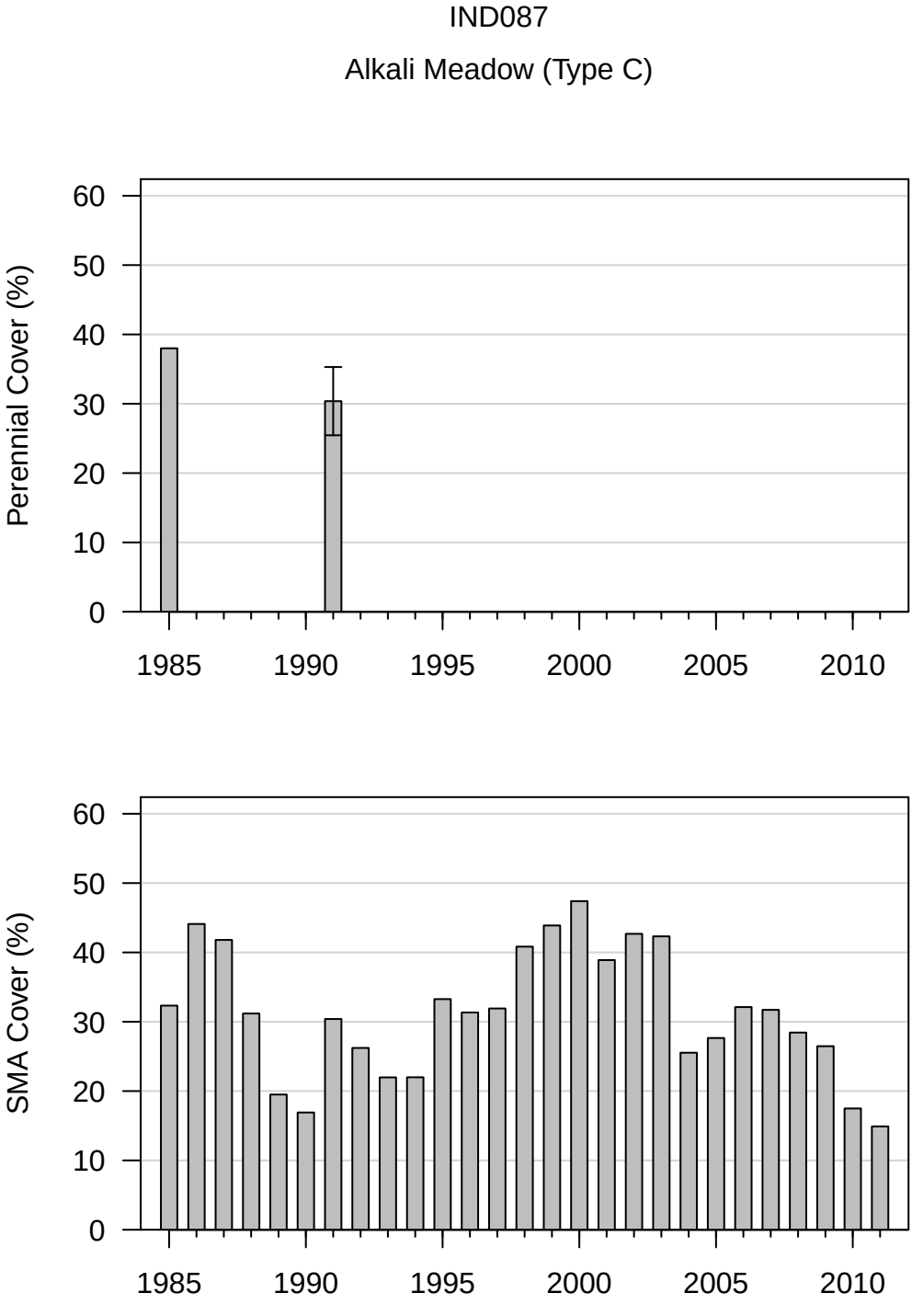


Figure 69: 1991 Control

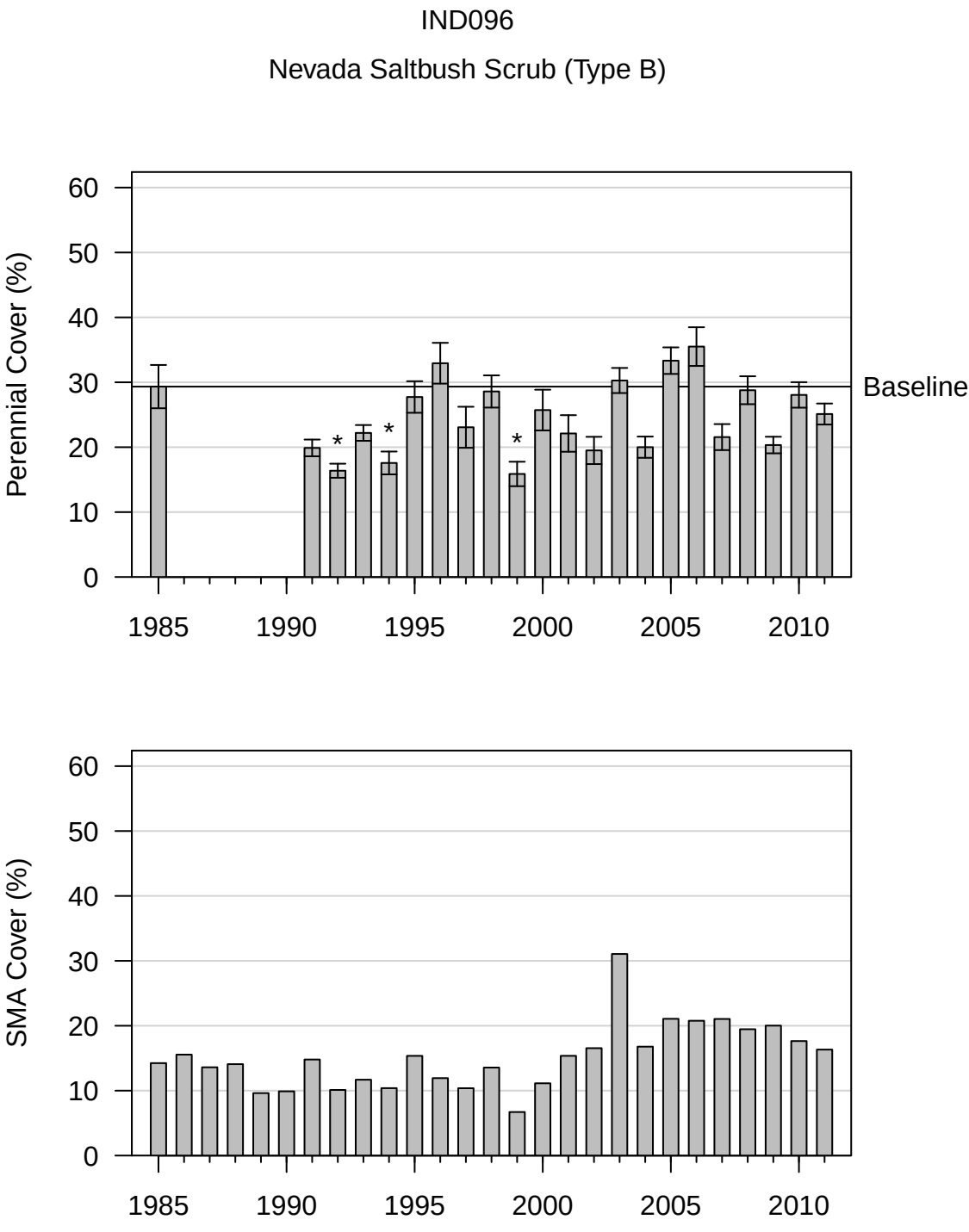


Figure 70: 2011 Control

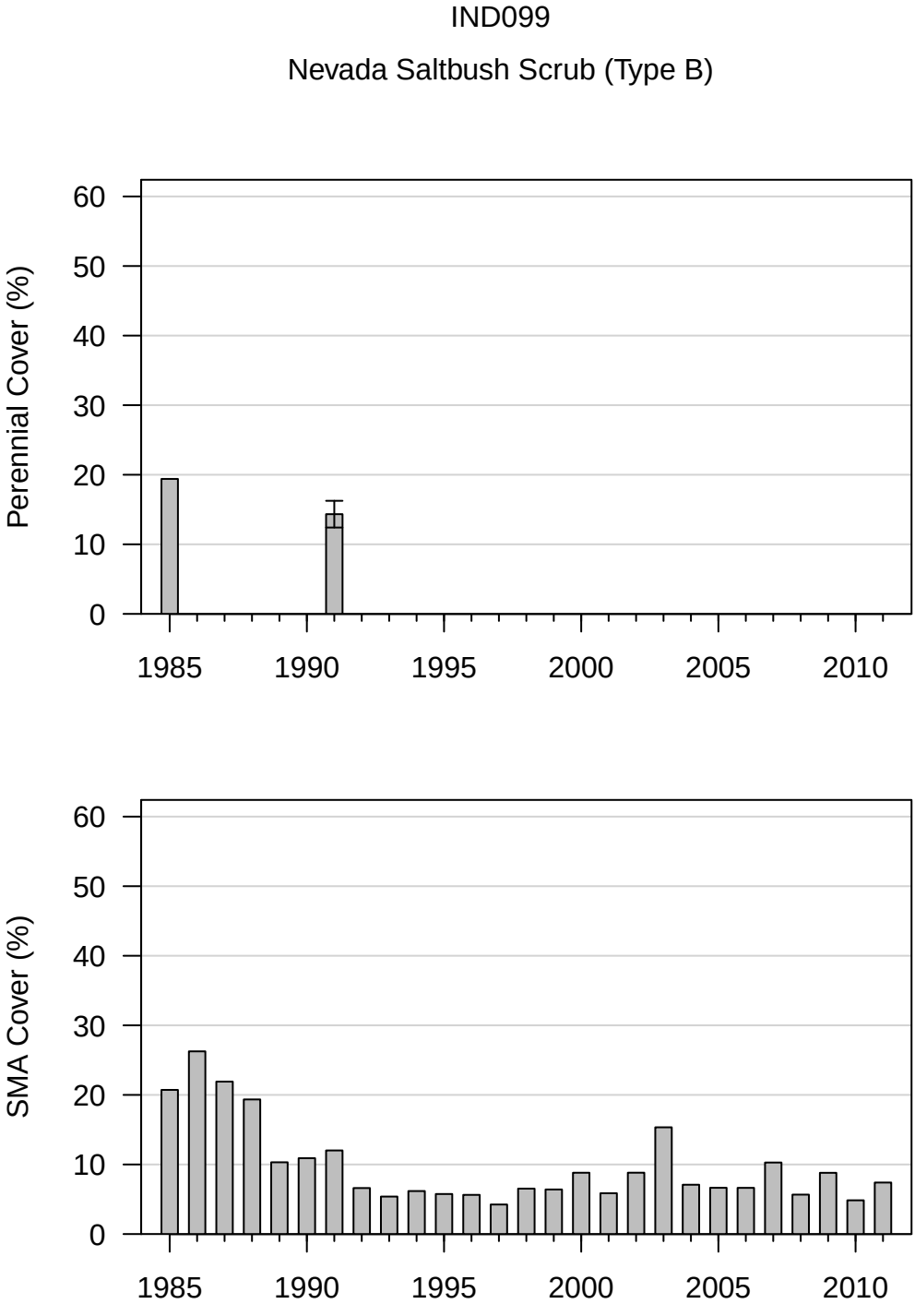


Figure 71: 1991 Control

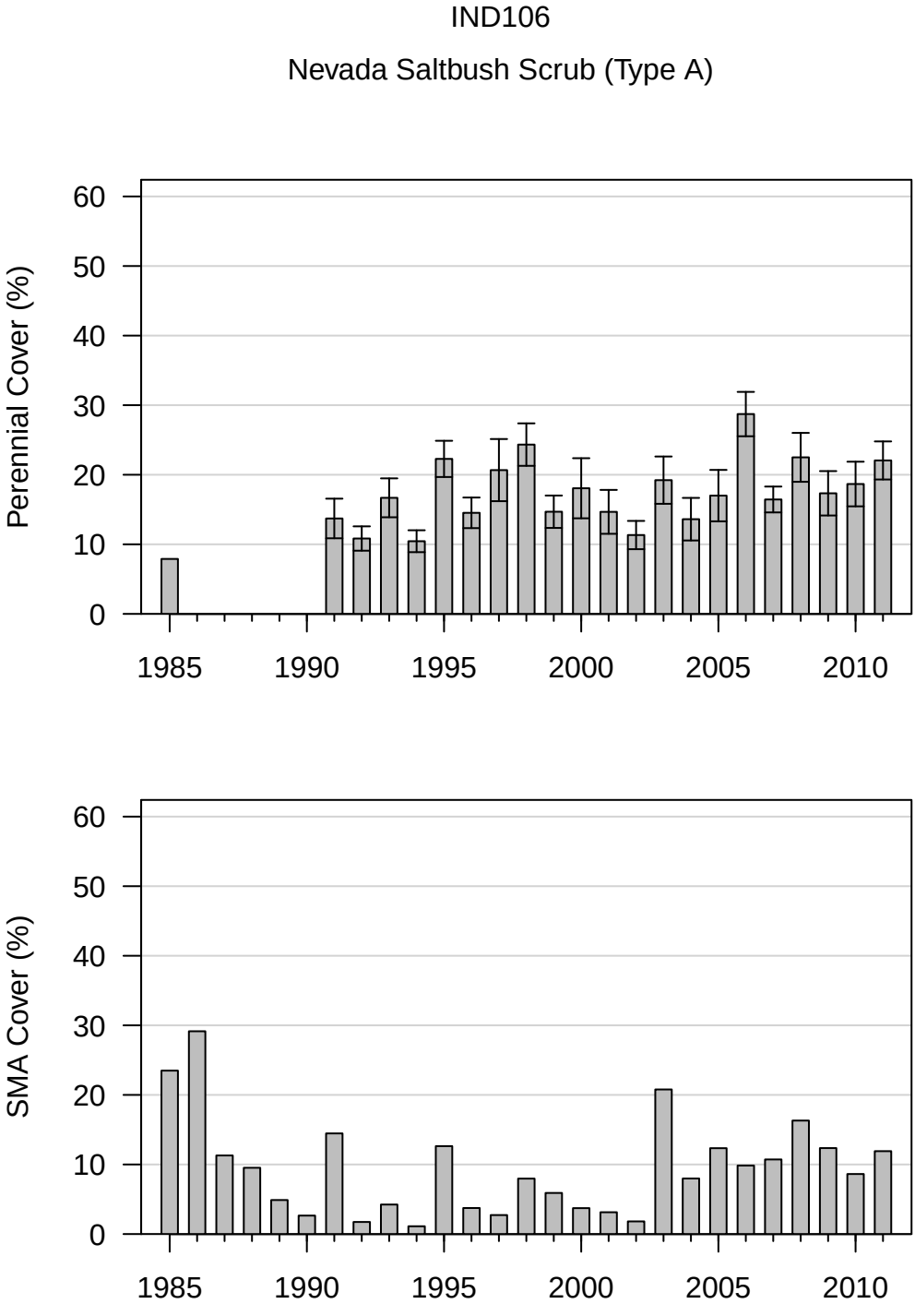


Figure 72: 2011 Wellfield

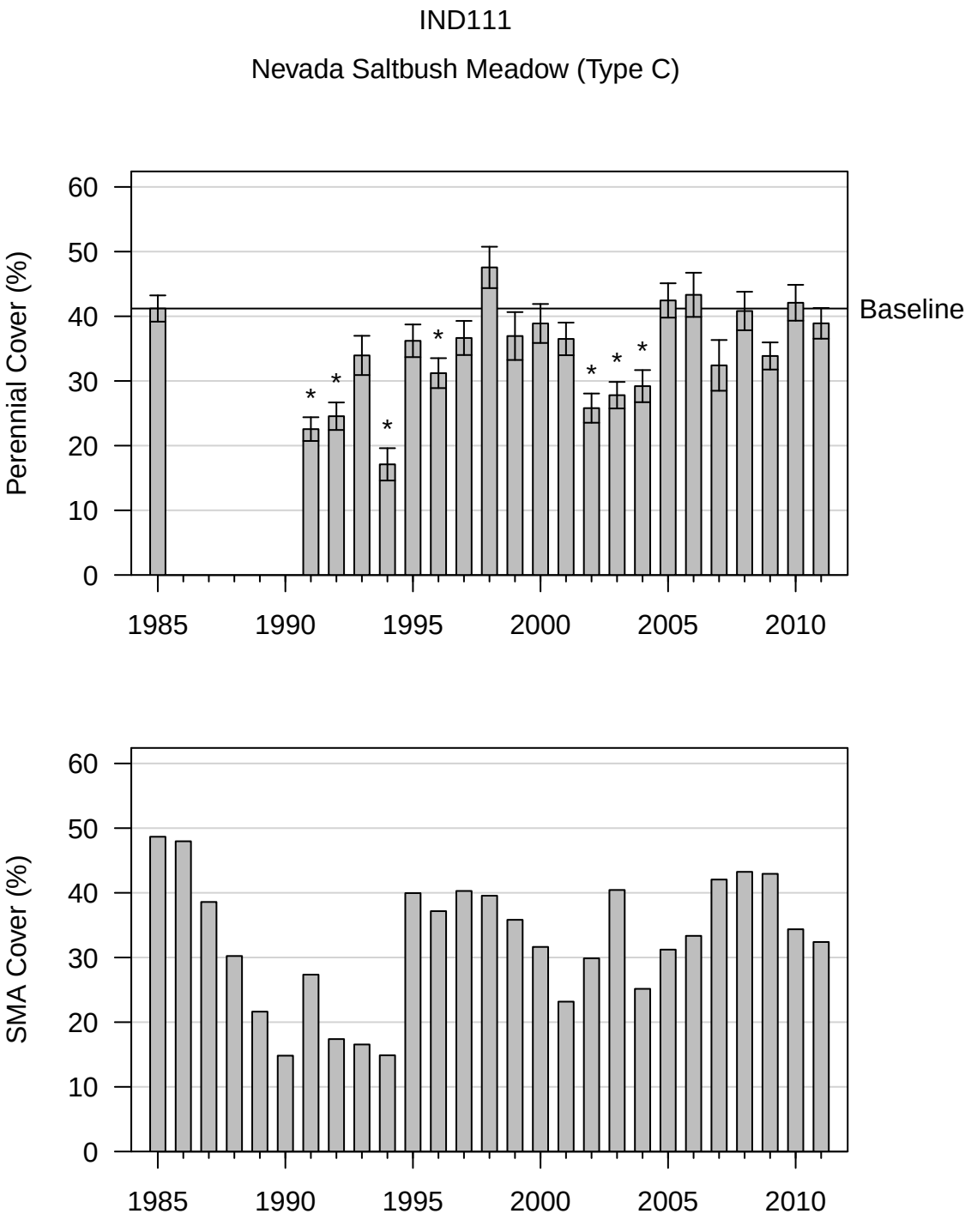


Figure 73: 2011 Wellfield

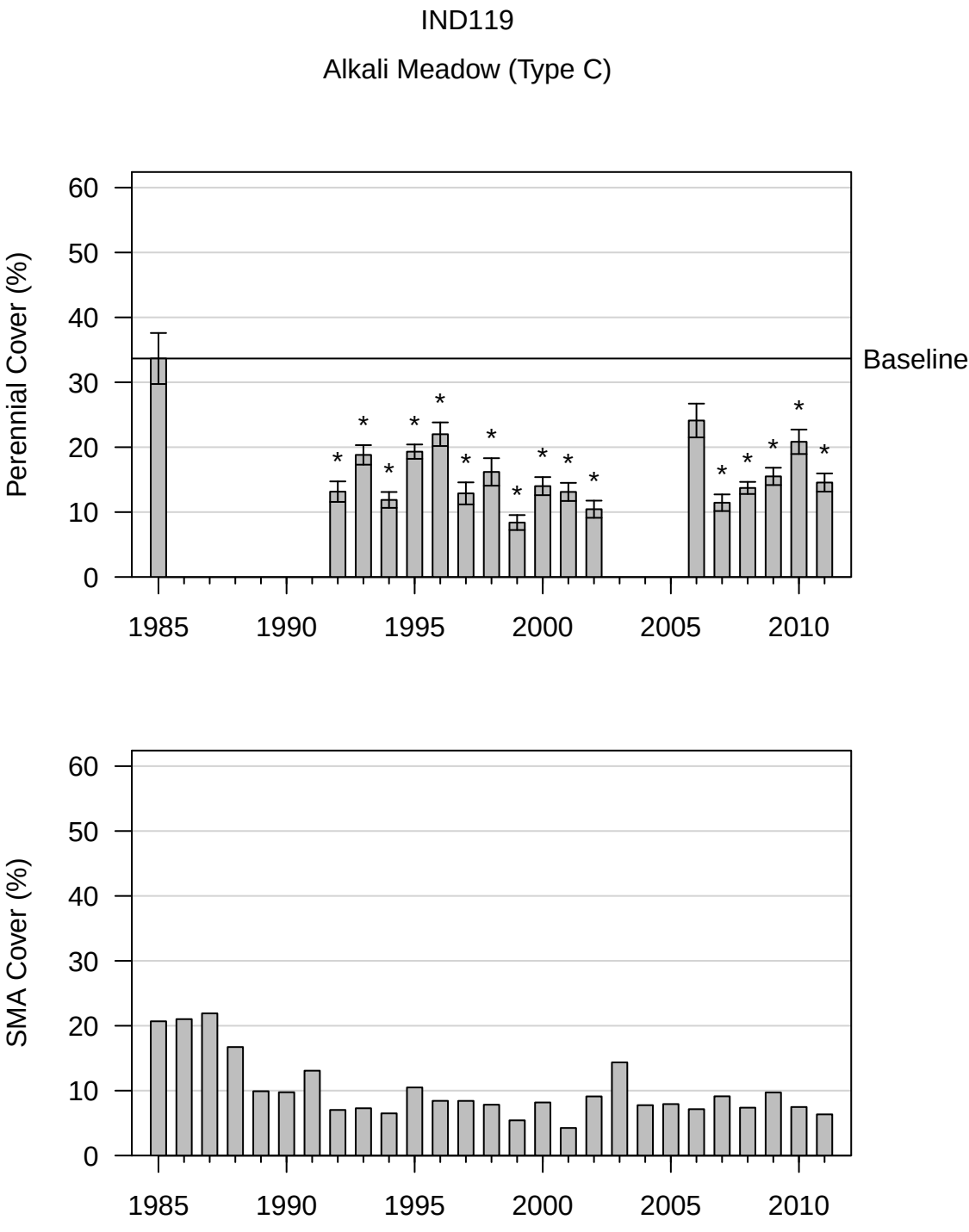


Figure 74: 2011 Control

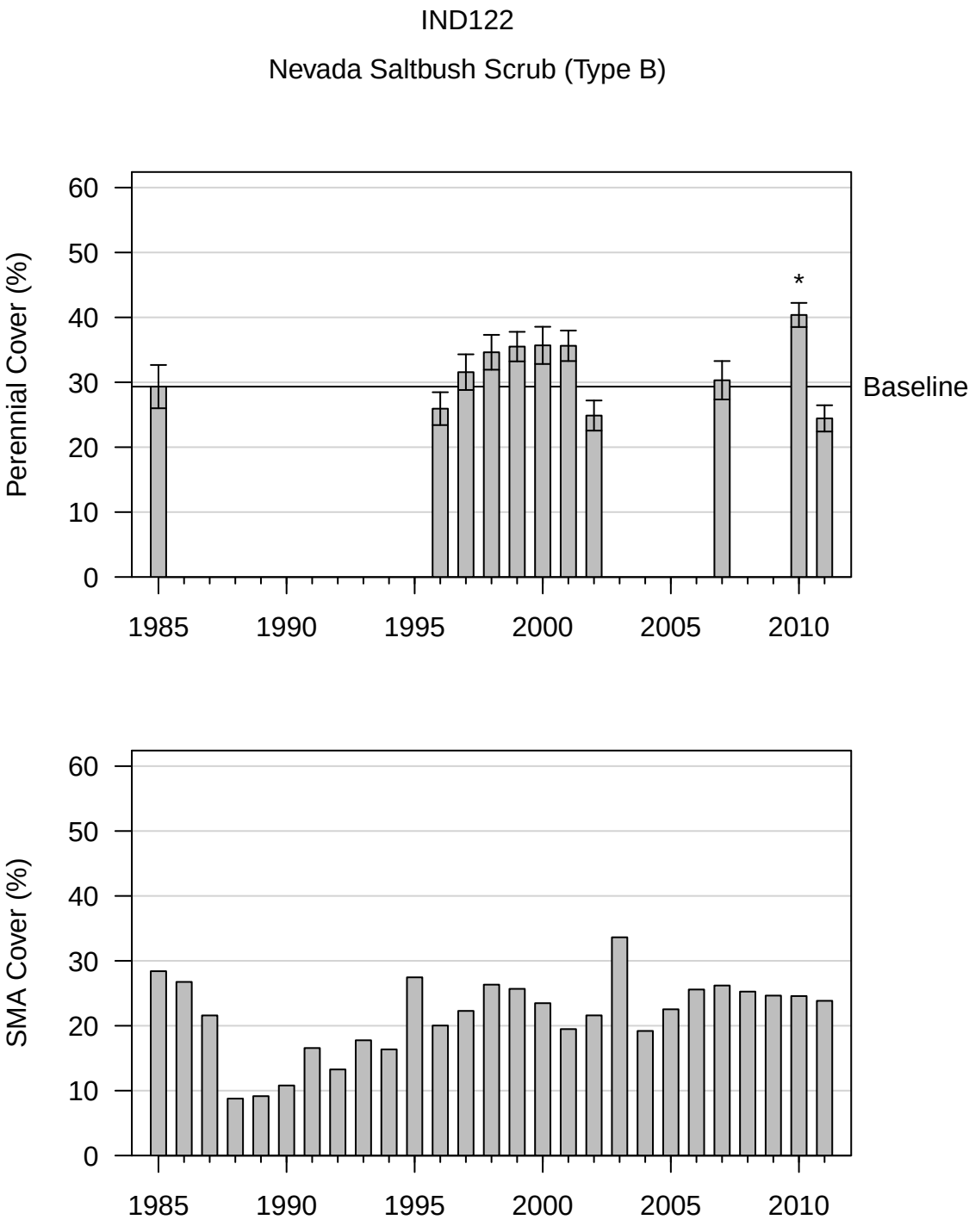


Figure 75: 2011 Control

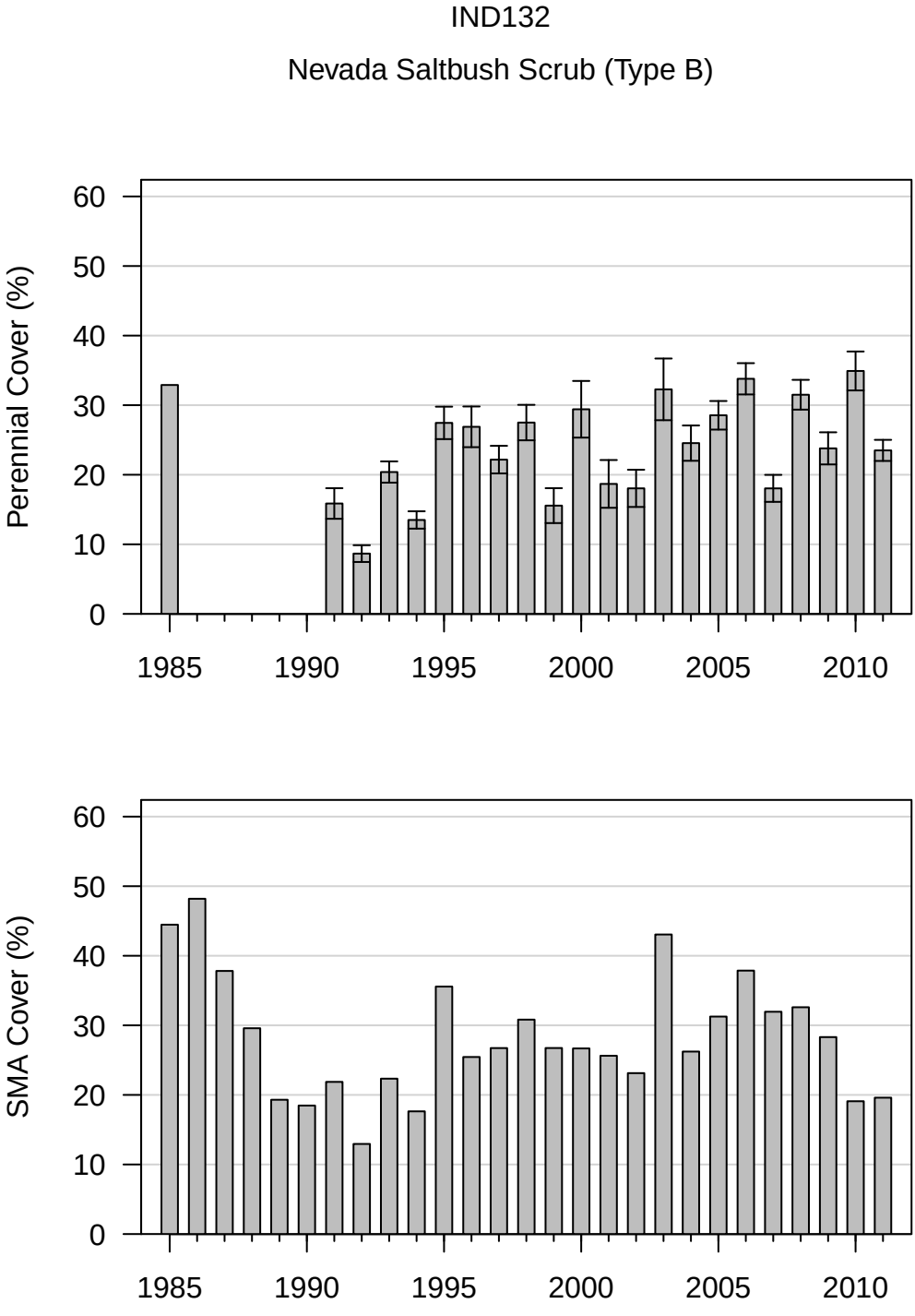
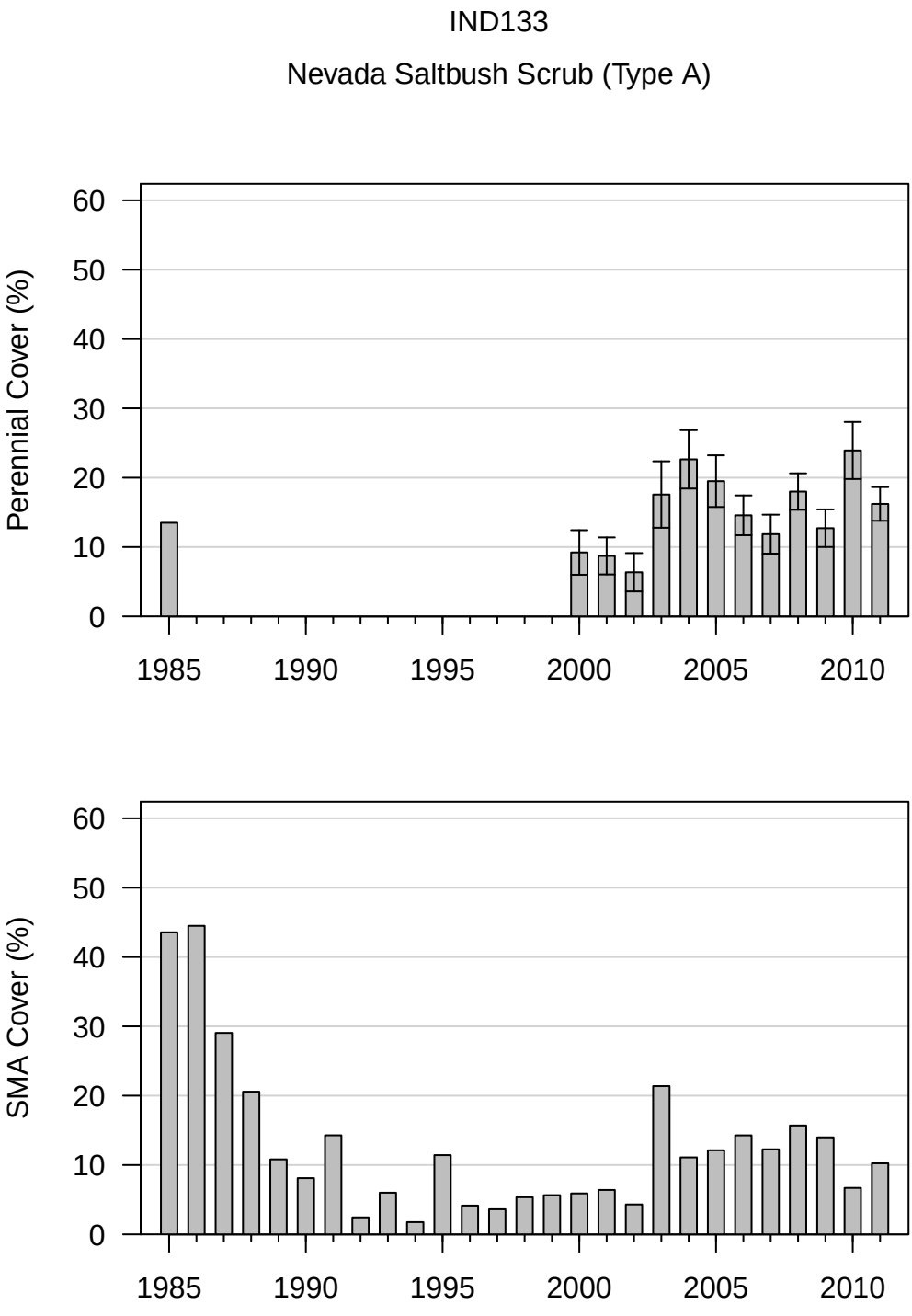


Figure 76: 2011 Wellfield



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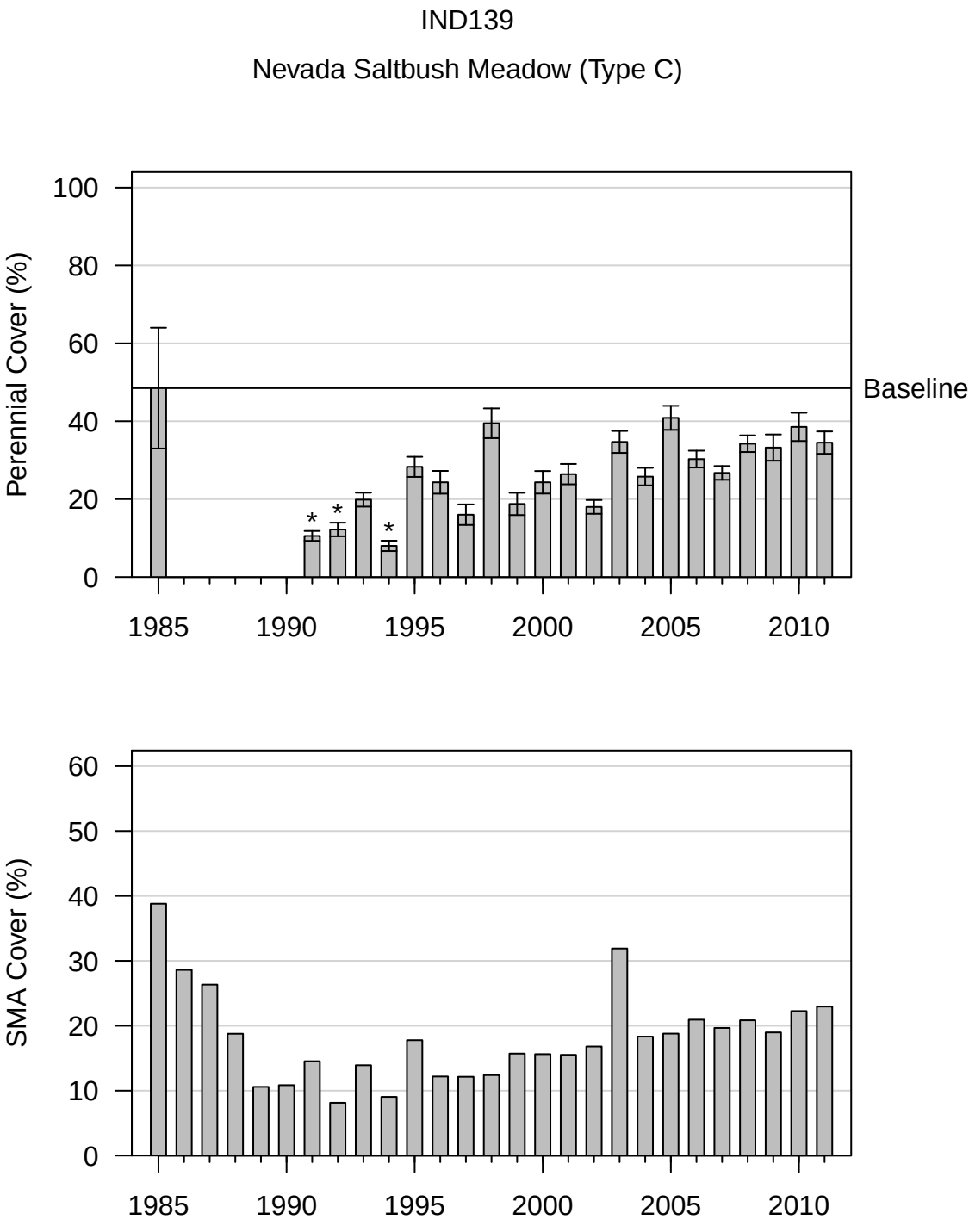


Figure 78: 2011 Wellfield

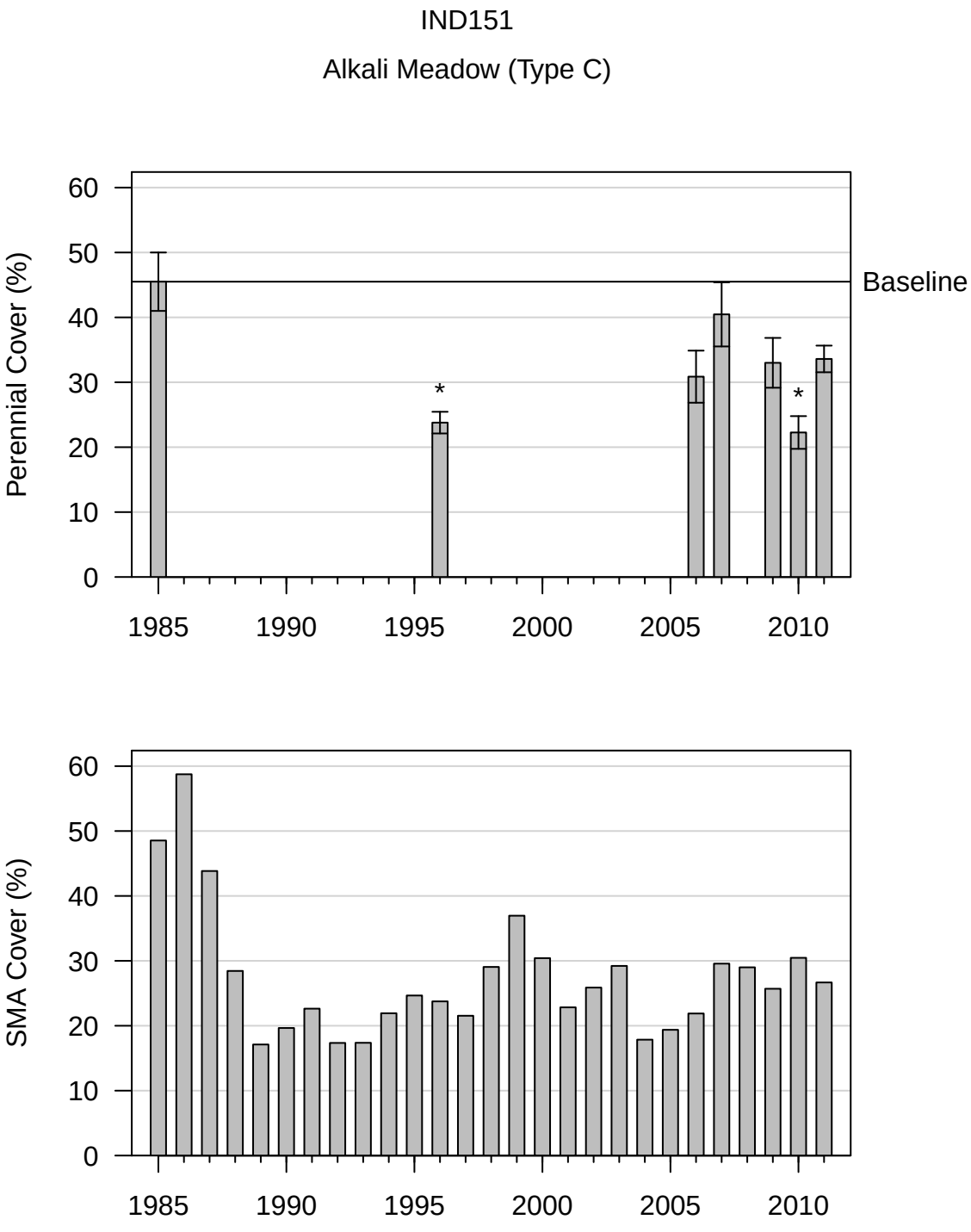


Figure 79: 2011 Control

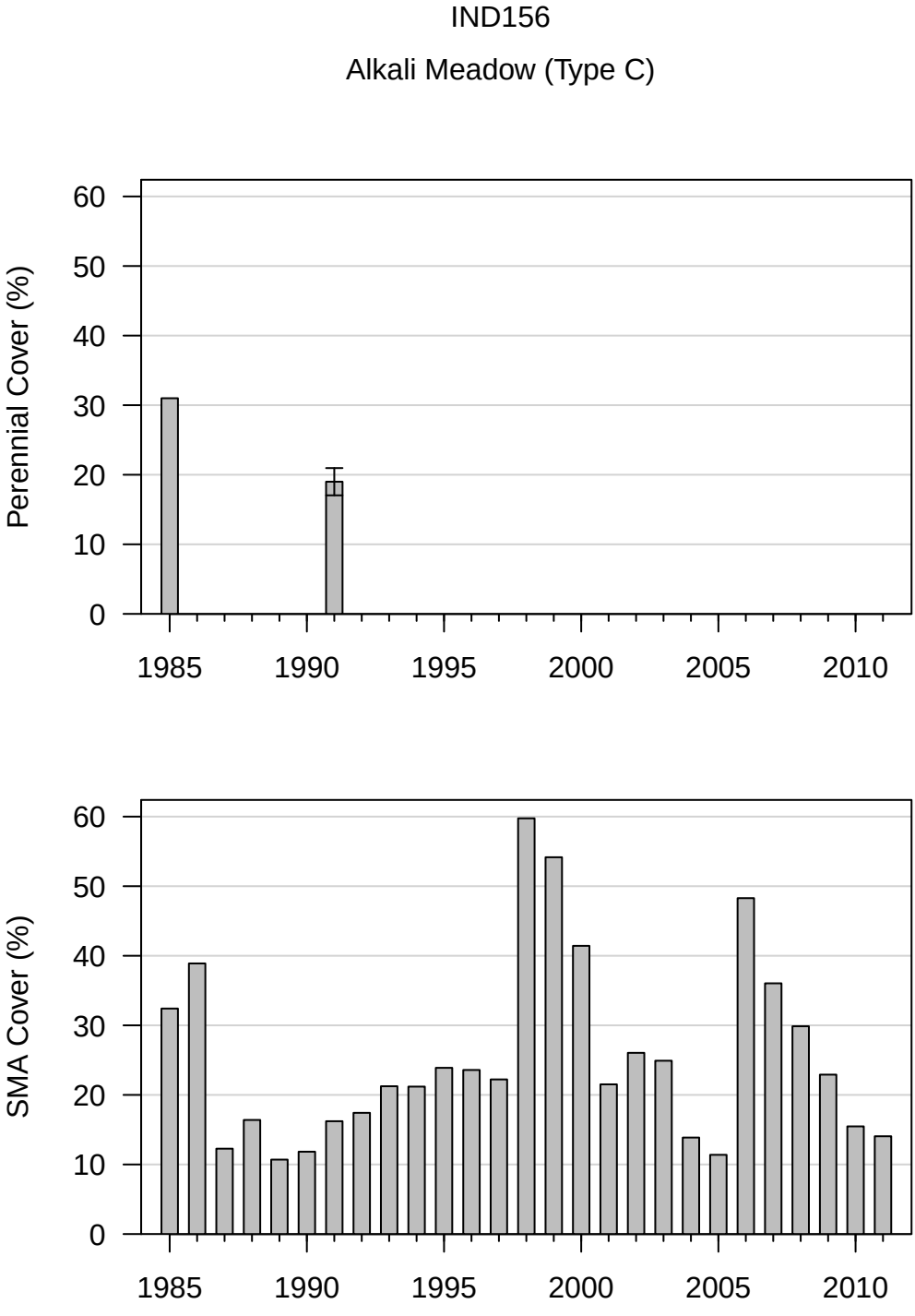
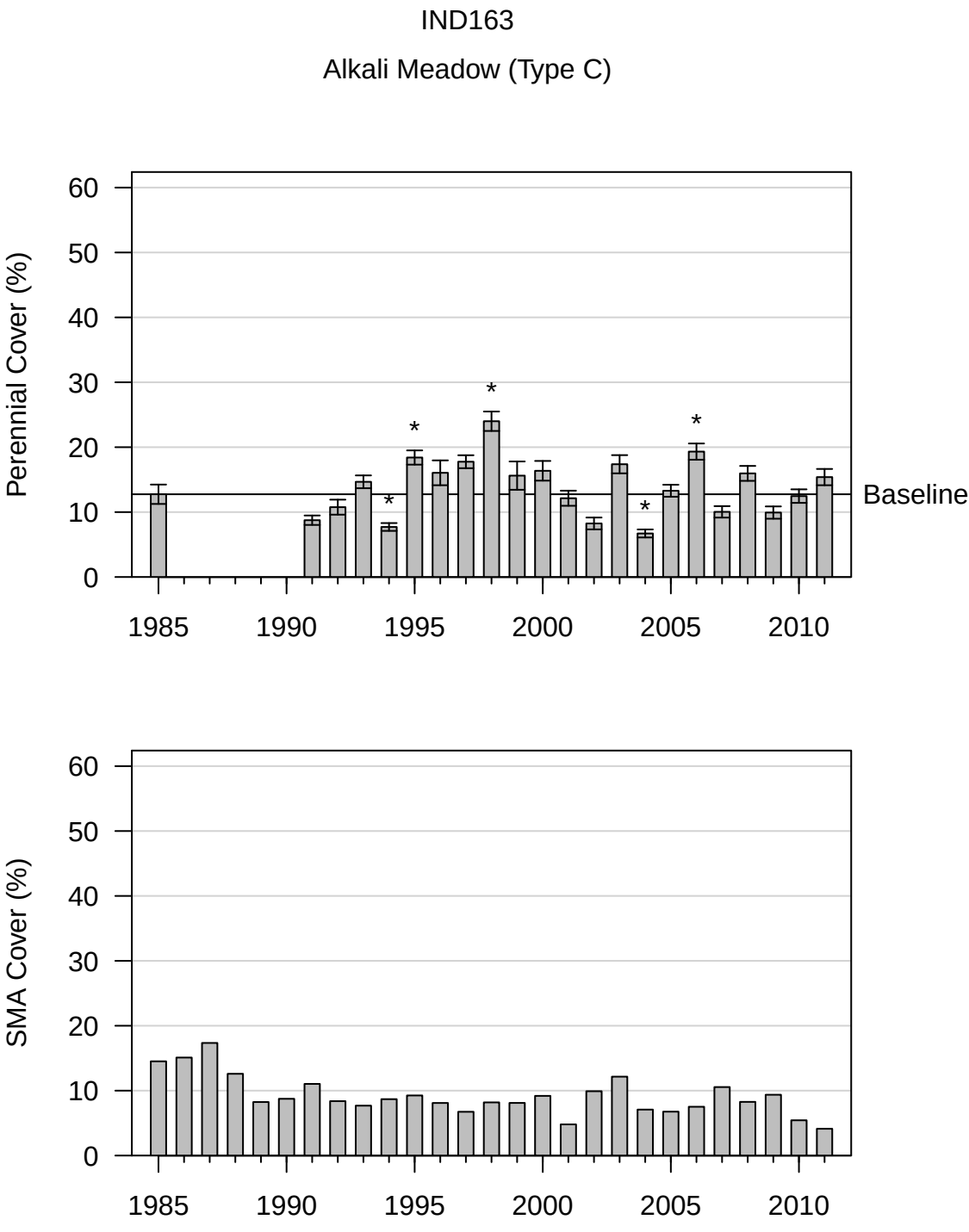


Figure 80: 1991 Control



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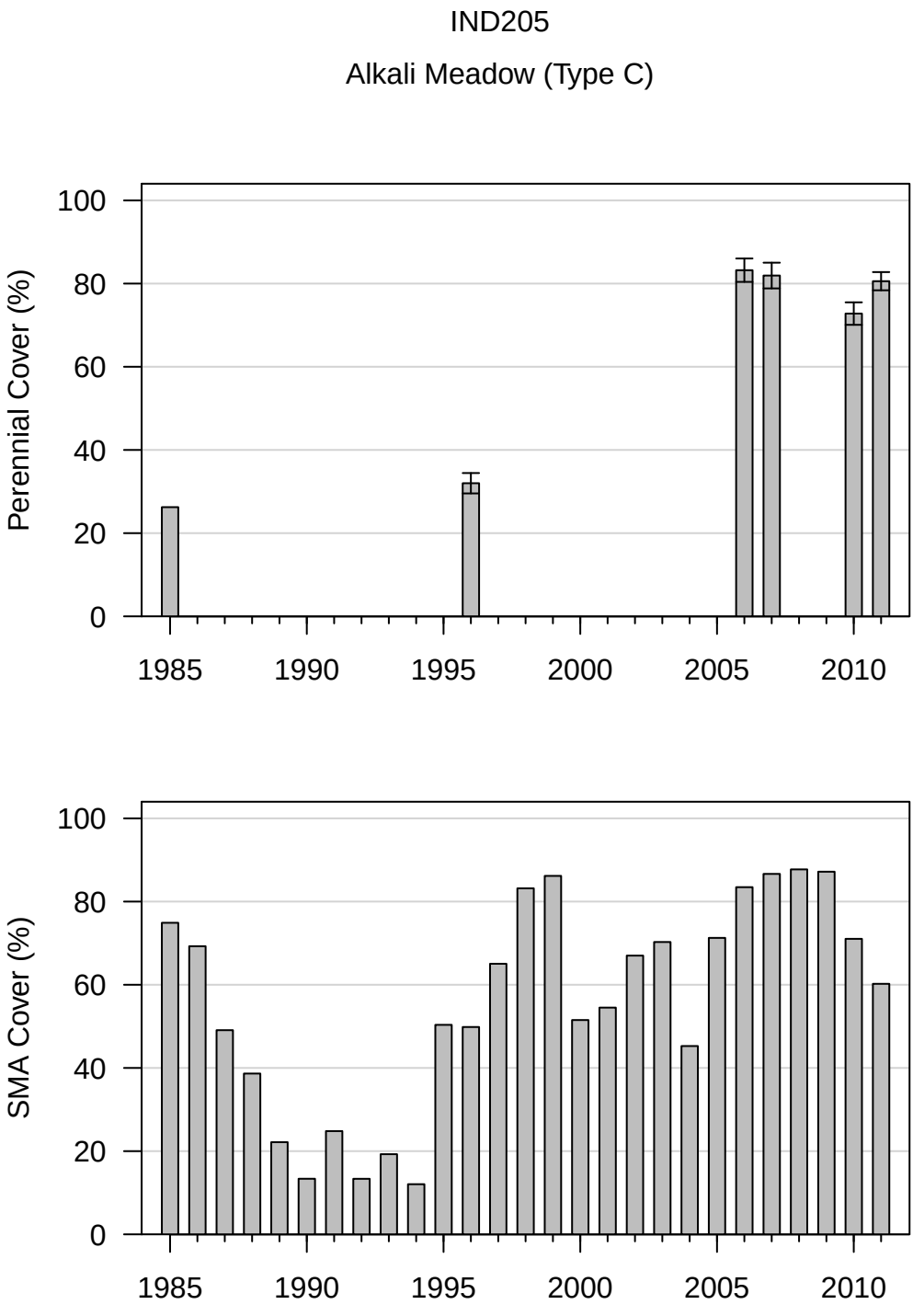


Figure 82: 2011 Wellfield

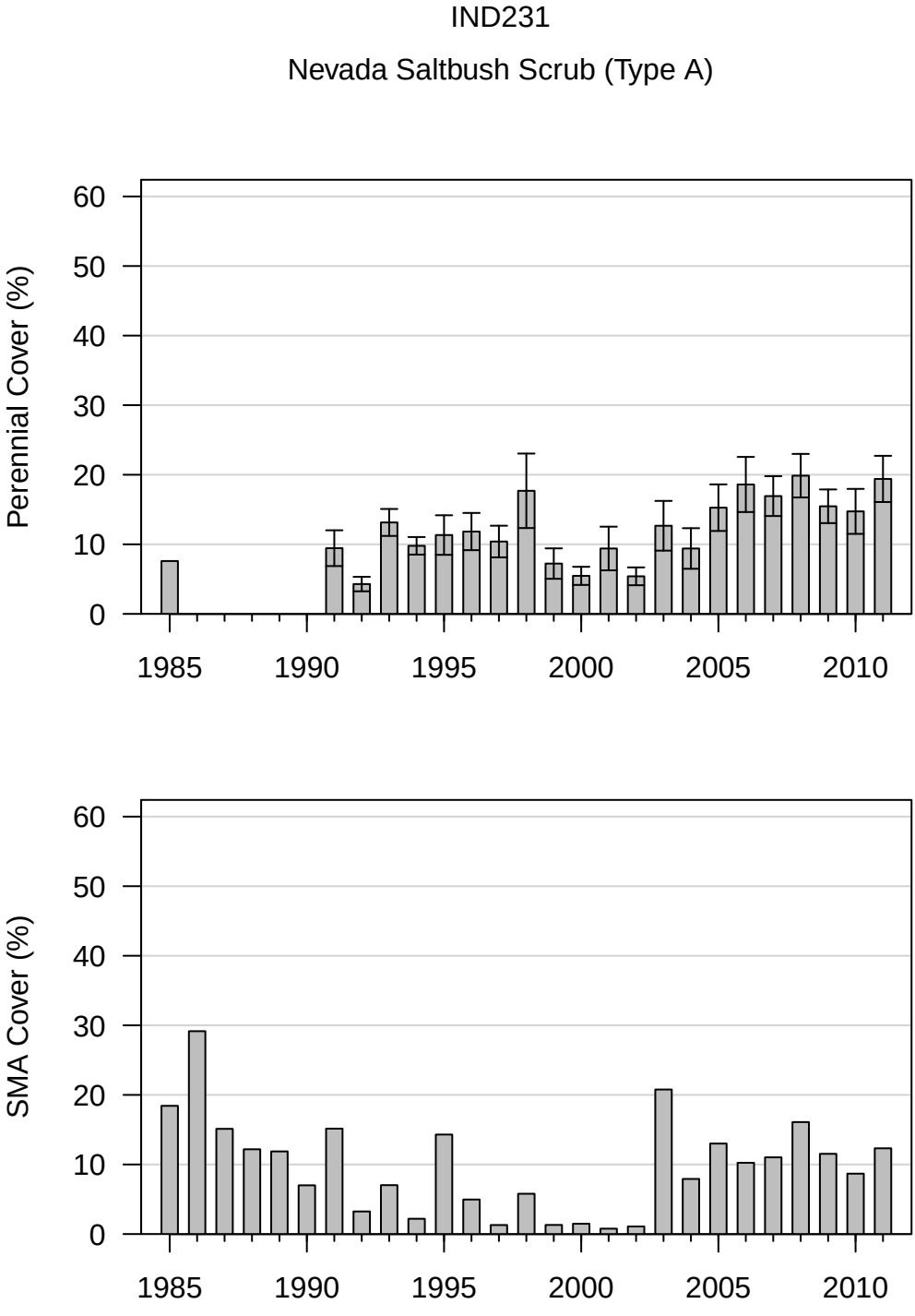


Figure 83: 2011 Wellfield

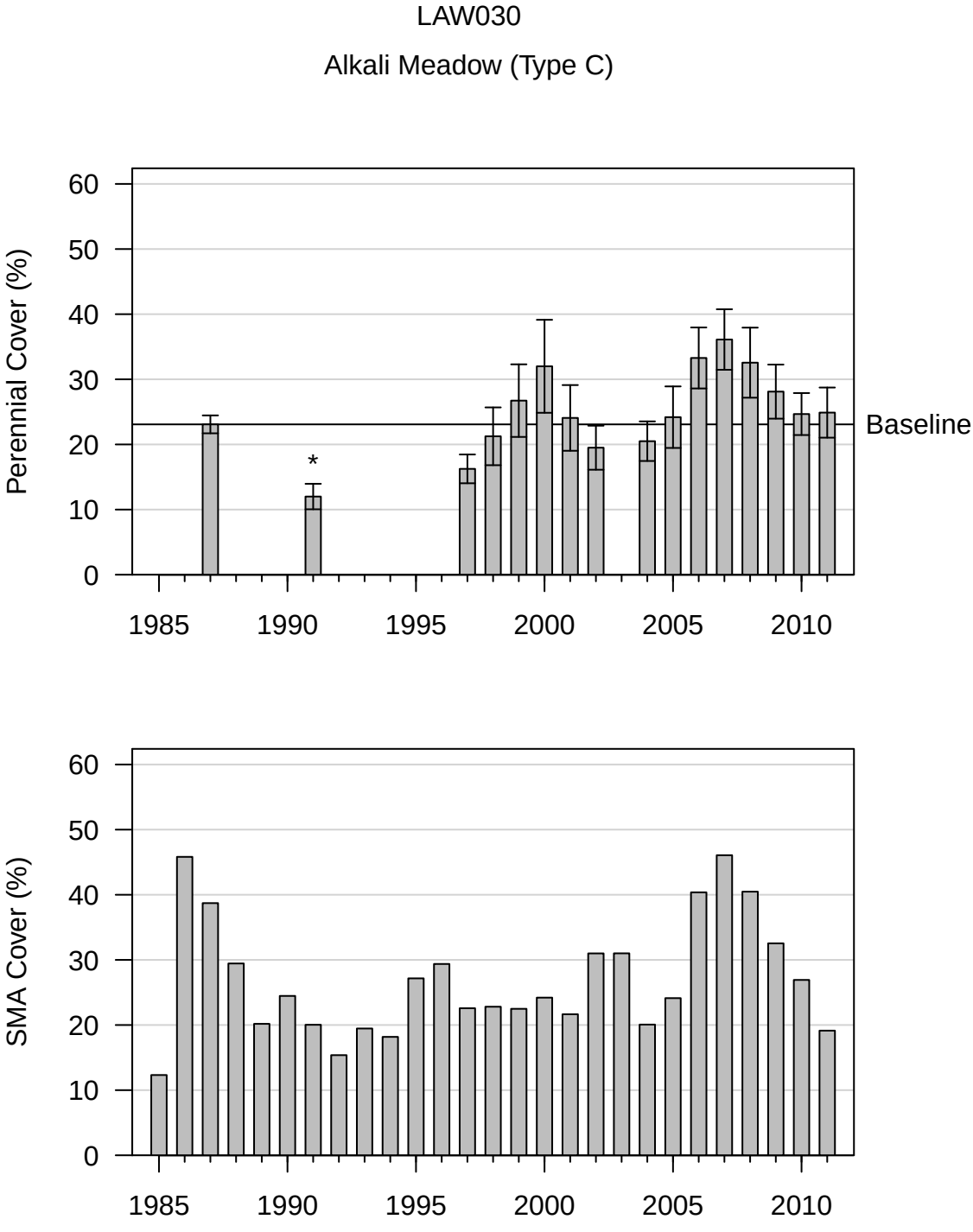


Figure 84: 2011 Wellfield

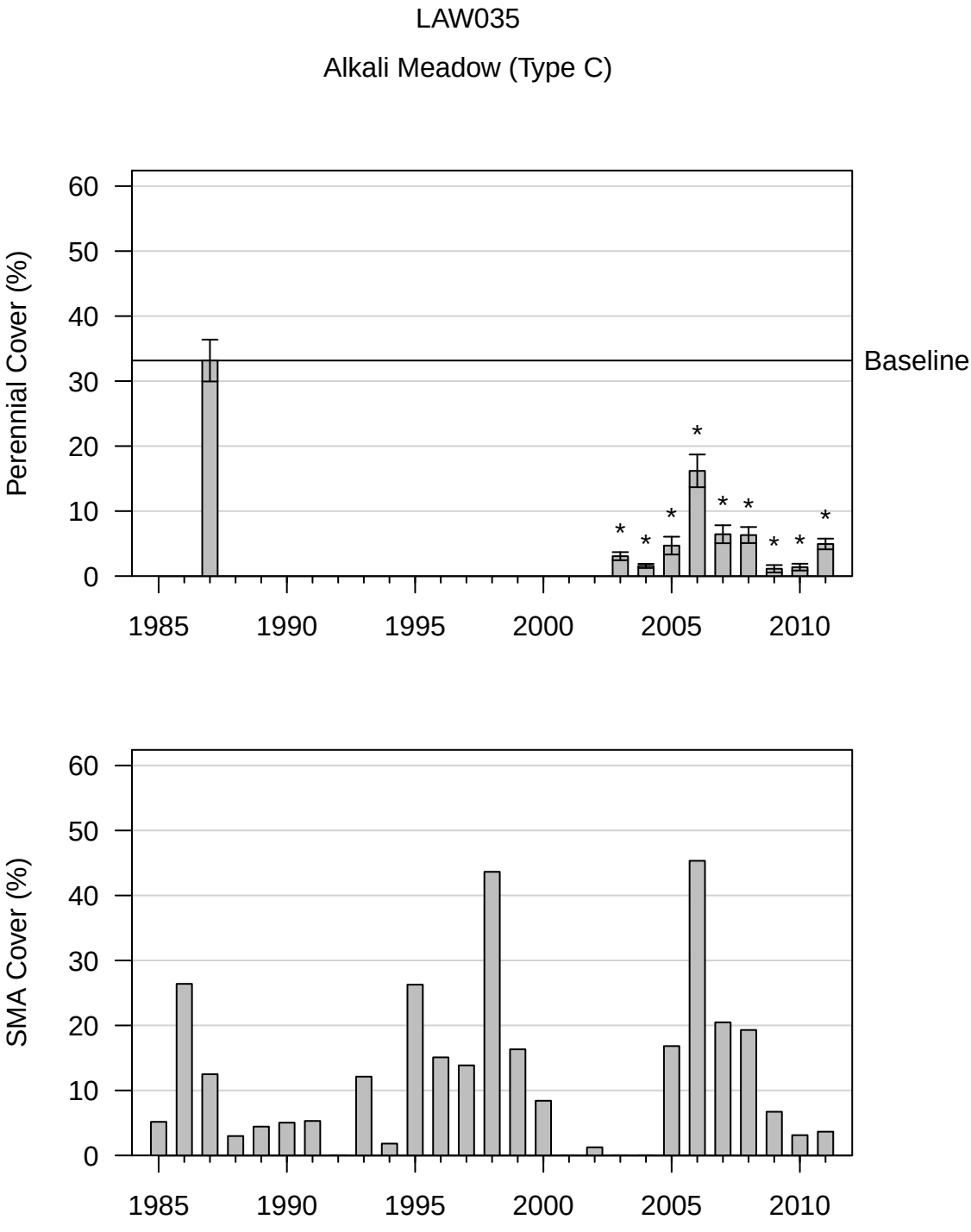


Figure 85: 2011 Wellfield

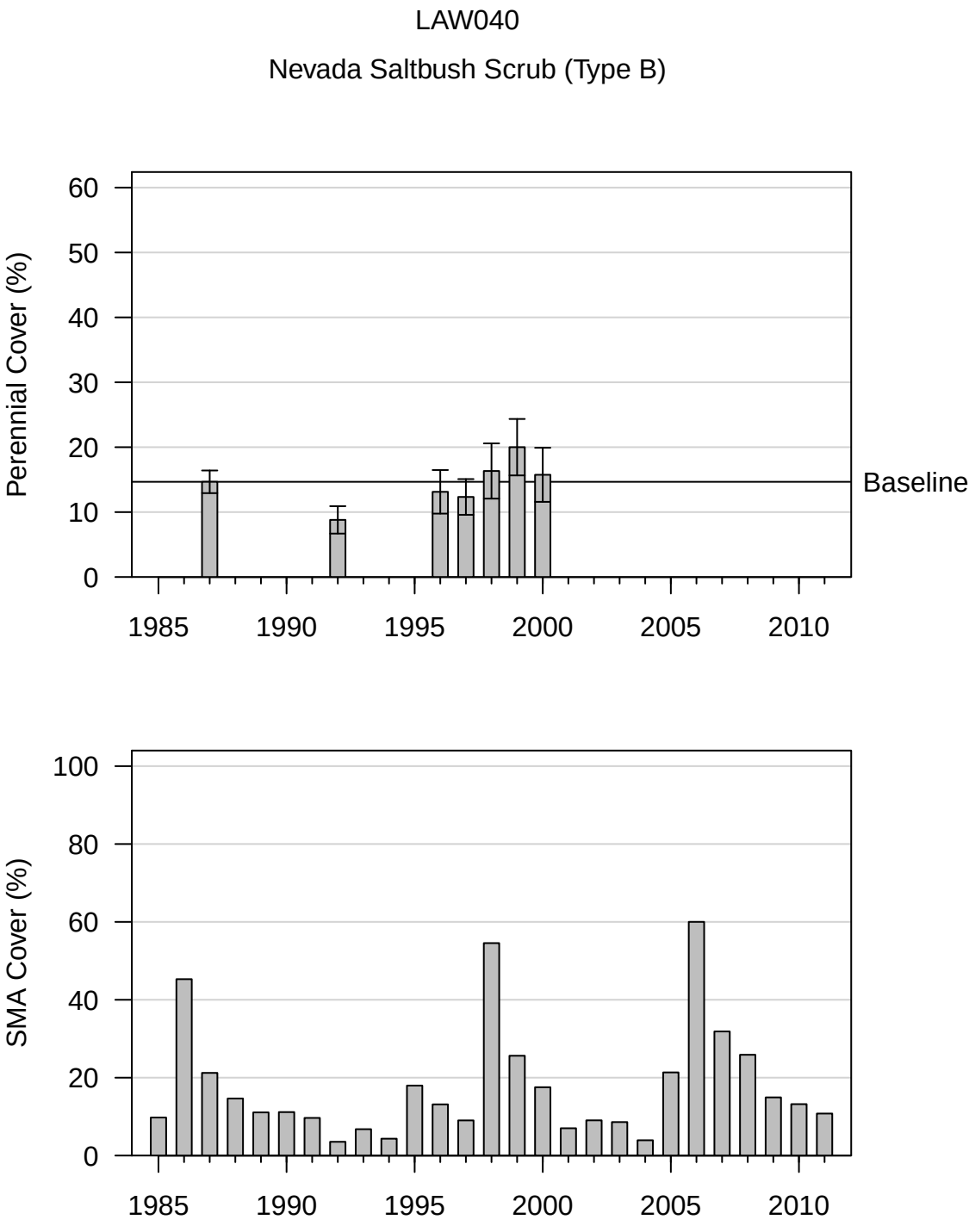


Figure 86: 2000 Wellfield

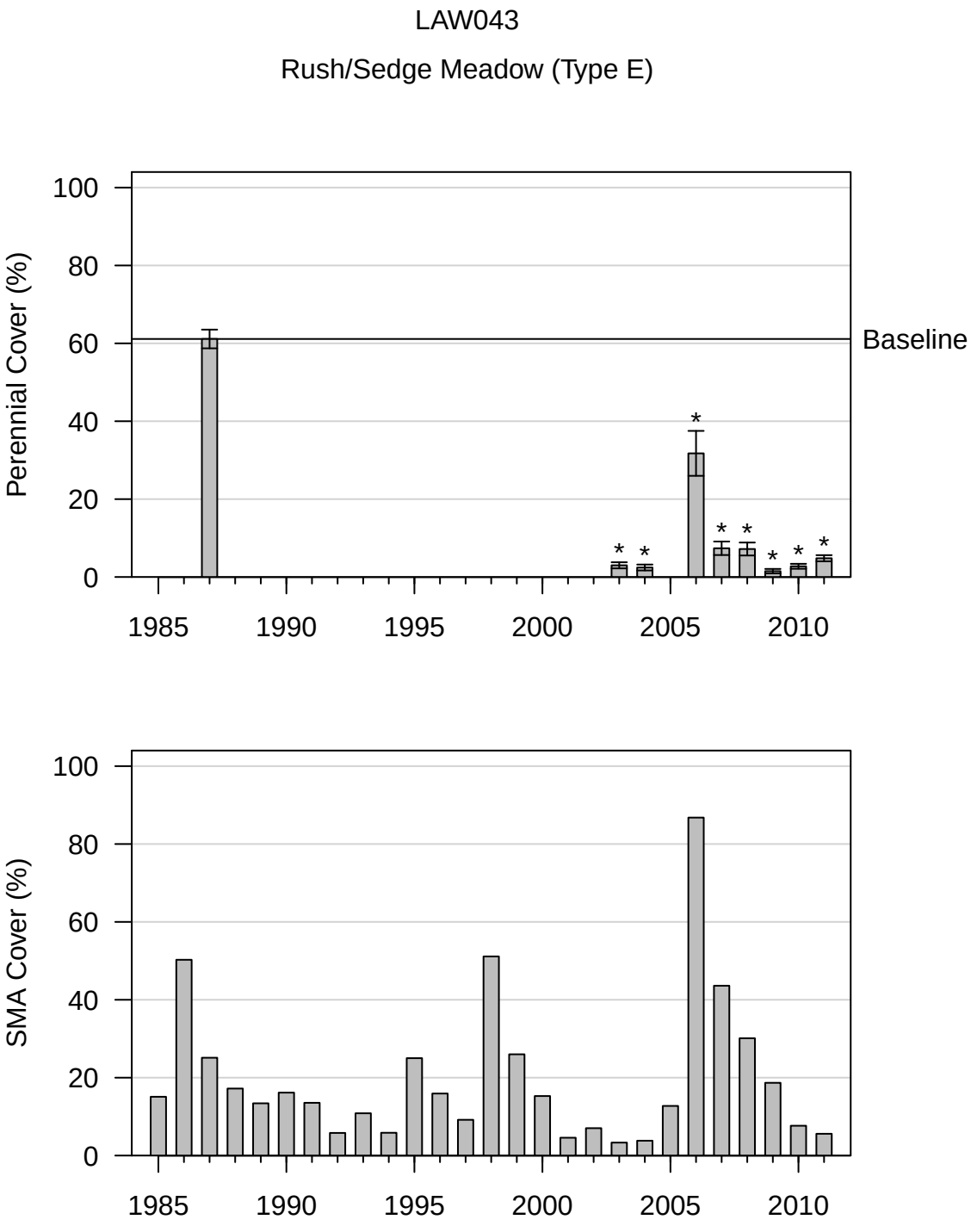
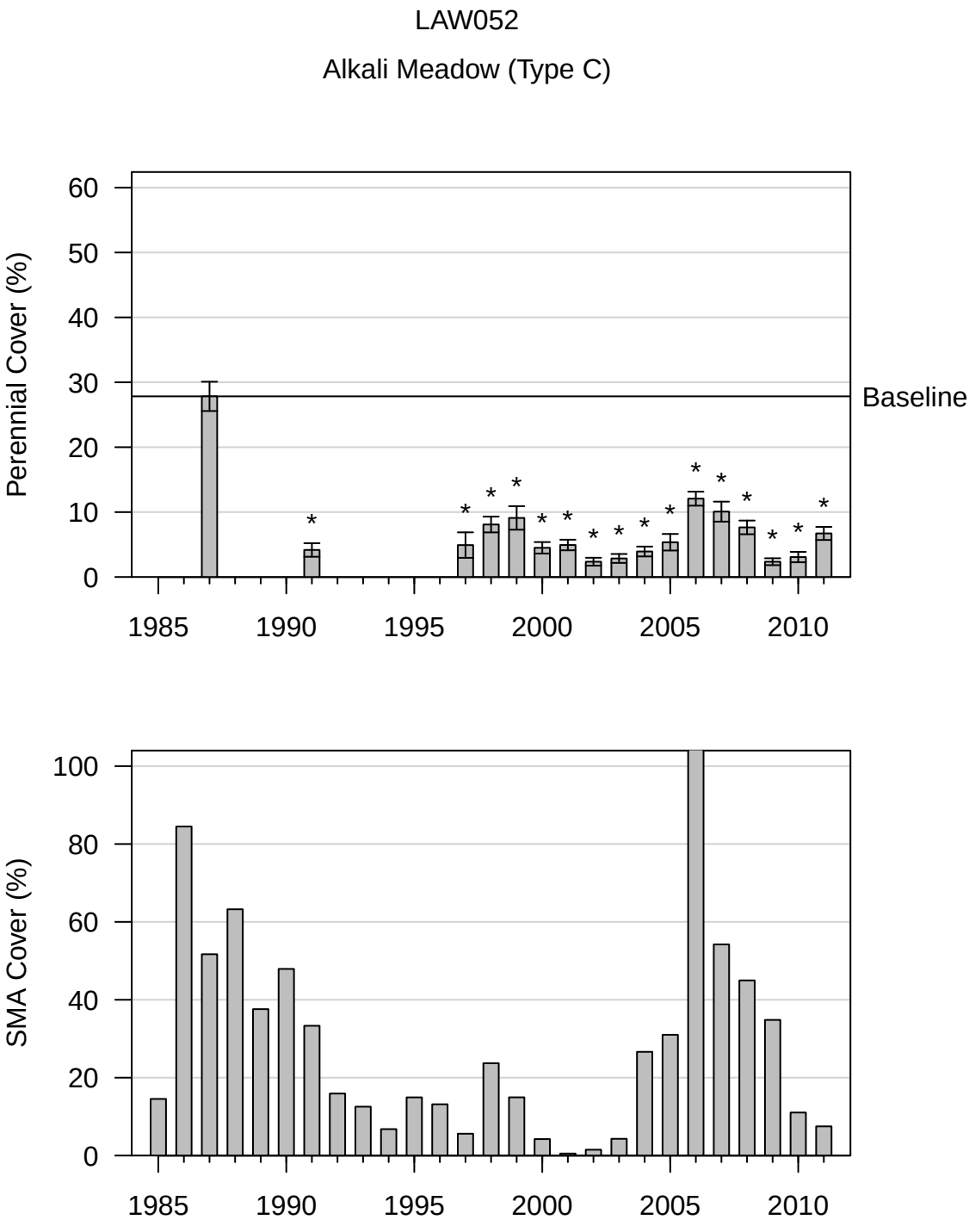


Figure 87: 2011 Wellfield



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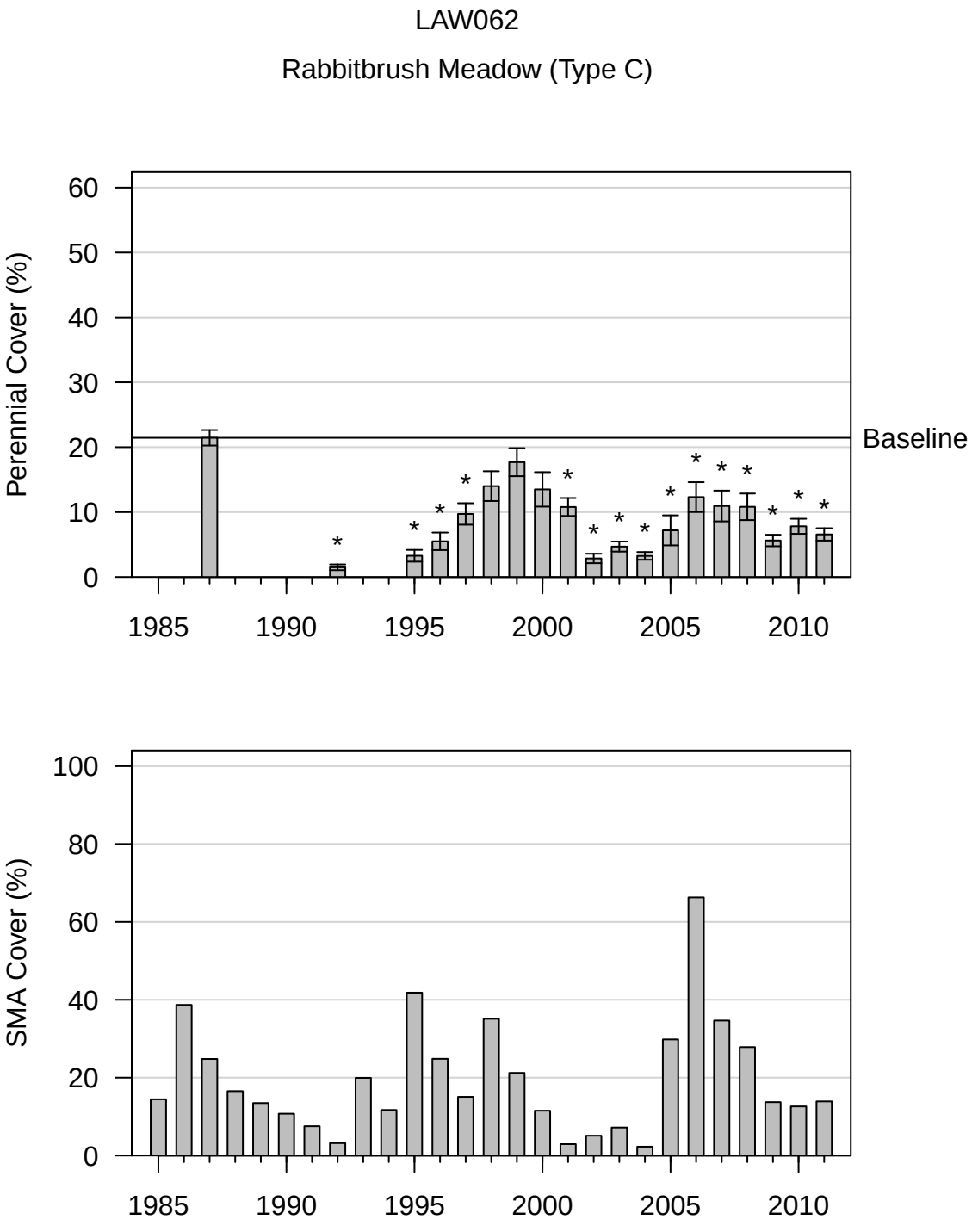

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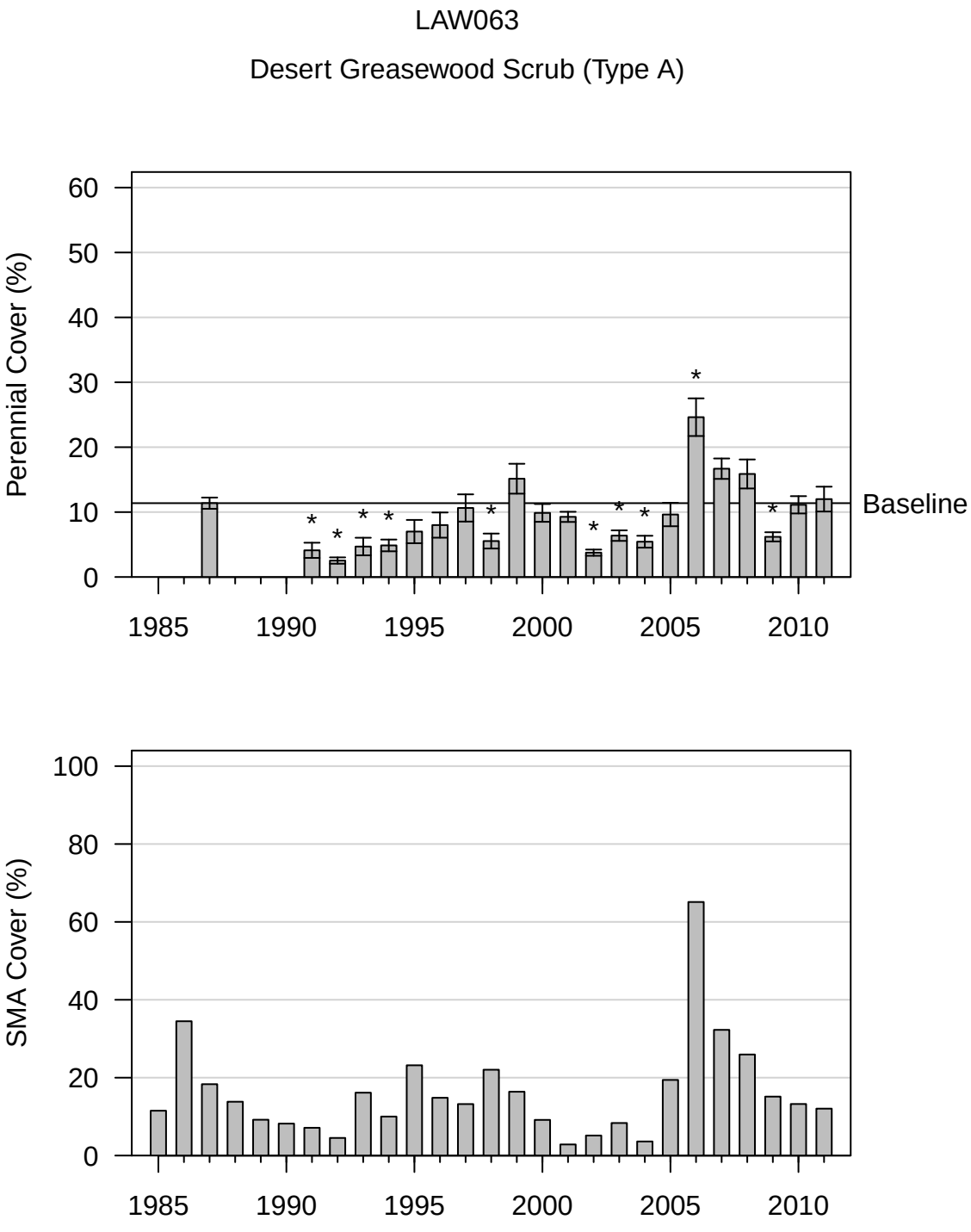

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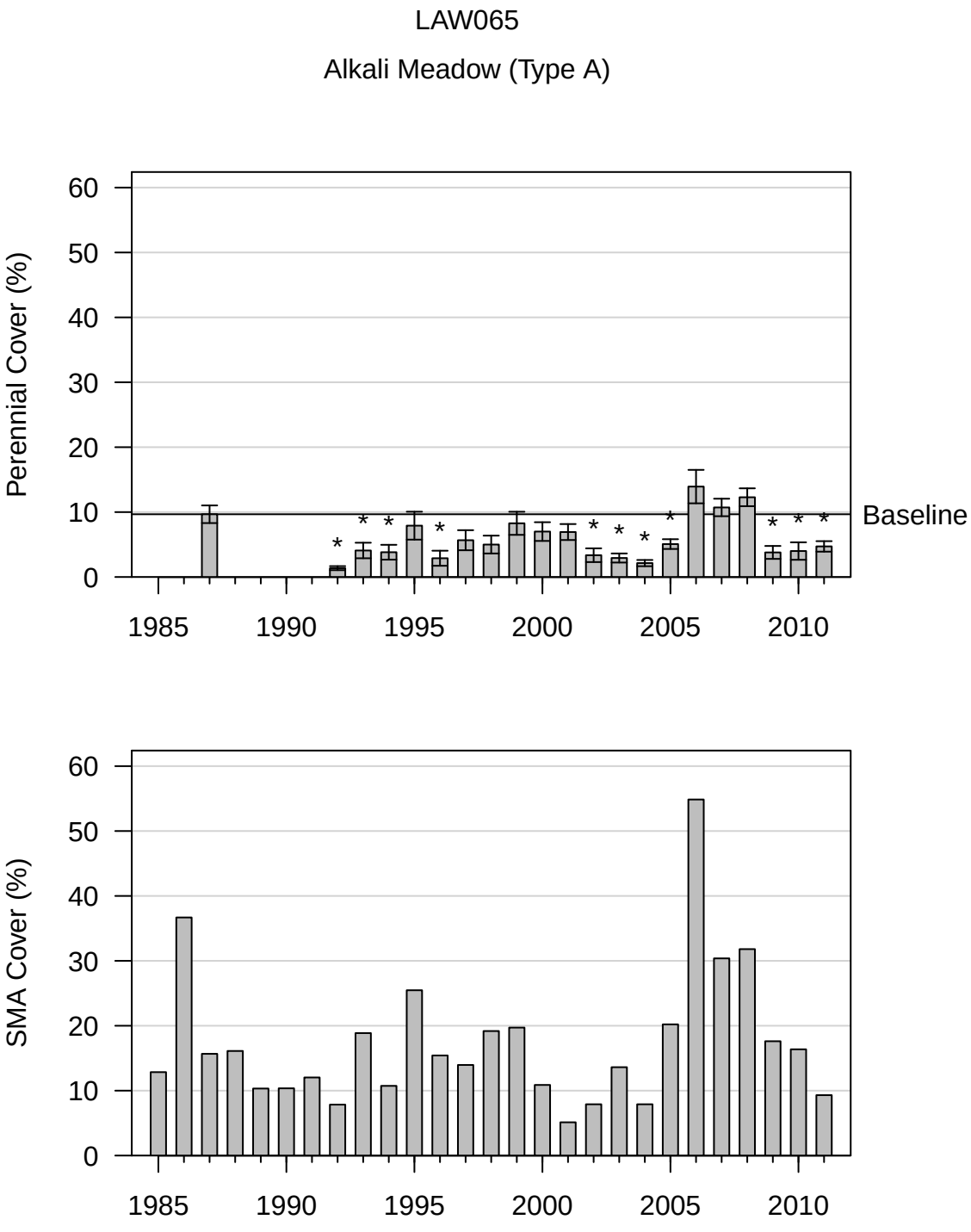


Figure 91: 2011 Wellfield

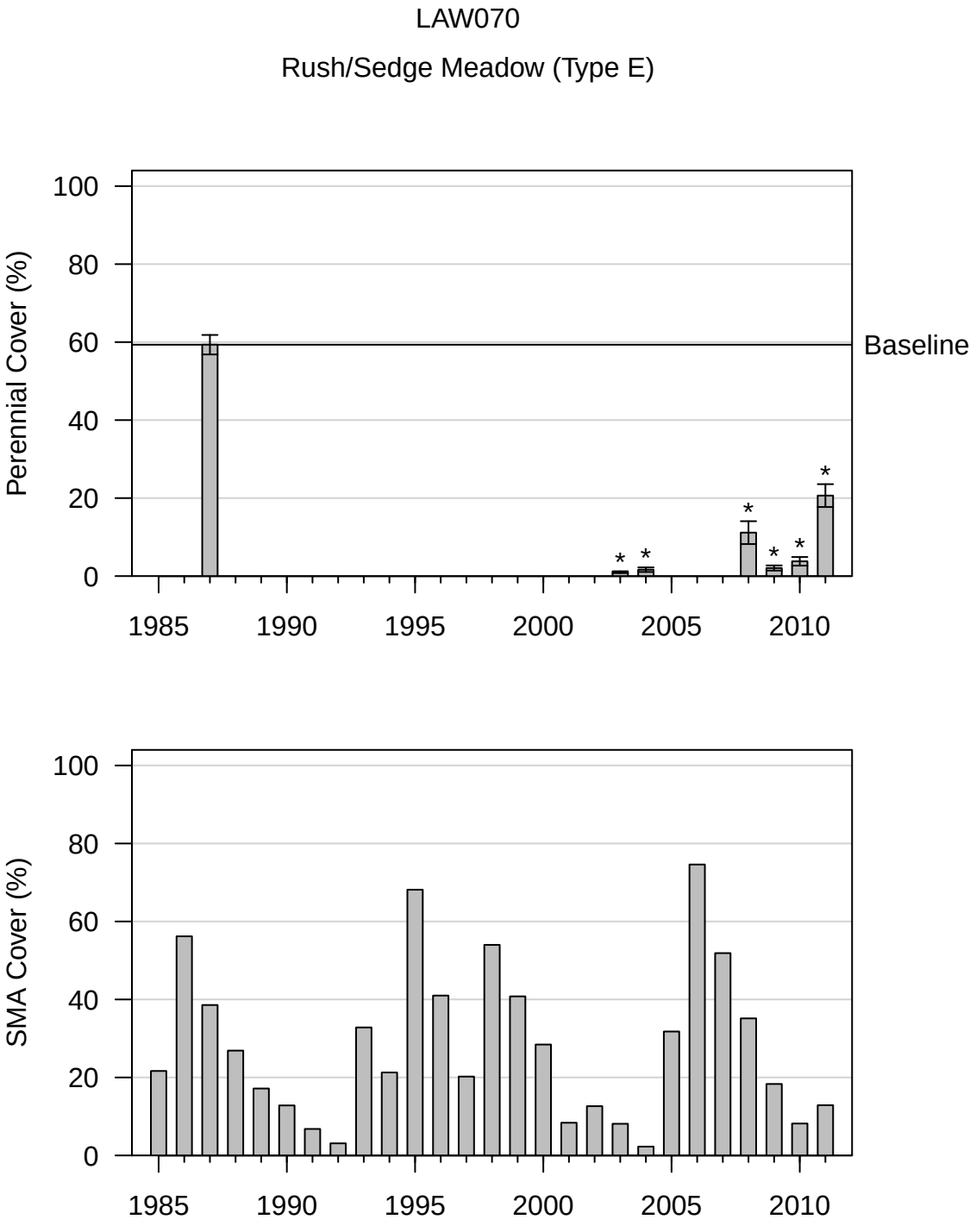


Figure 92: 2011 Wellfield

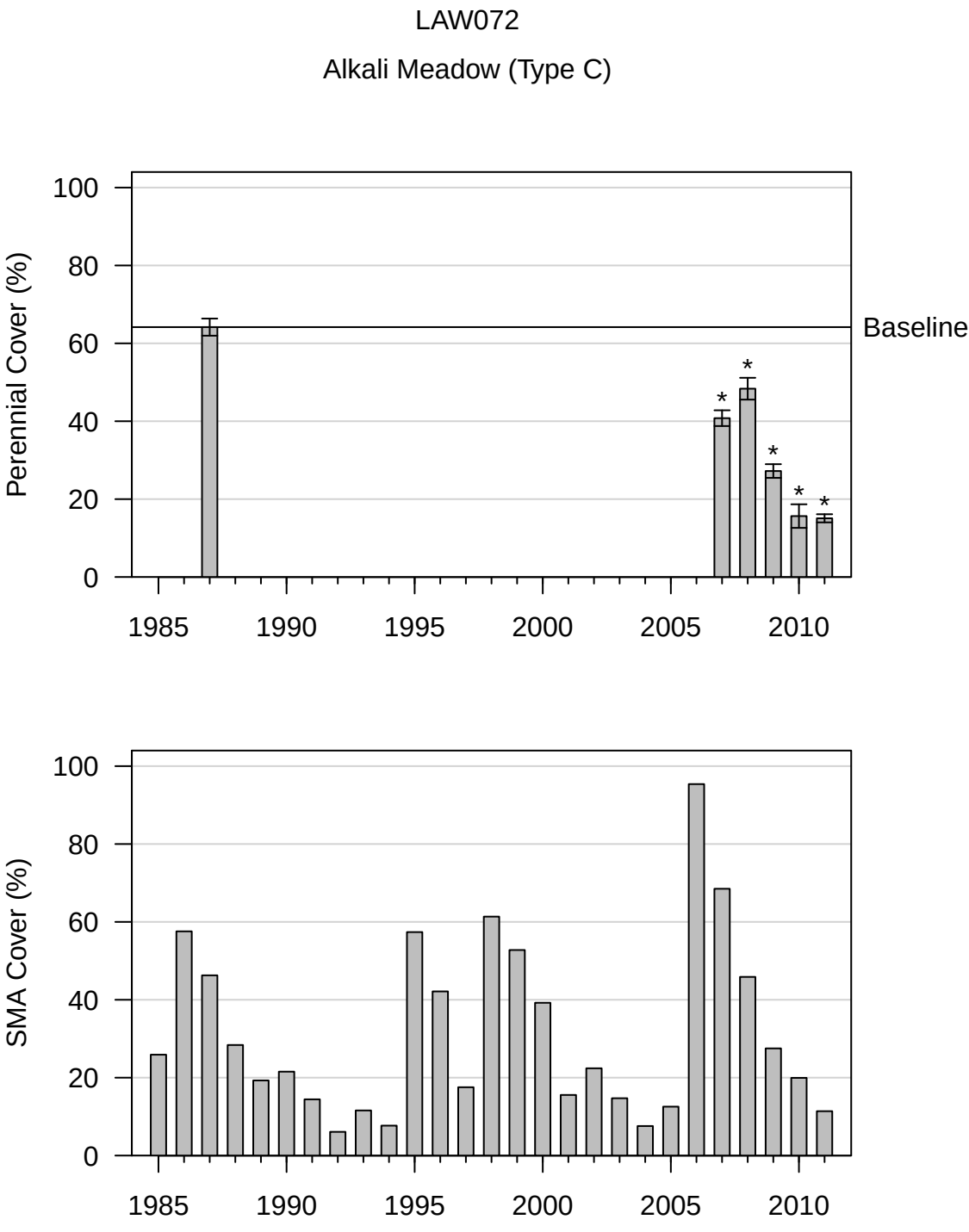


Figure 93: 2011 Wellfield

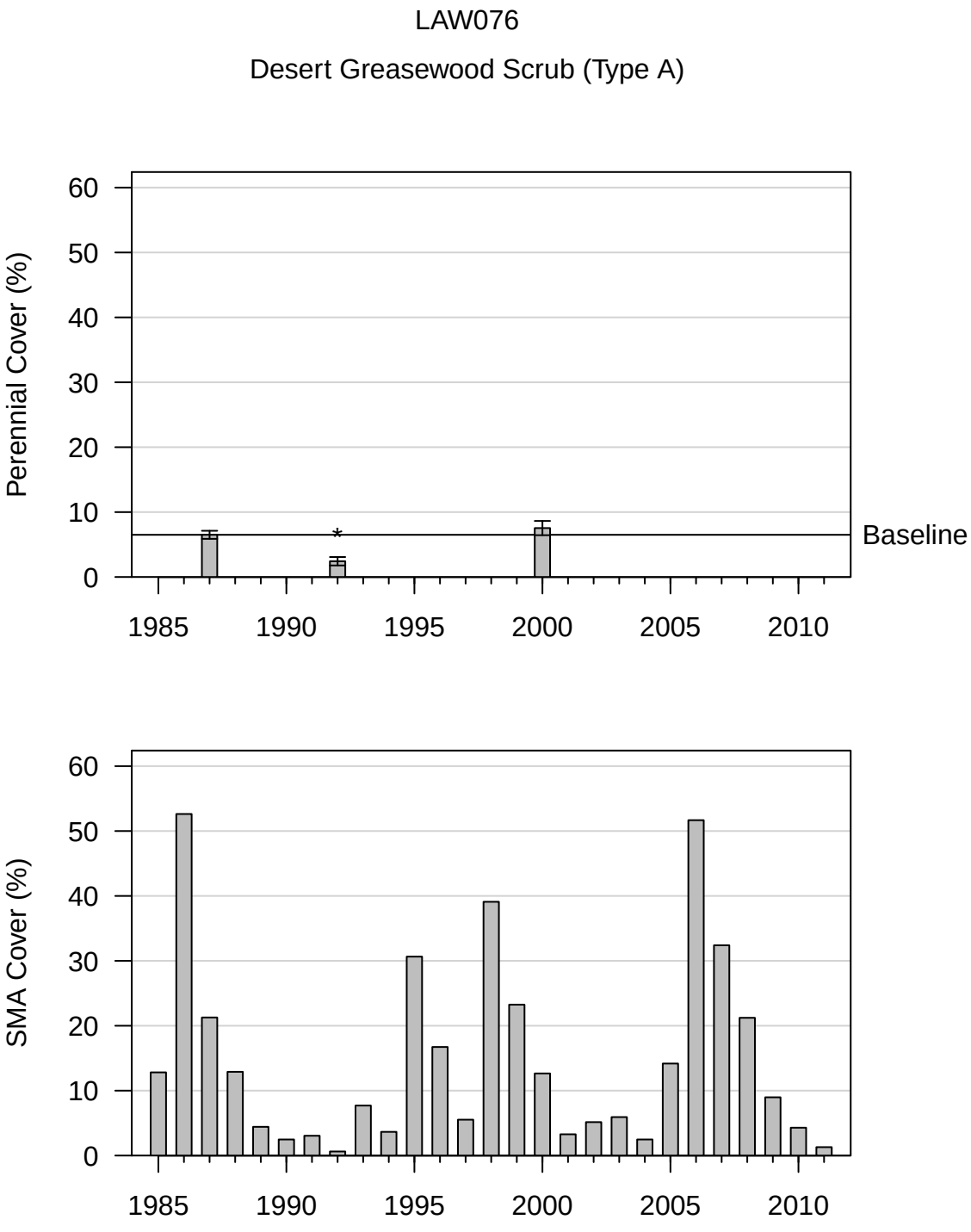


Figure 94: 2000 Wellfield

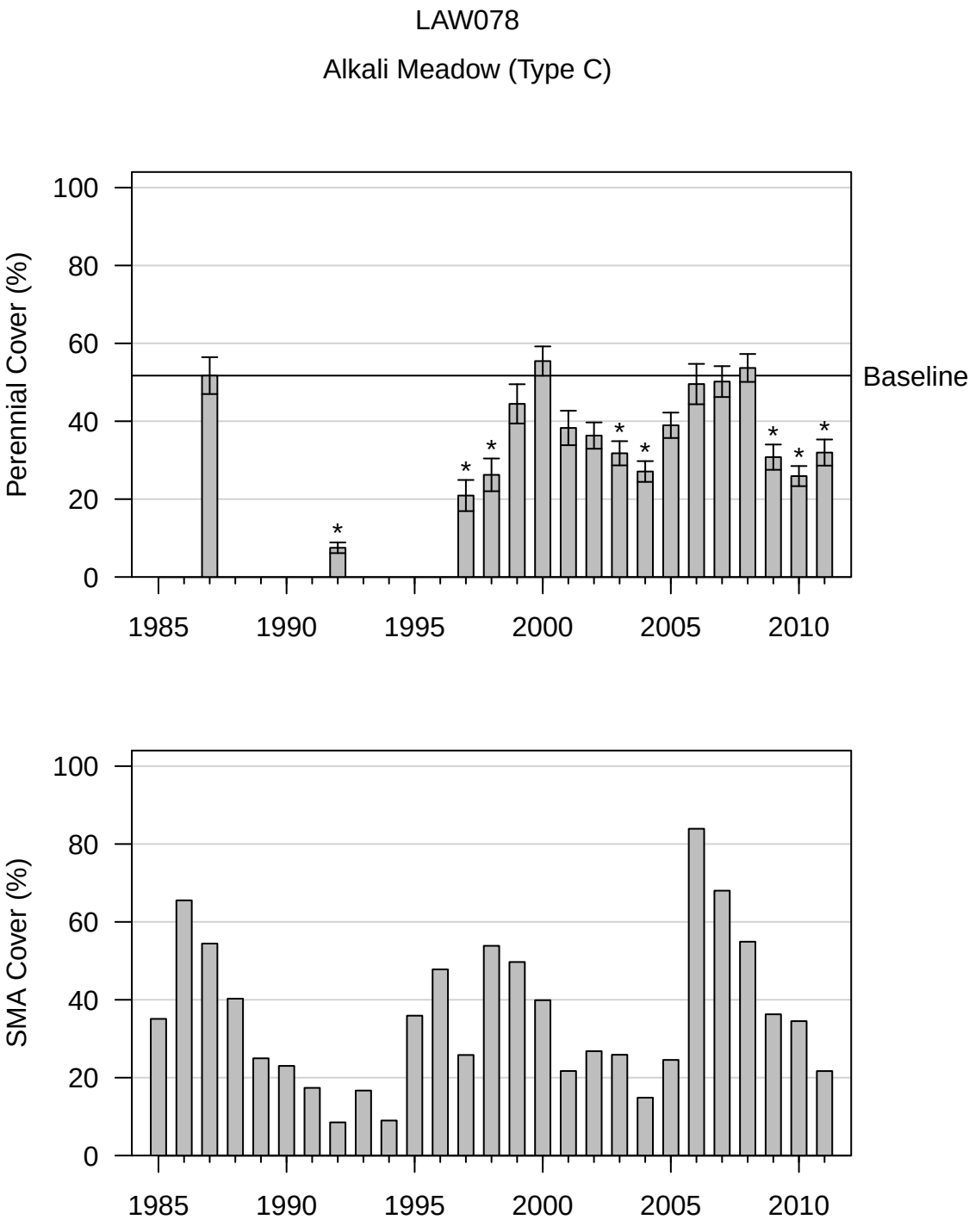
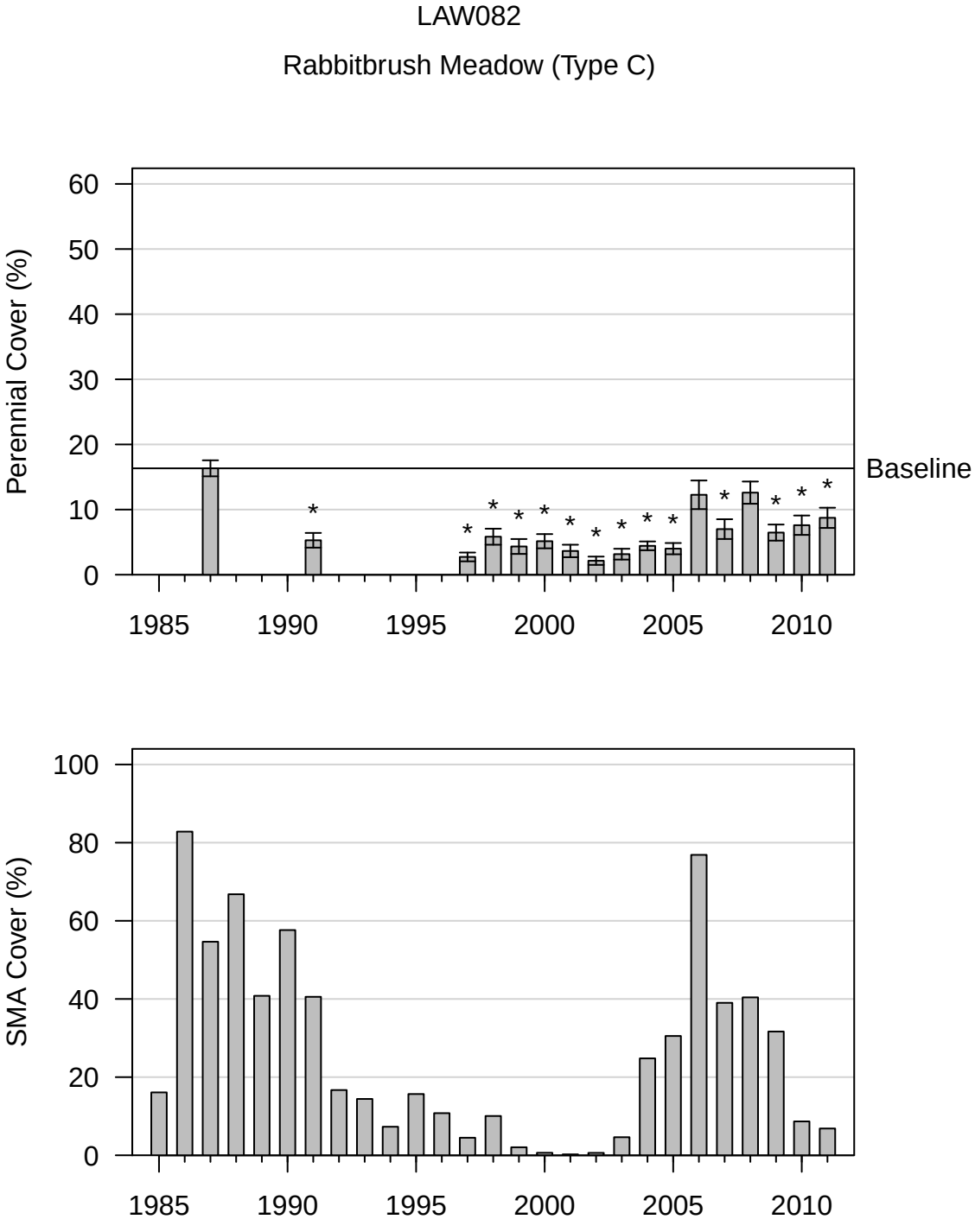


Figure 95: 2011 Wellfield



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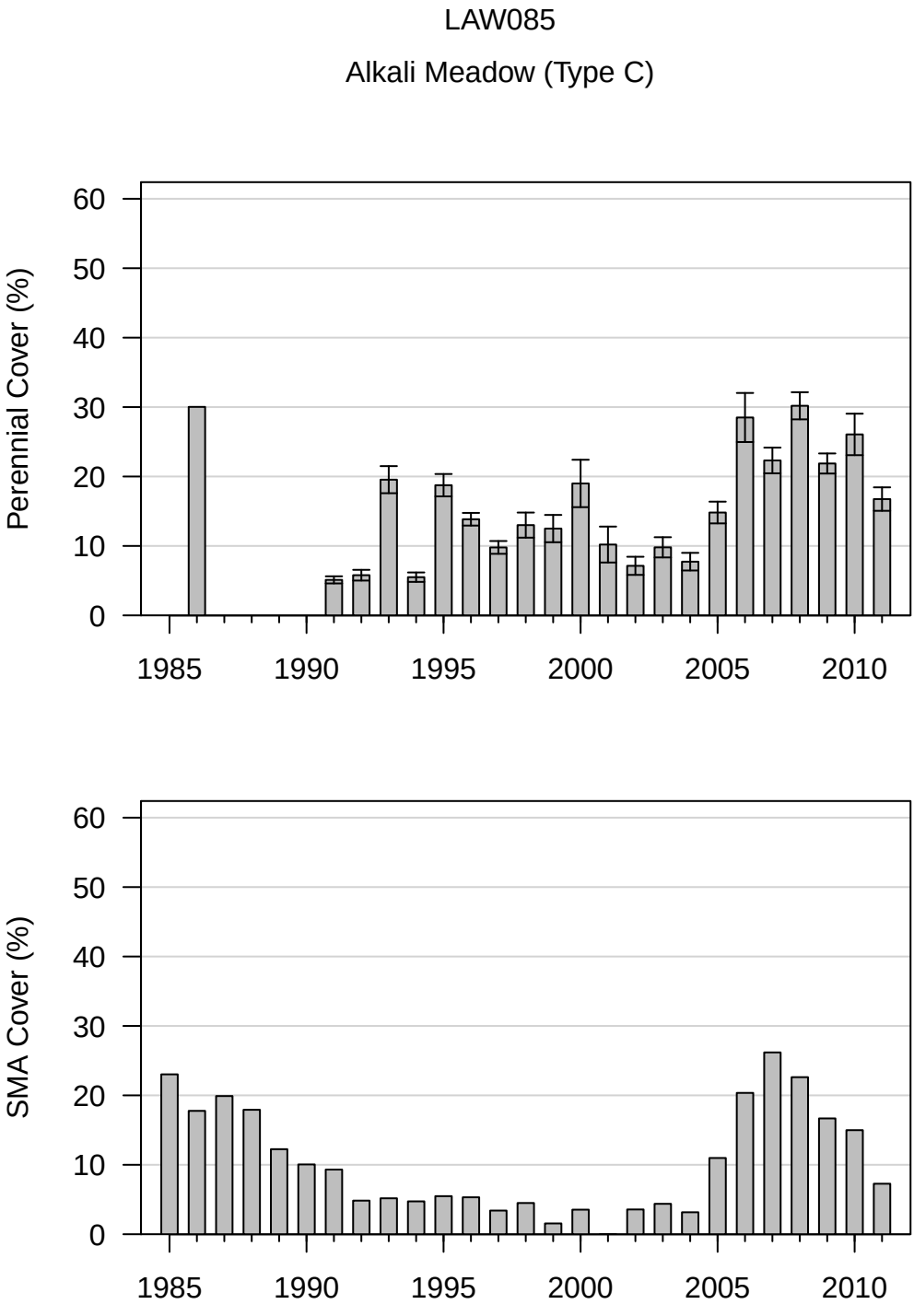

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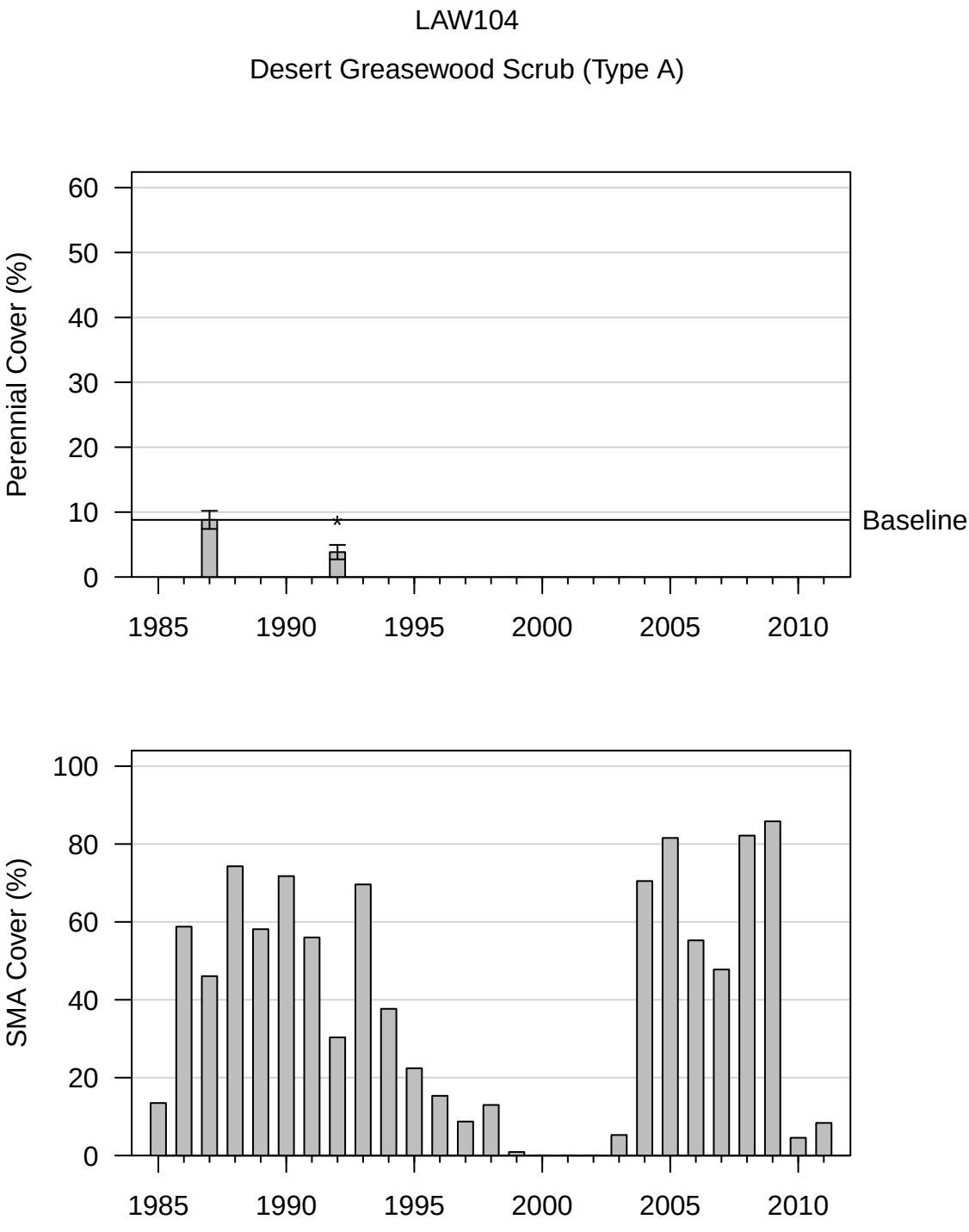
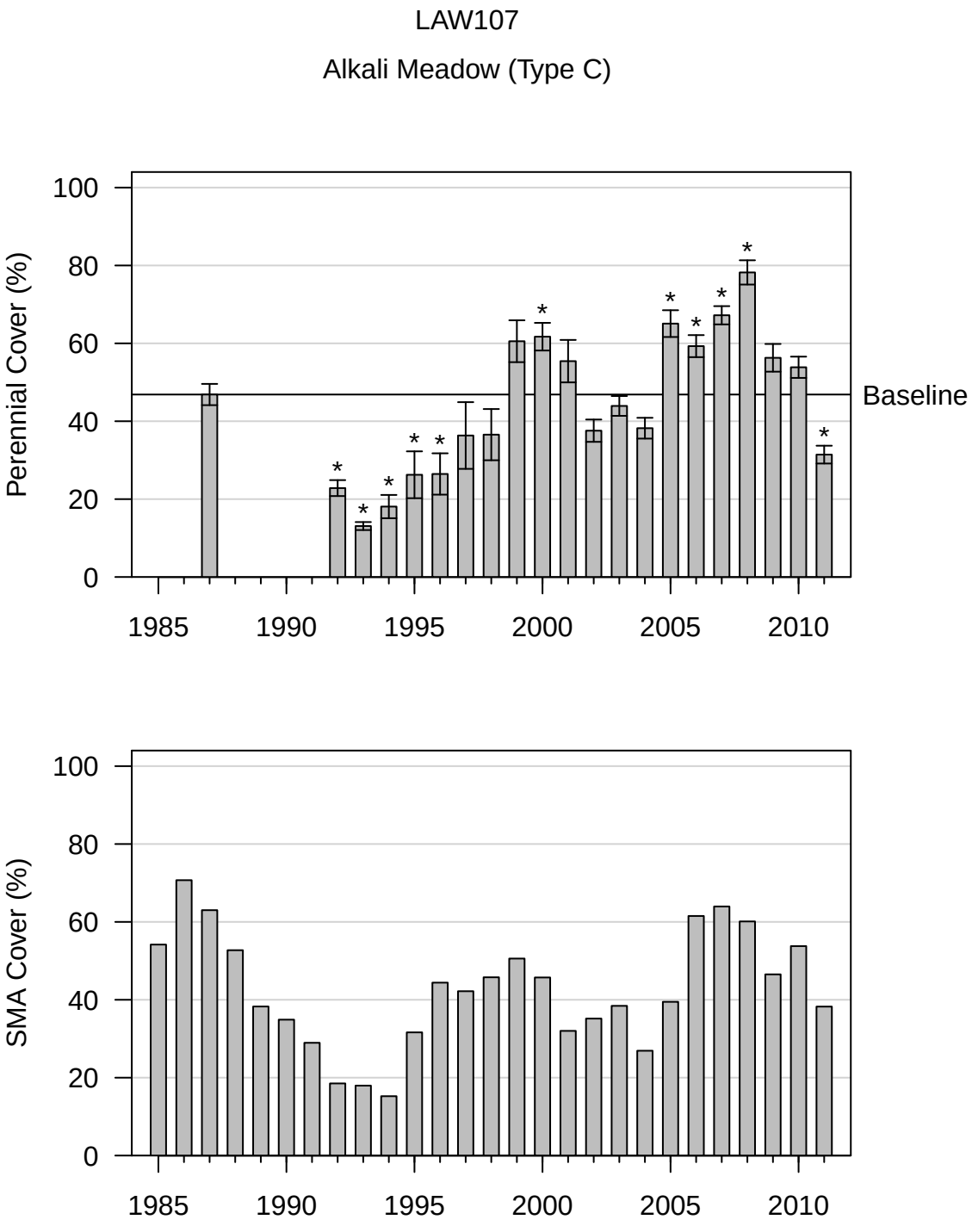


Figure 98: 1992 Wellfield



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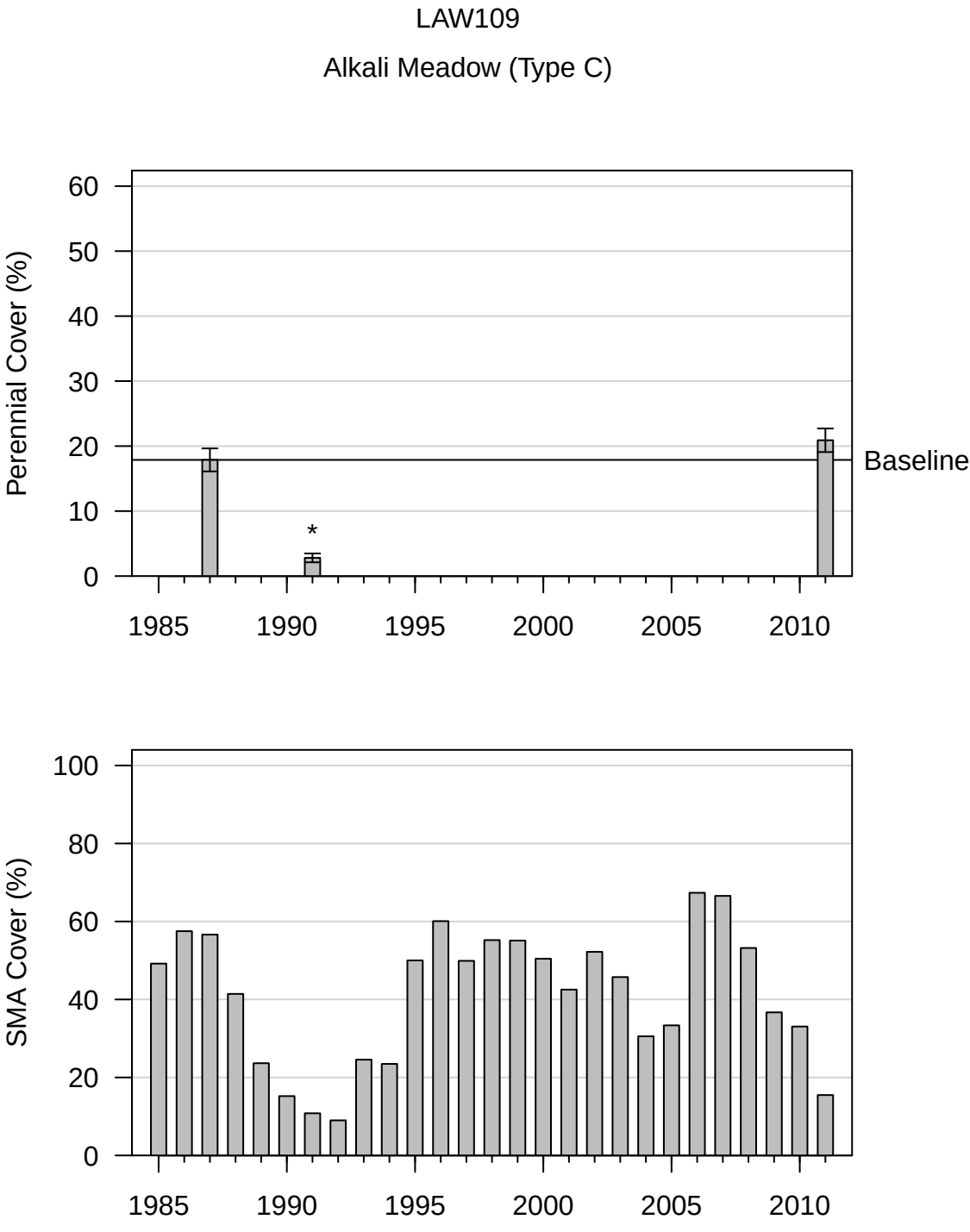


Figure 100: 2011 Wellfield

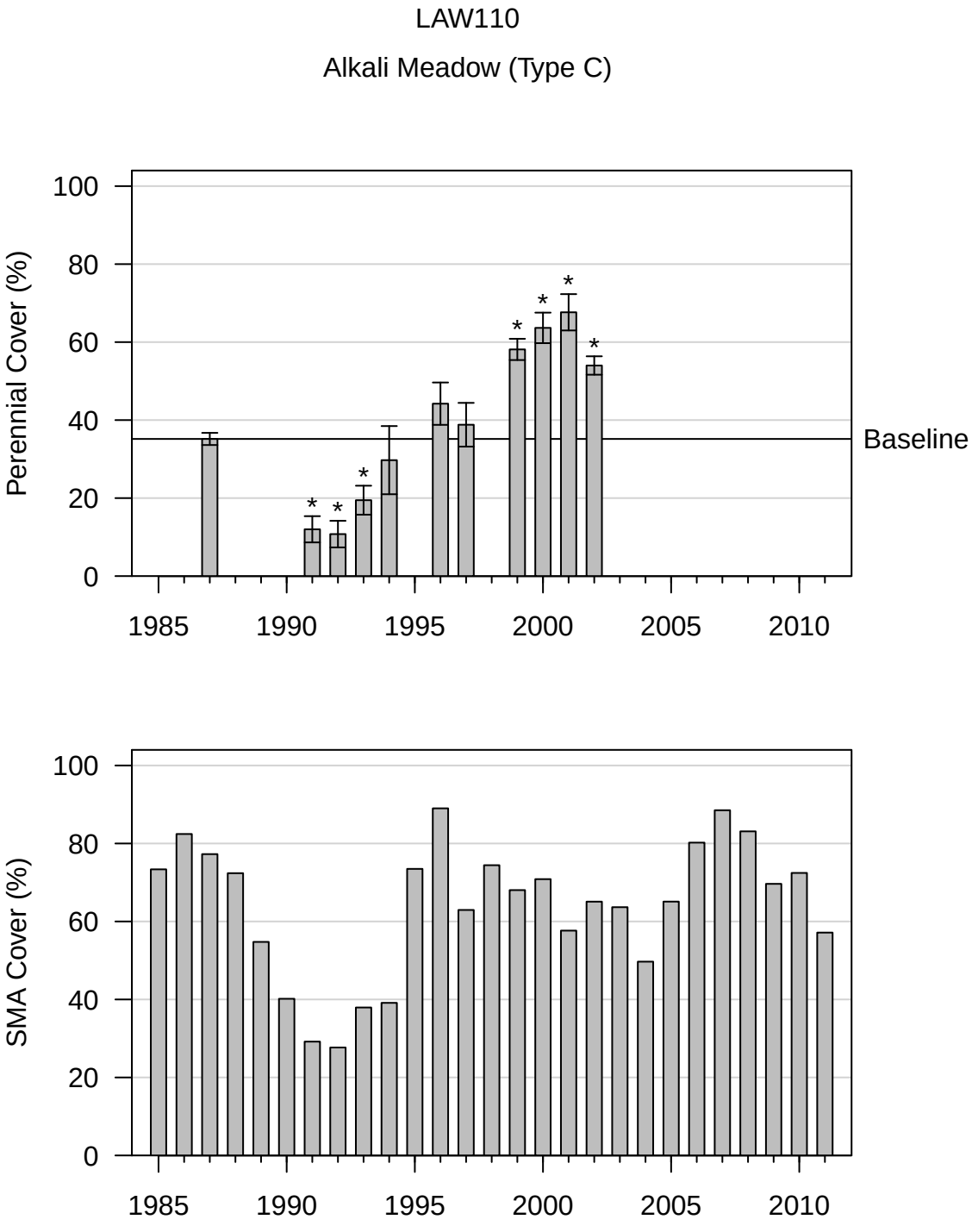


Figure 101: 2002 Wellfield

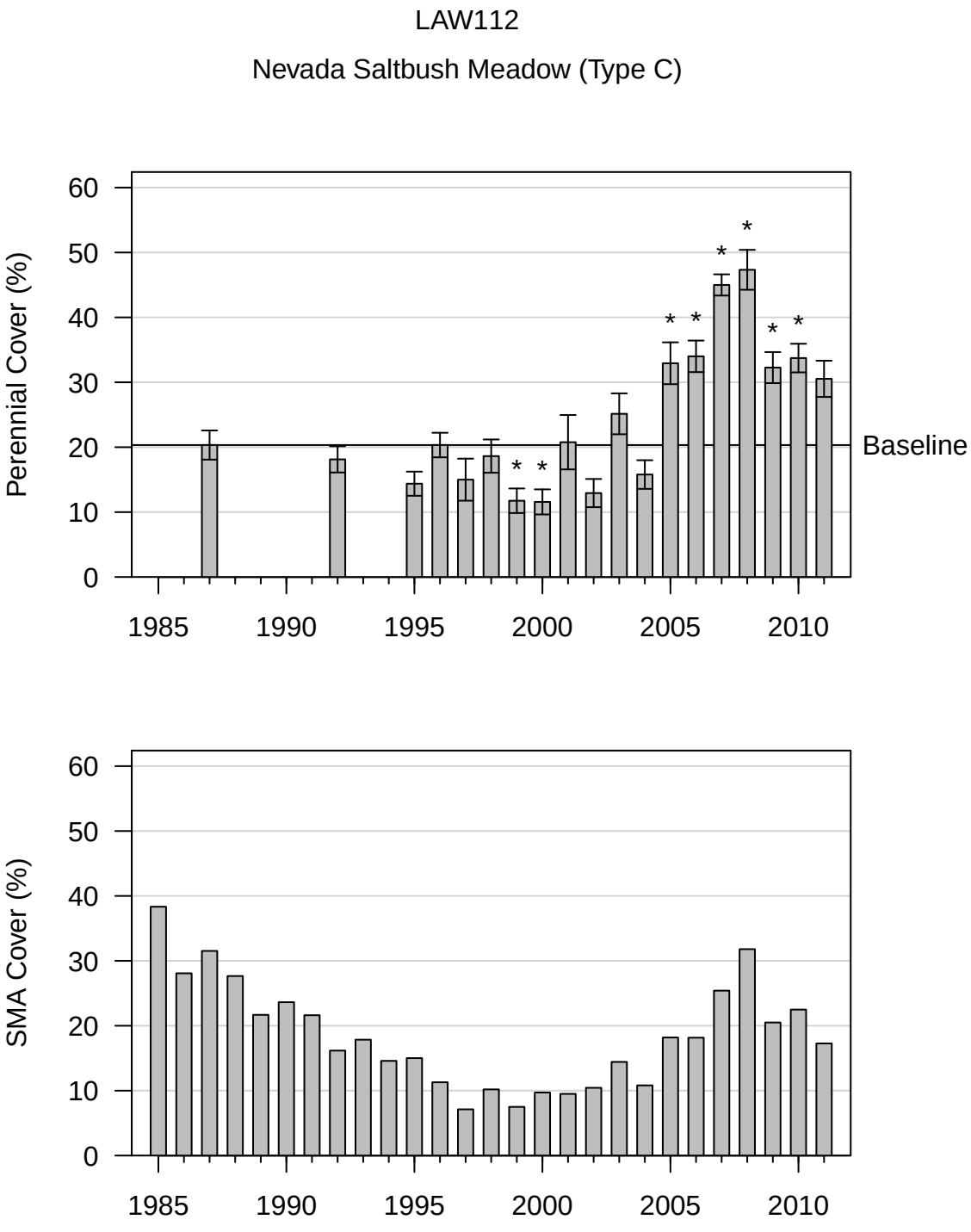


Figure 102: 2011 Wellfield

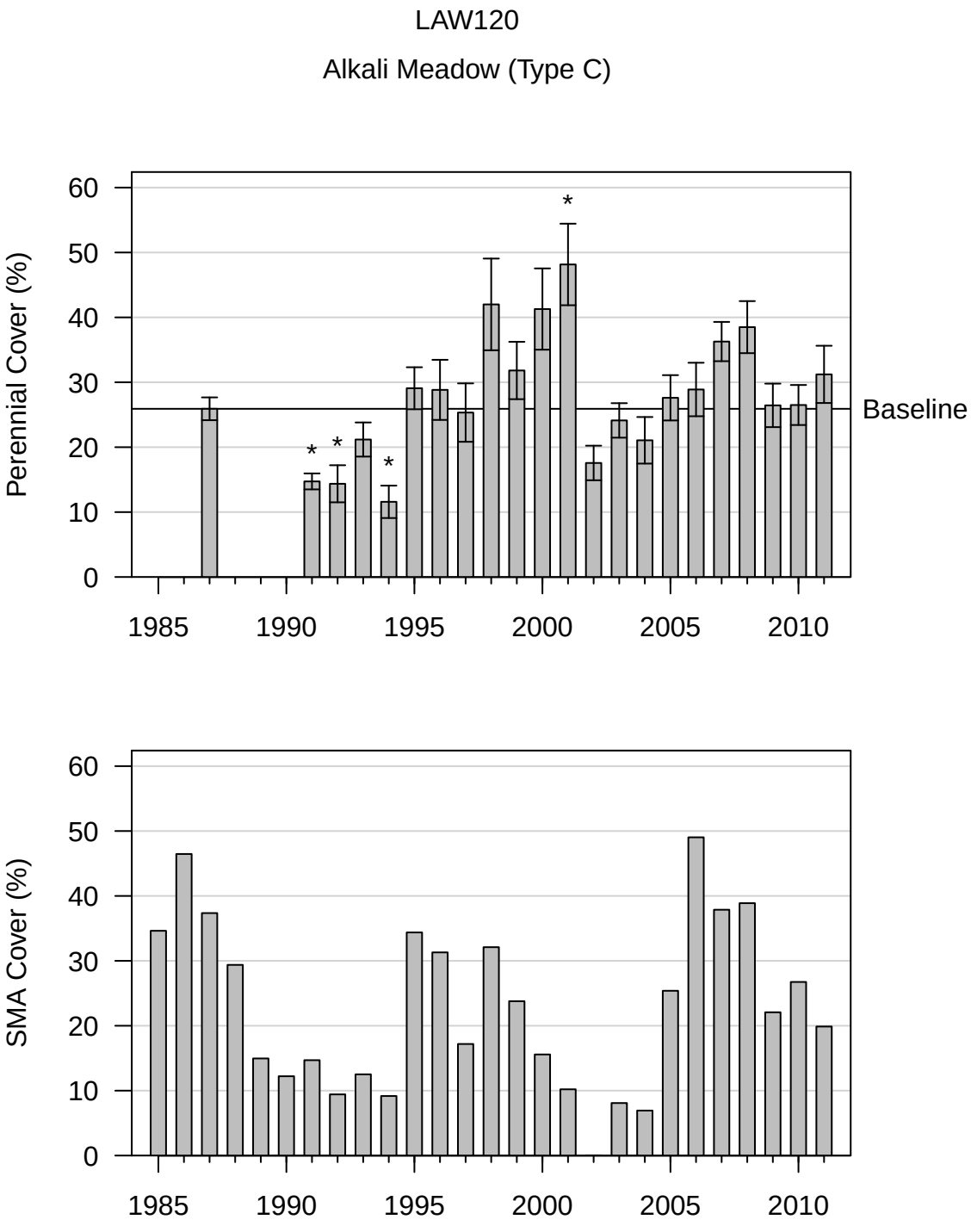


Figure 103: 2011 Wellfield

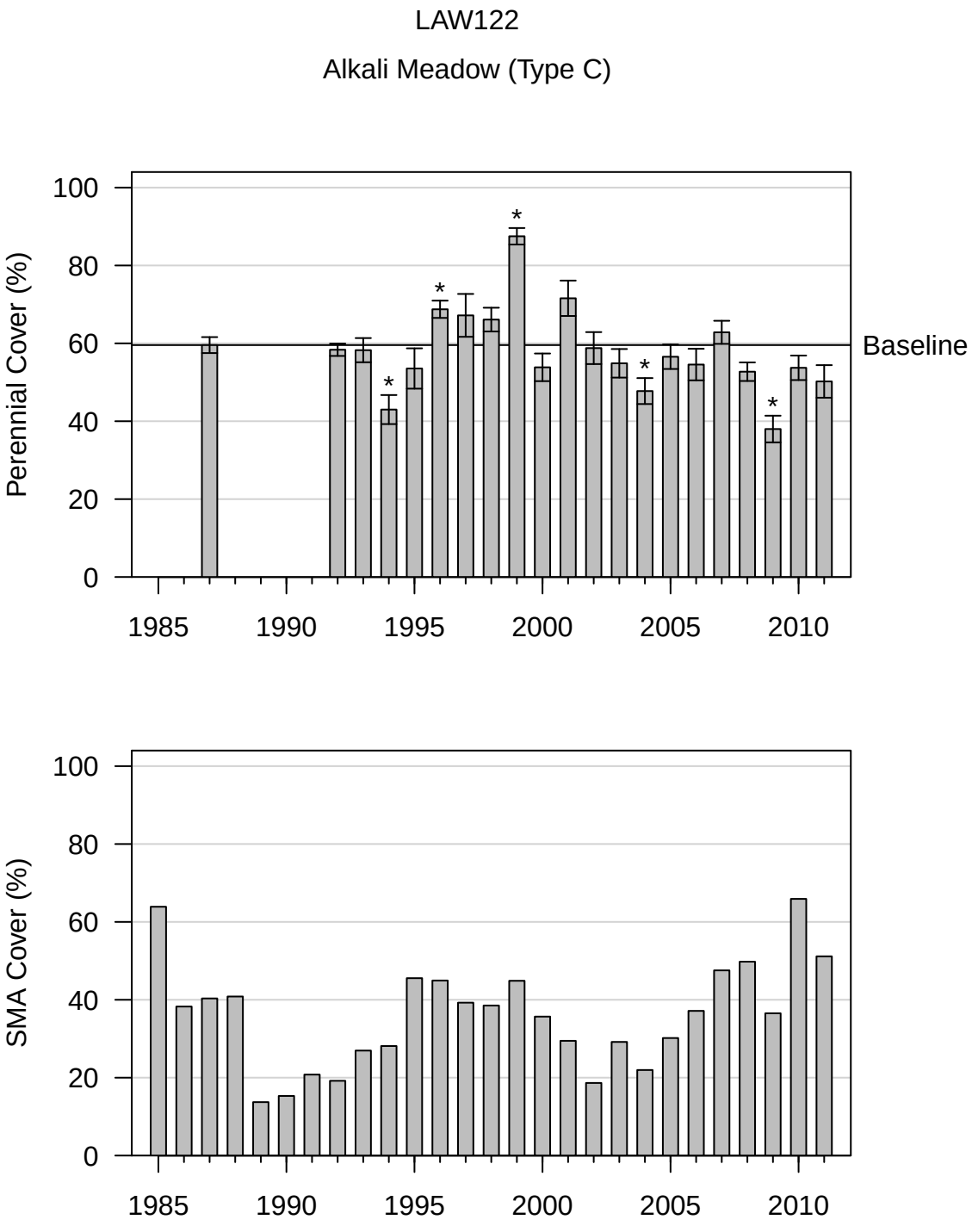


Figure 104: 2011 Wellfield

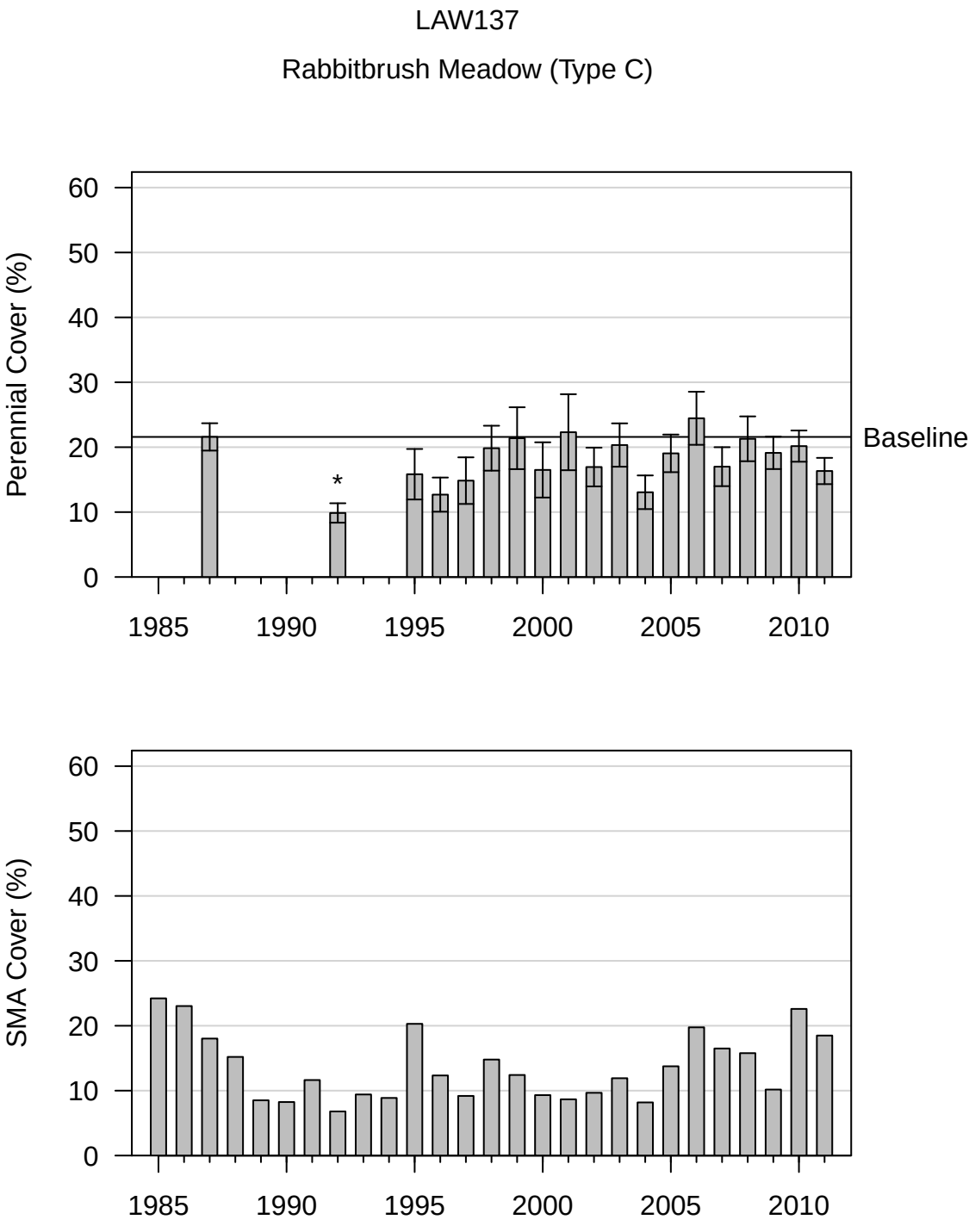


Figure 105: 2011 Wellfield

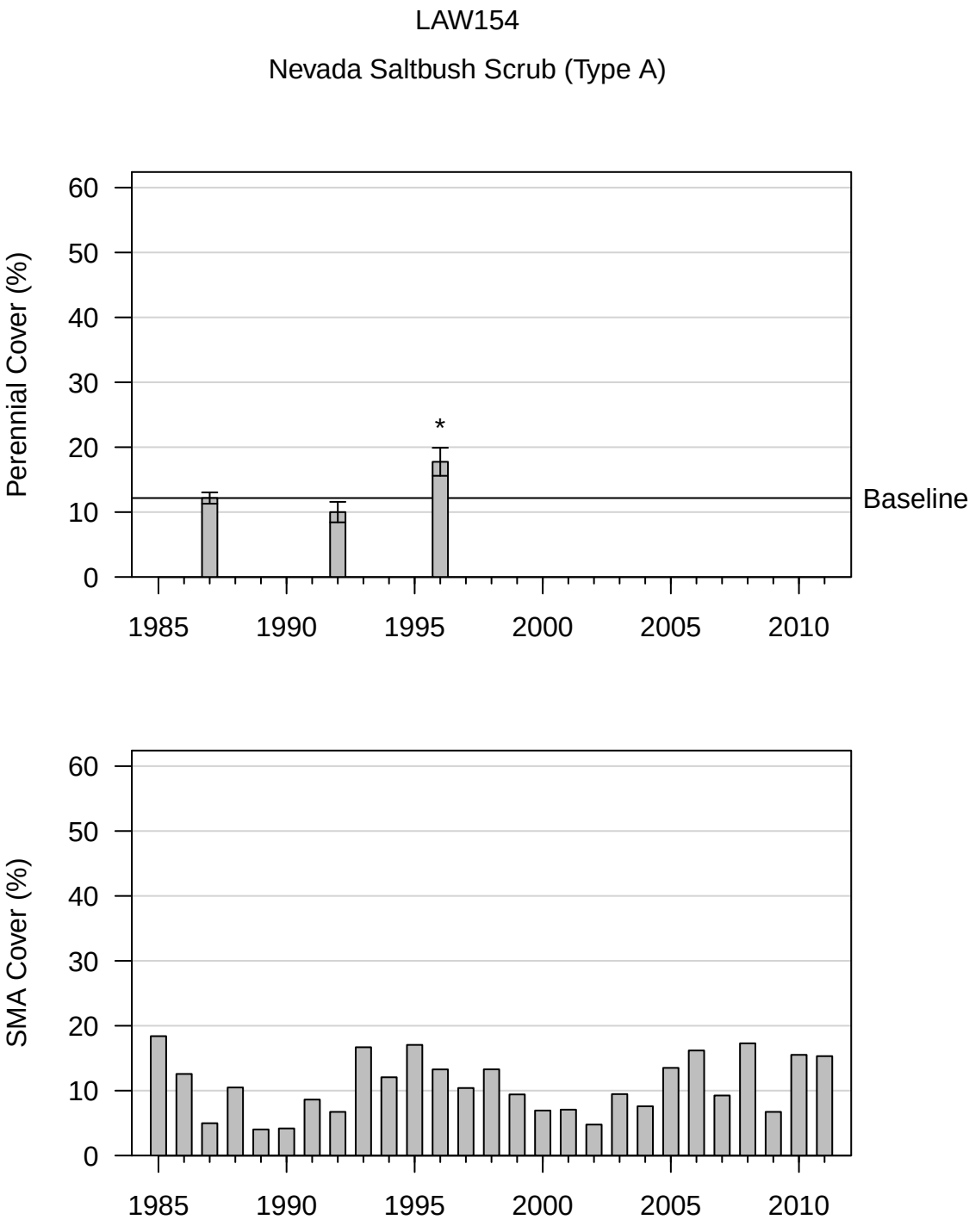


Figure 106: 1996 Control

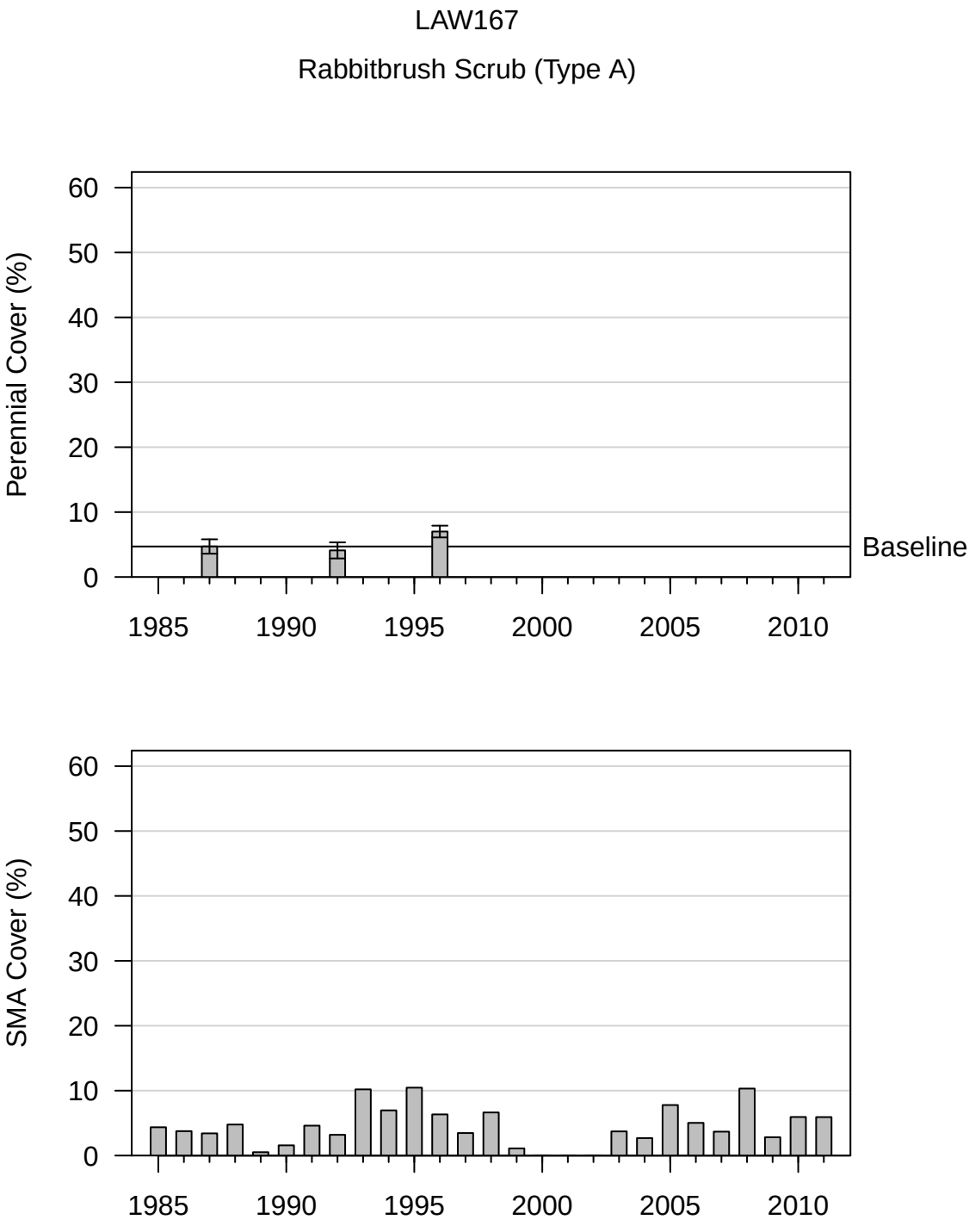


Figure 107: 1996 Control

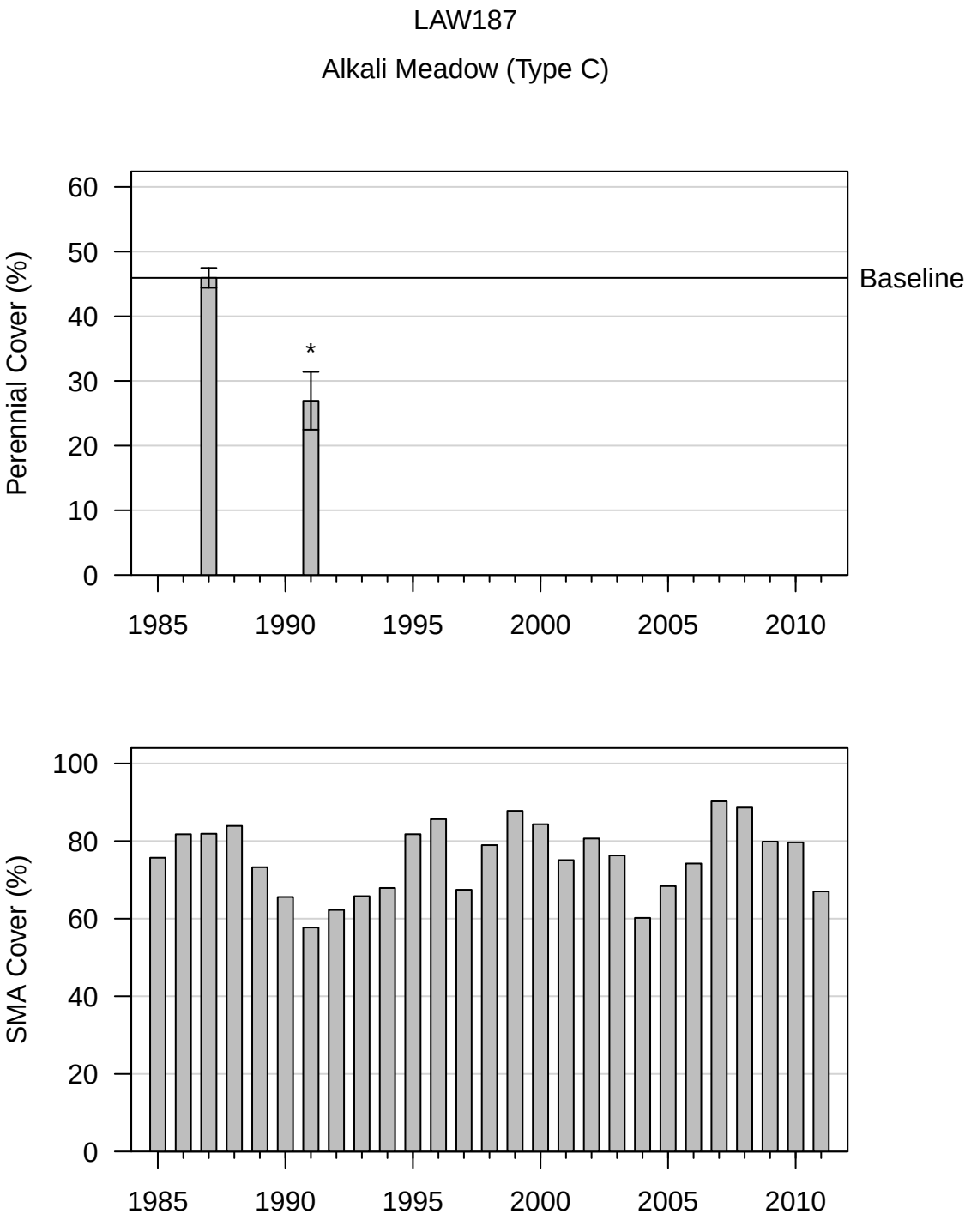


Figure 108: 1991 Control

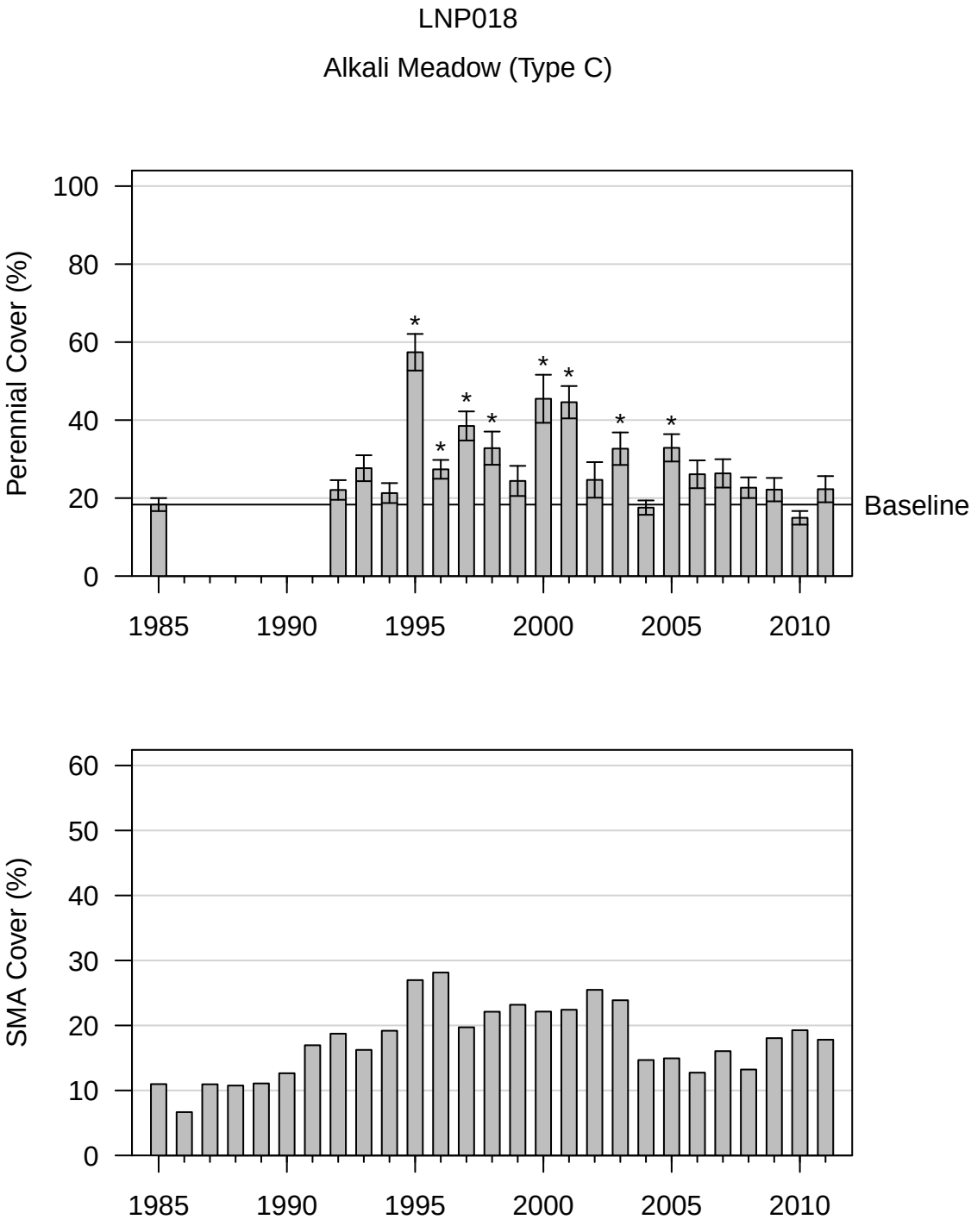


Figure 109: 2011 Control

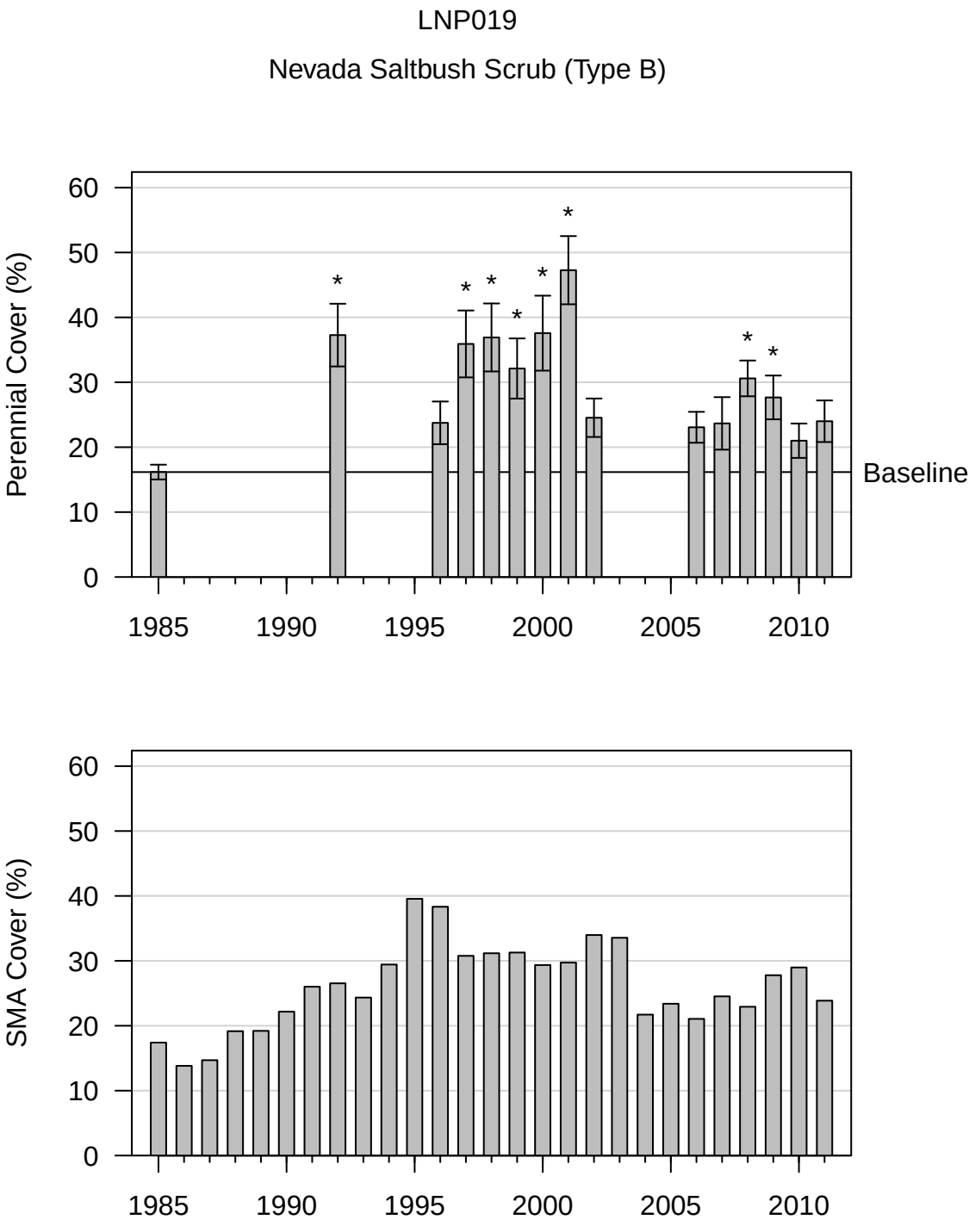


Figure 110: 2011 Control

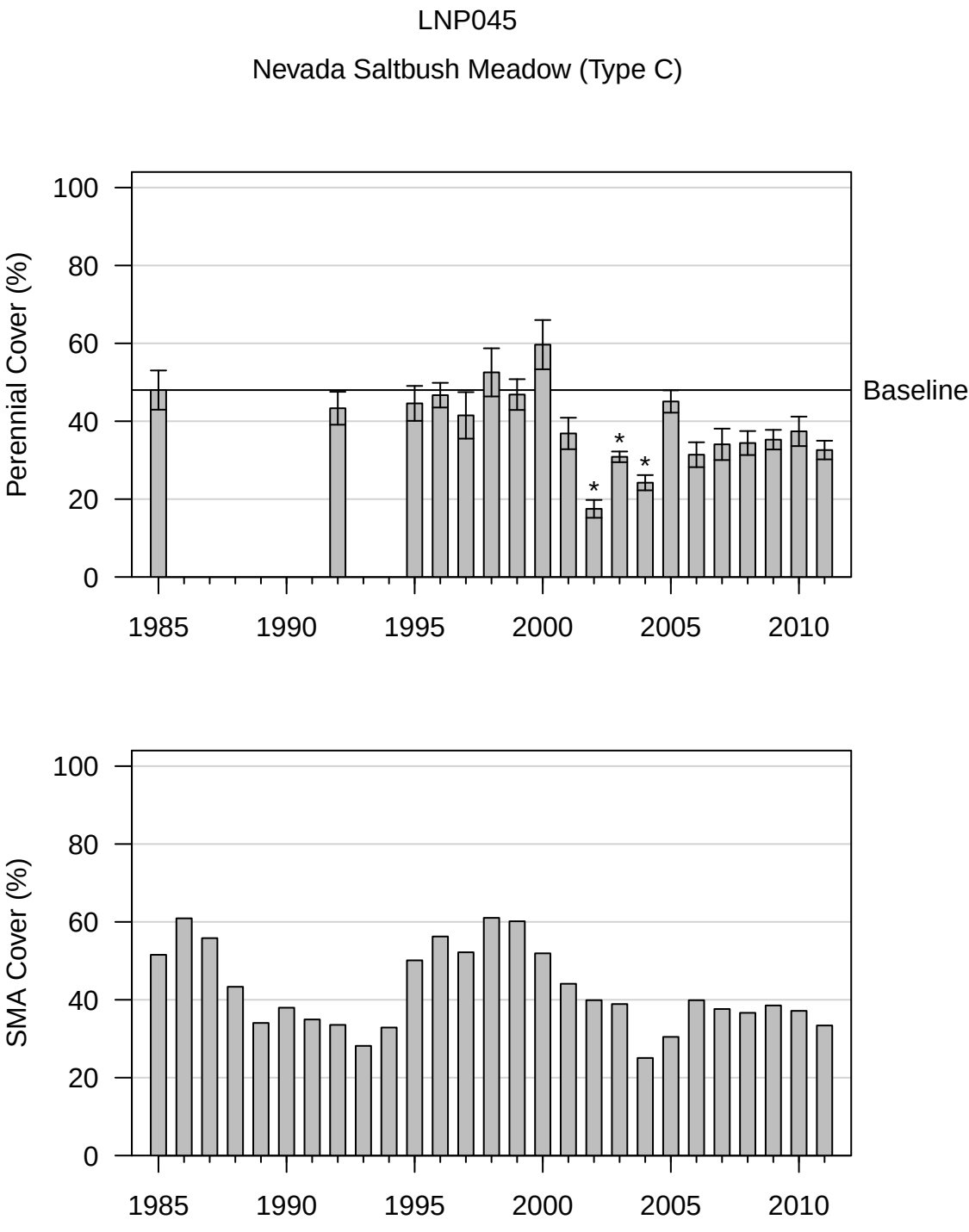


Figure 111: 2011 Wellfield

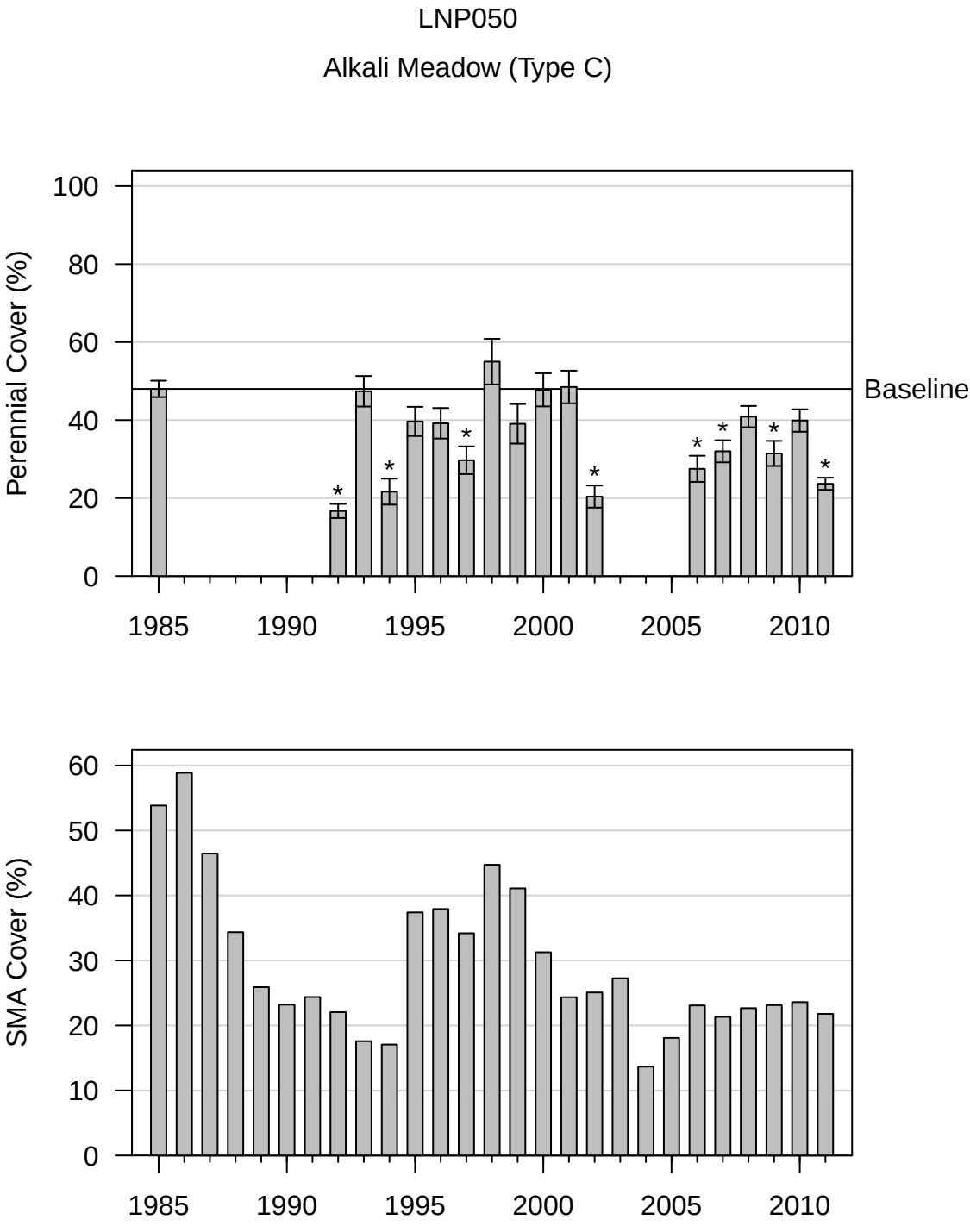


Figure 112: 2011 Control

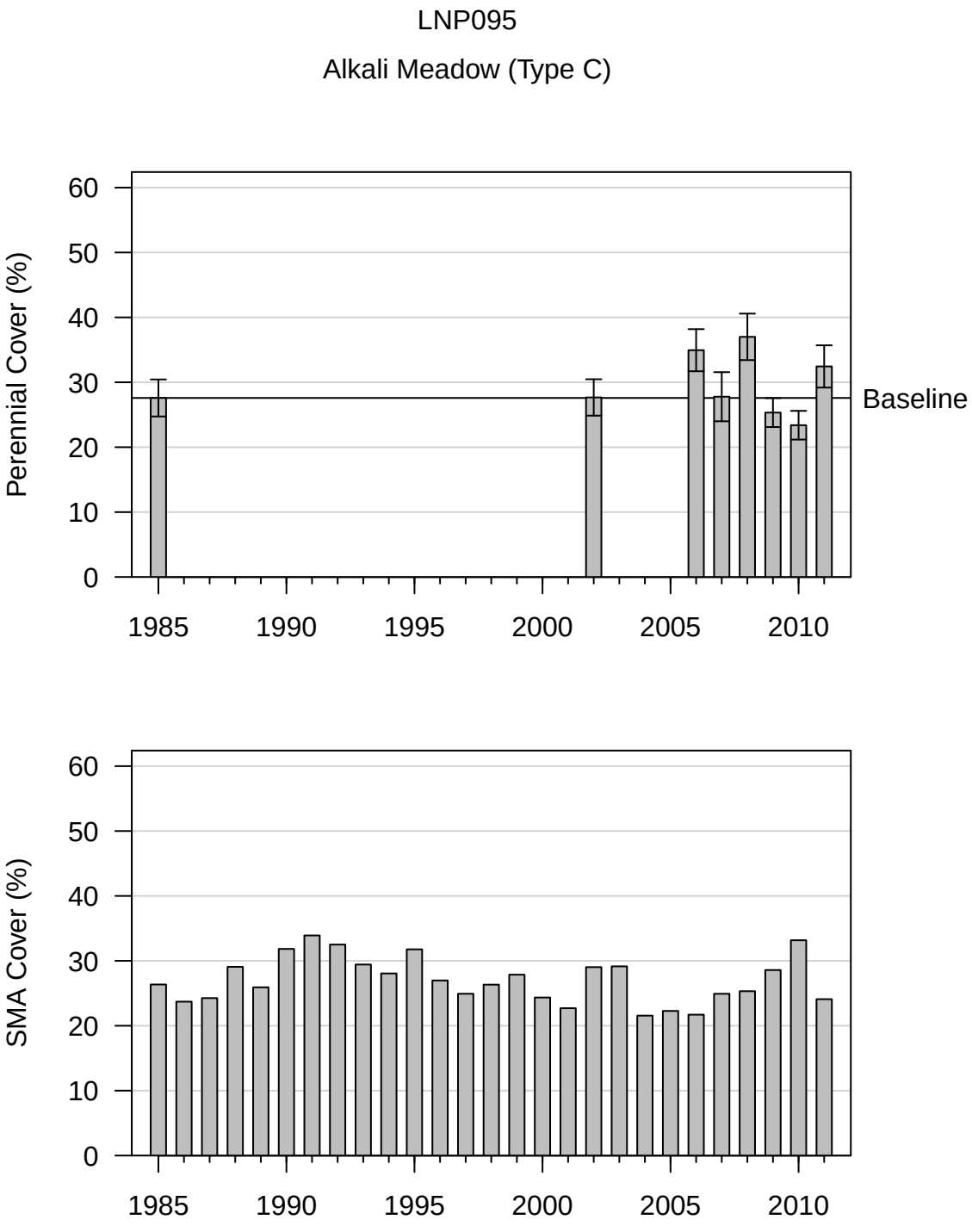


Figure 113: 2011 Control

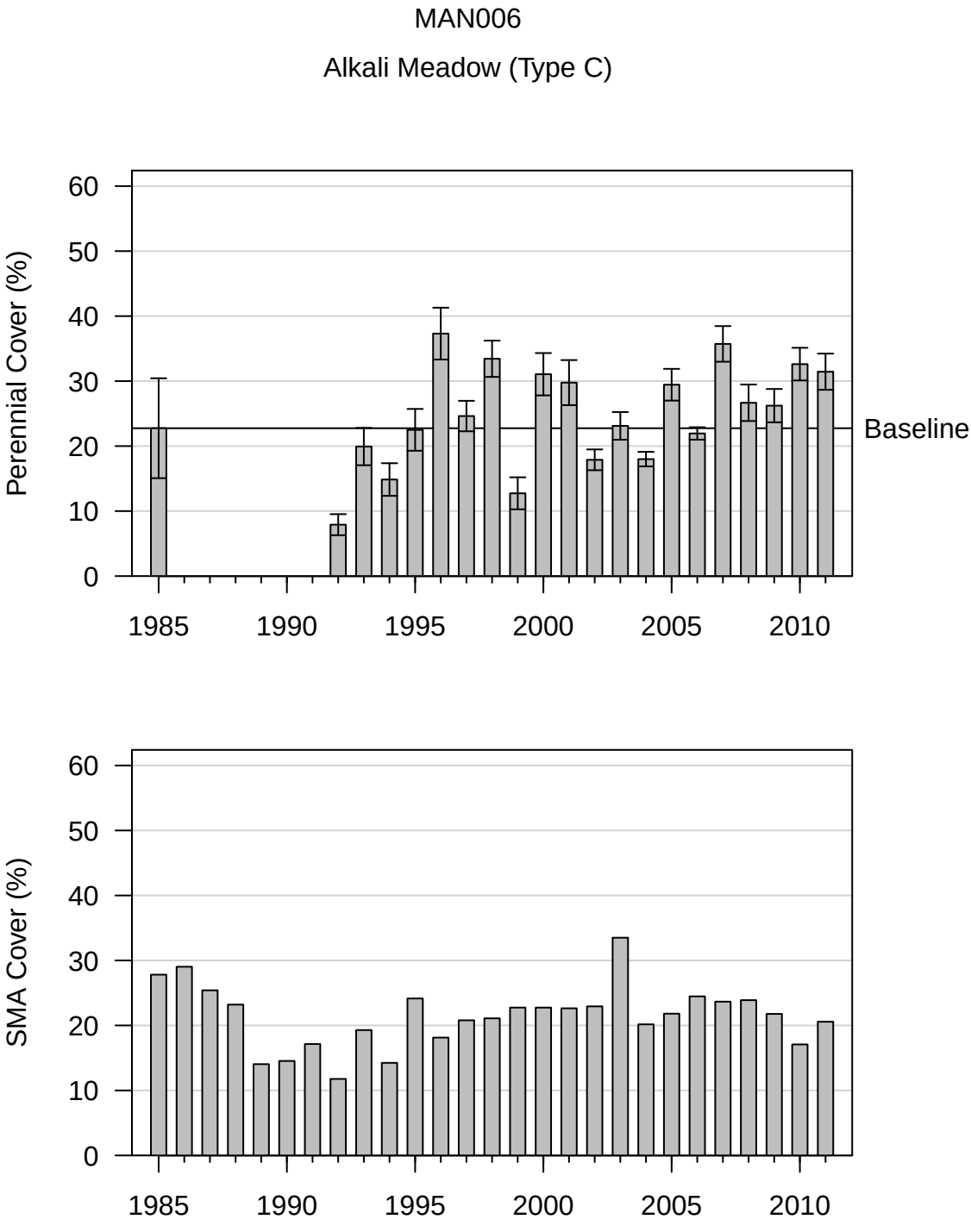


Figure 114: 2011 Wellfield

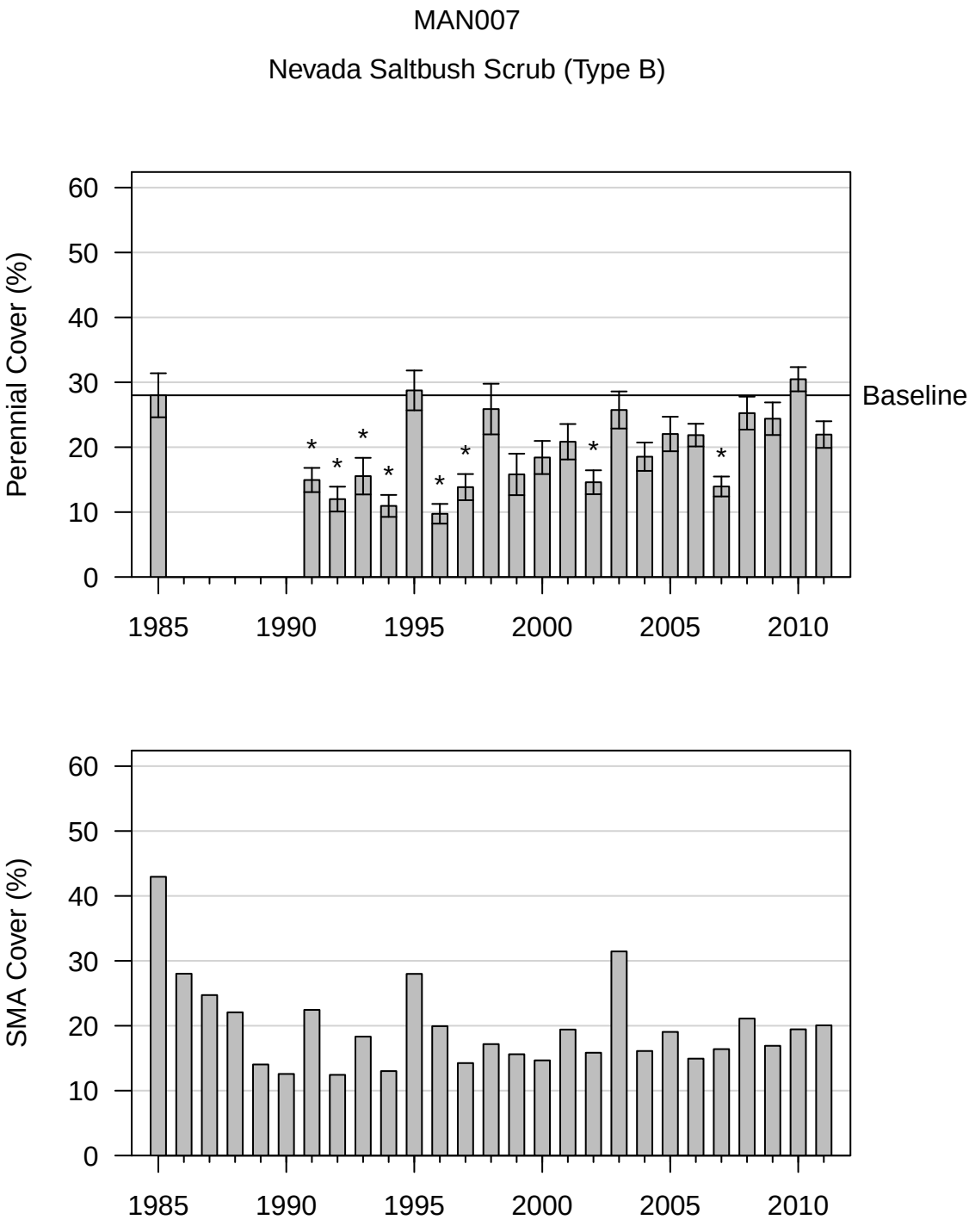


Figure 115: 2011 Wellfield

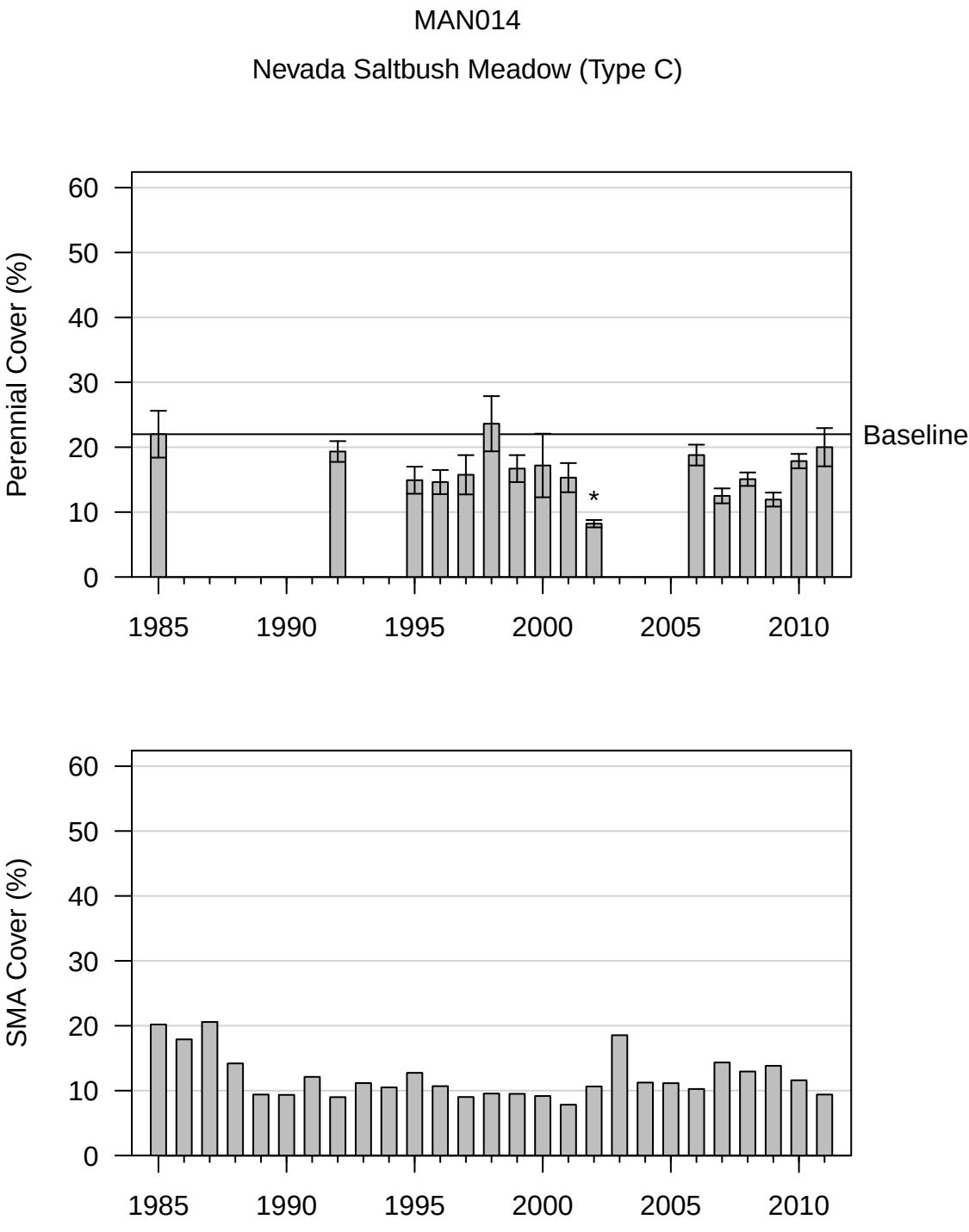


Figure 116: 2011 Control

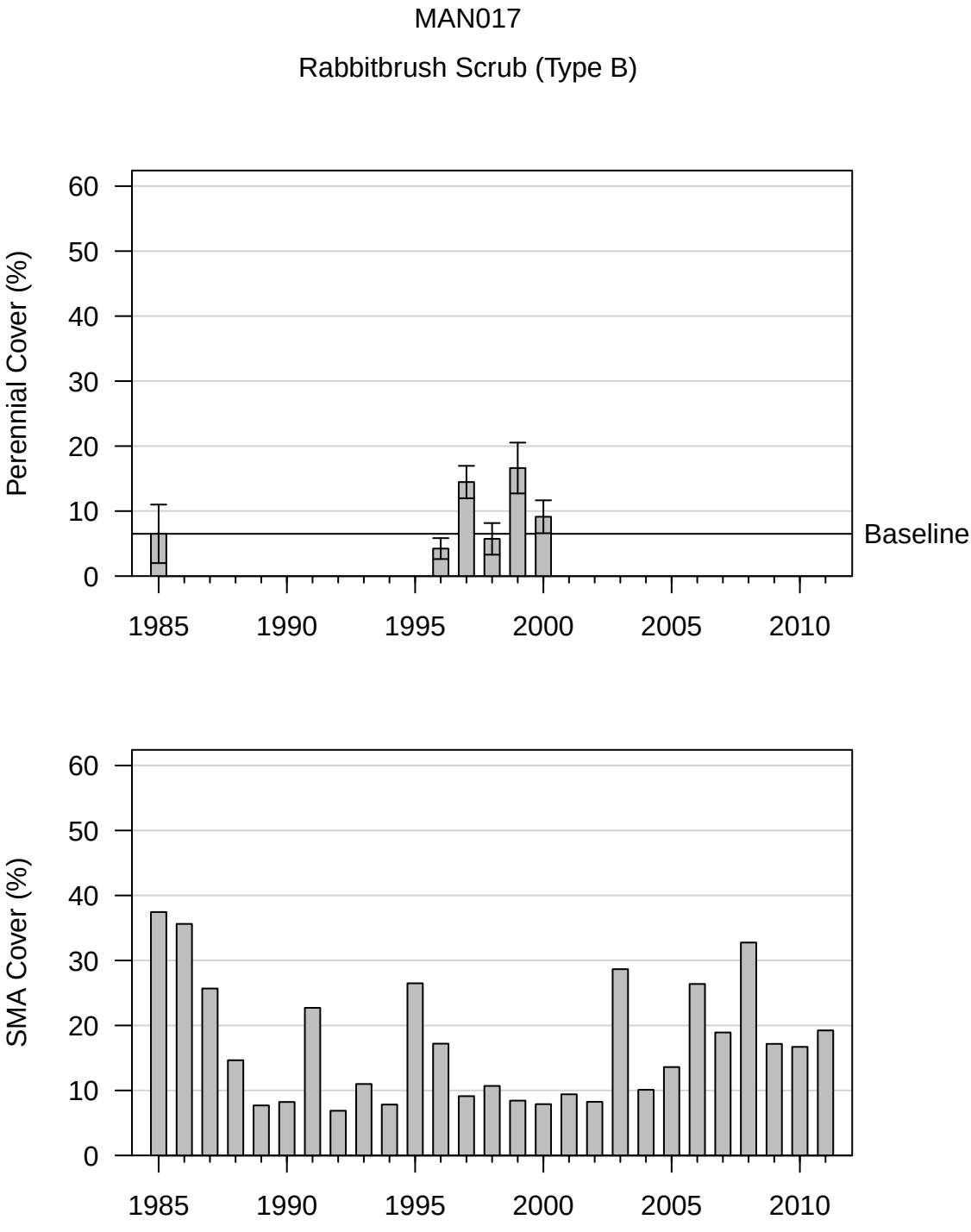


Figure 117: 2000 Wellfield

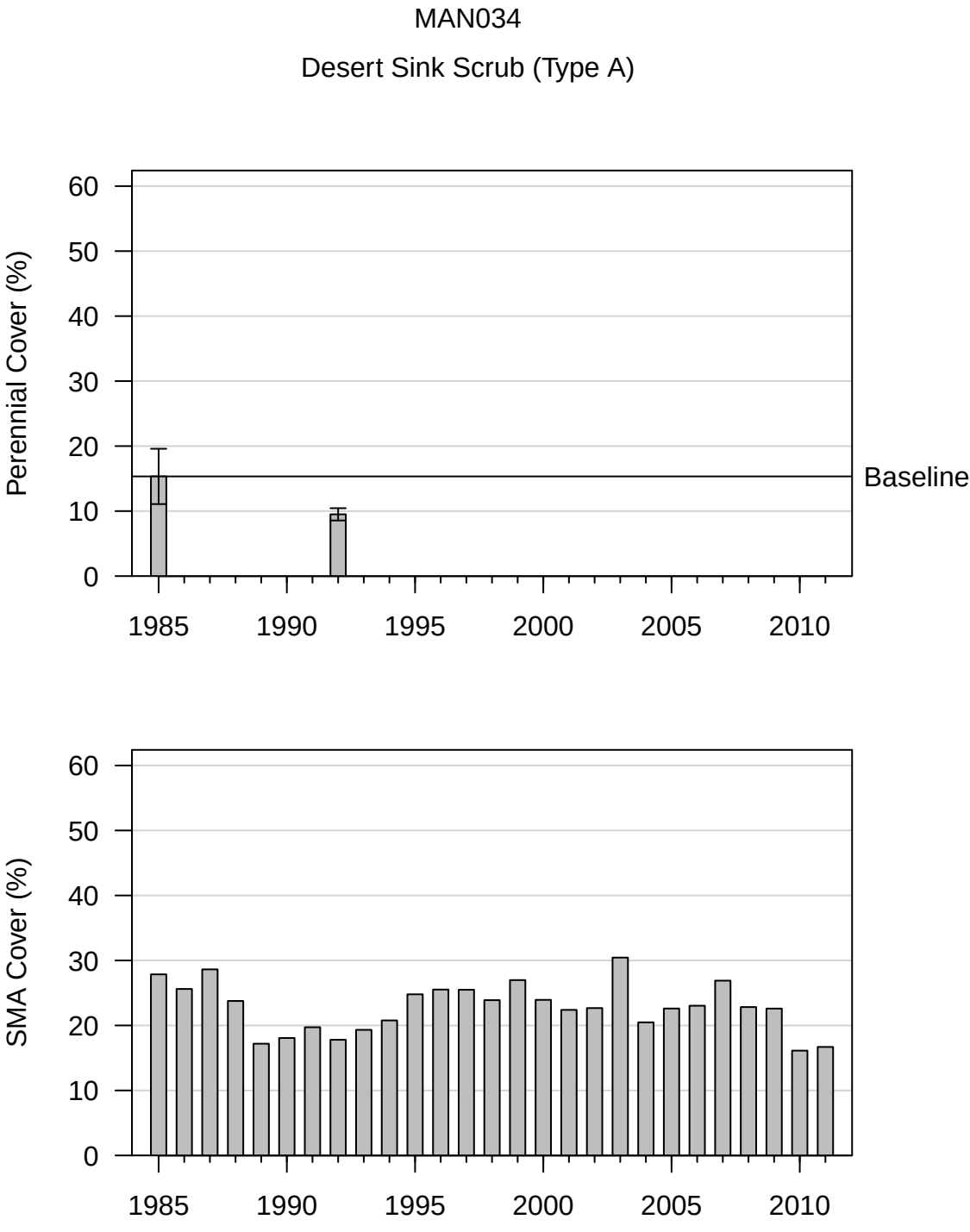


Figure 118: 1992 Wellfield

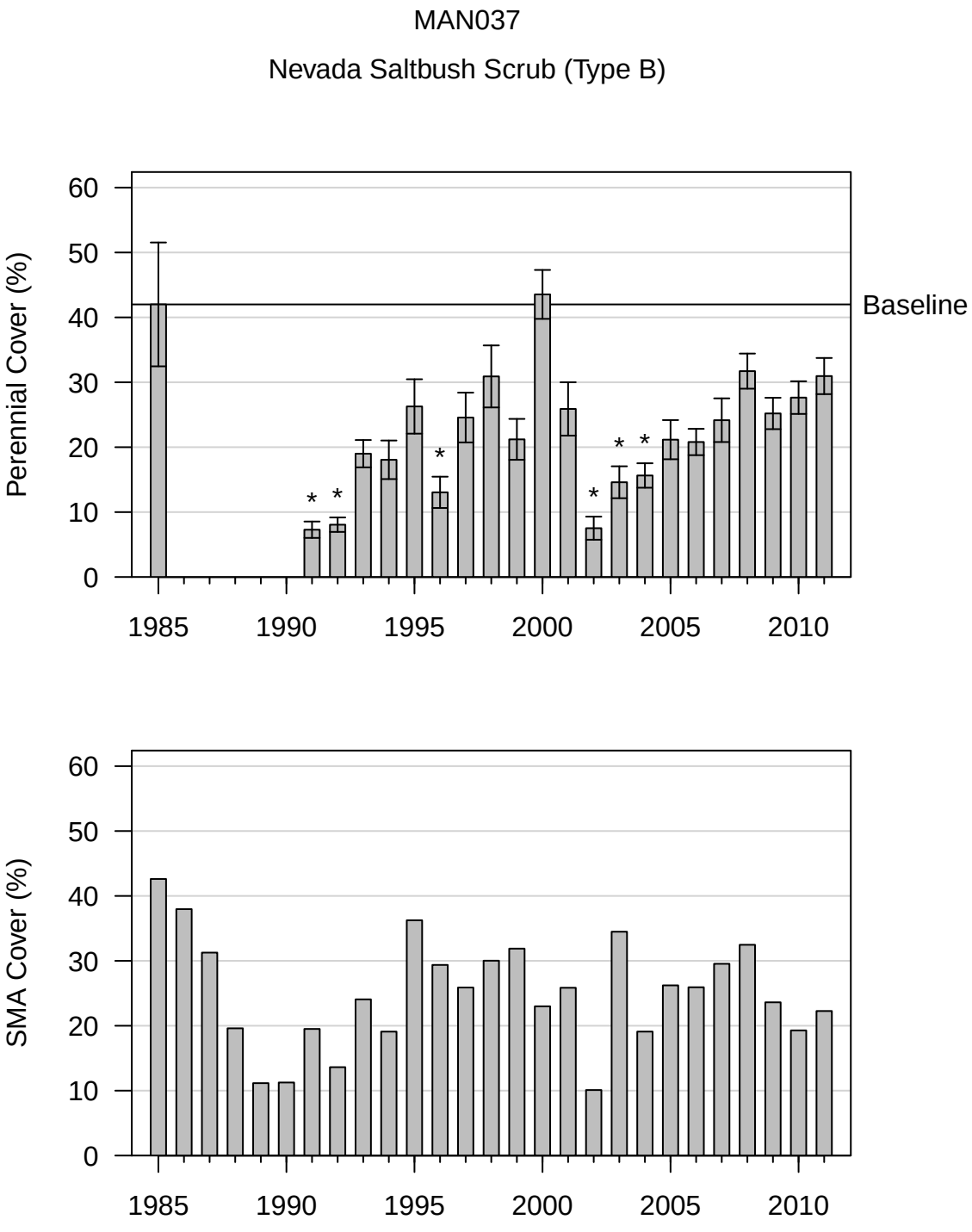


Figure 119: 2011 Wellfield

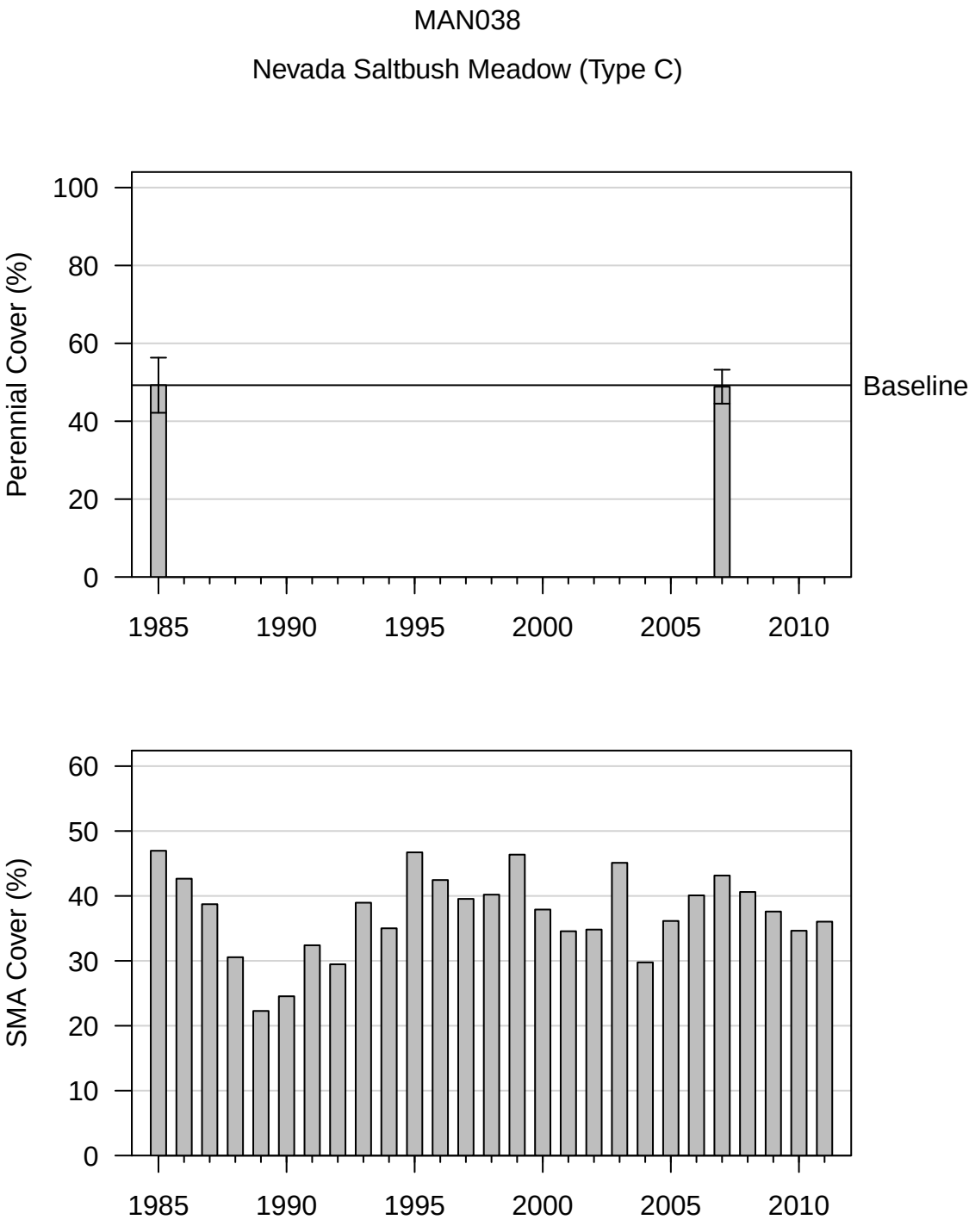


Figure 120: 2007 Wellfield

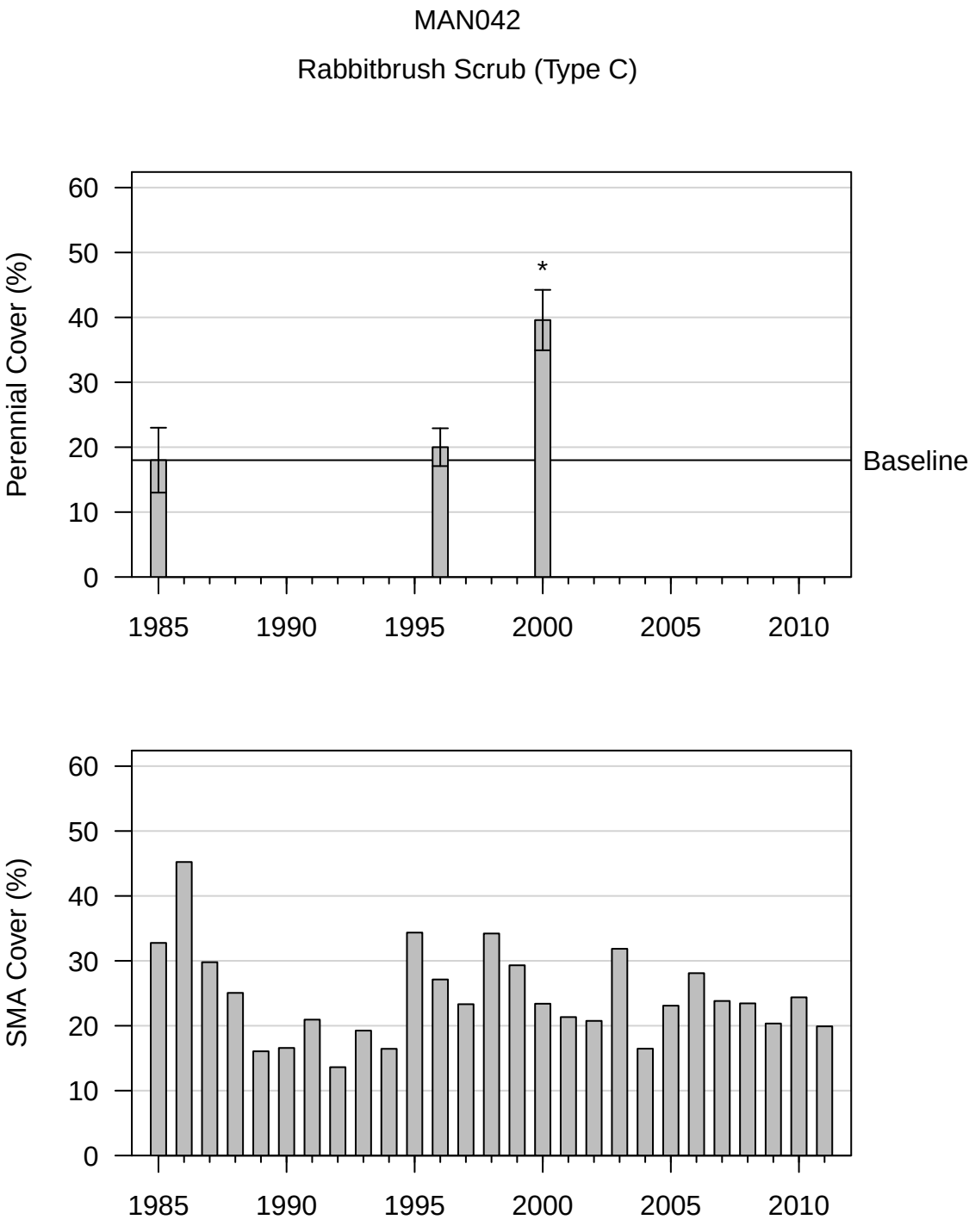


Figure 121: 2000 Wellfield

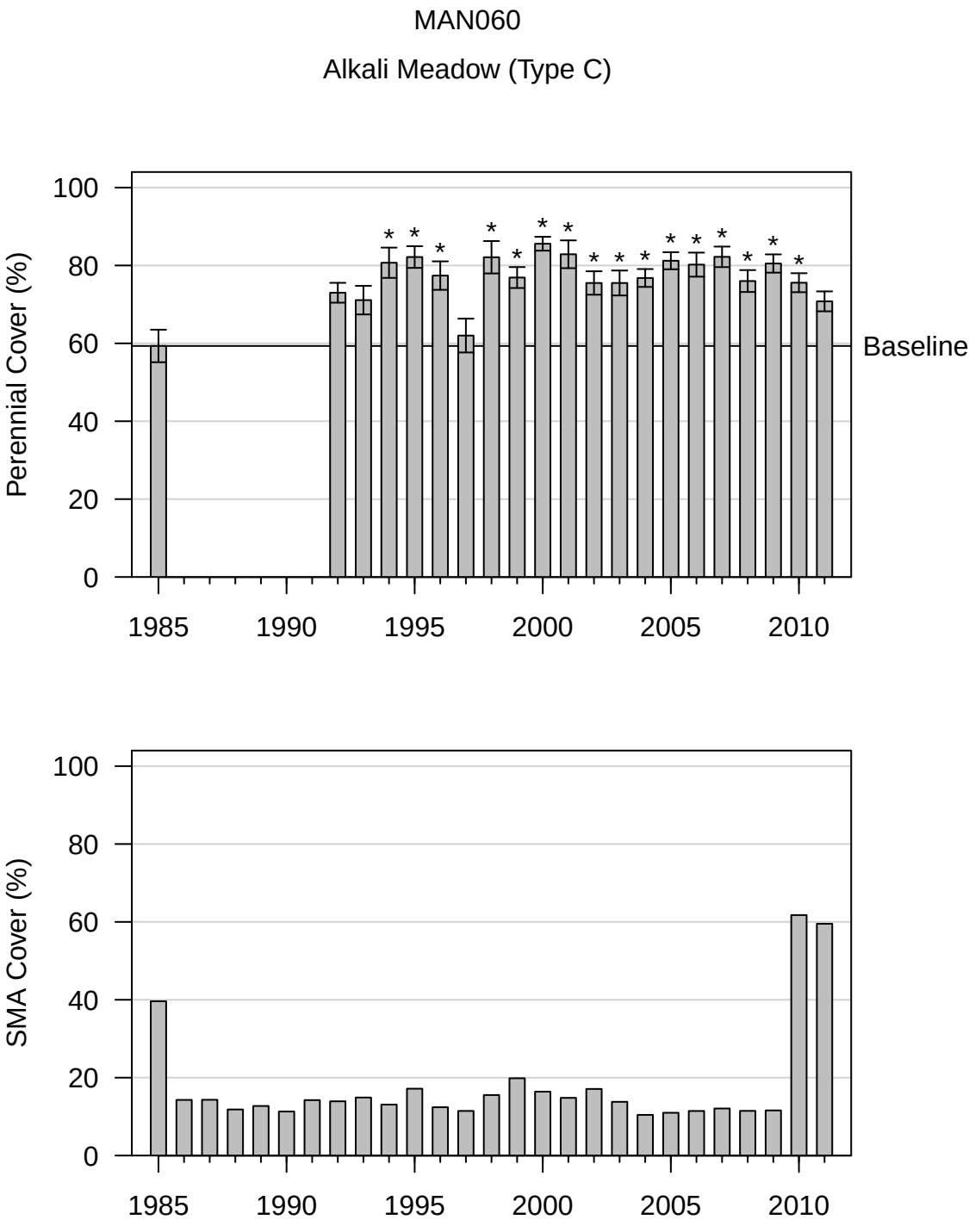


Figure 122: 2011 Control

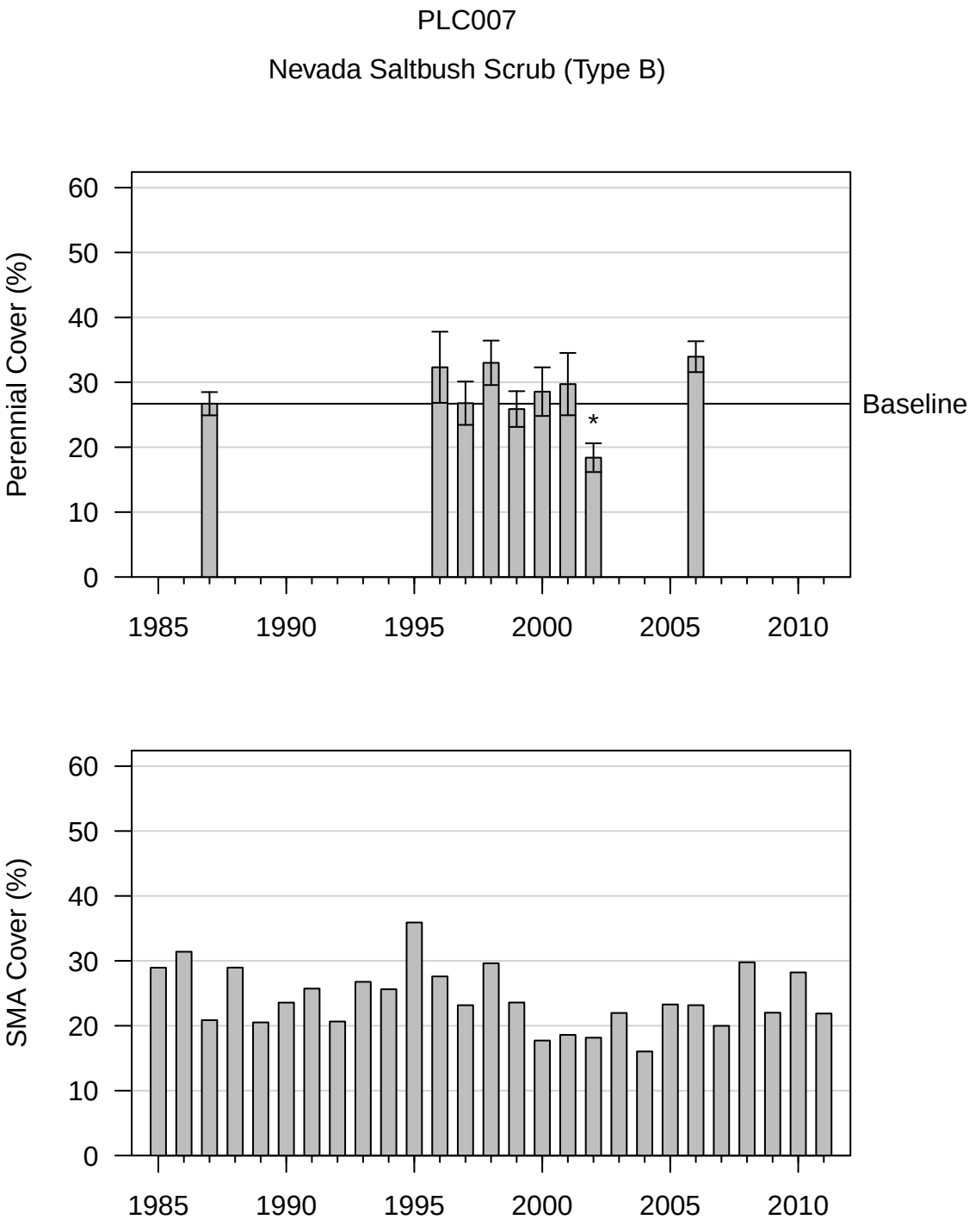


Figure 123: 2006 Wellfield

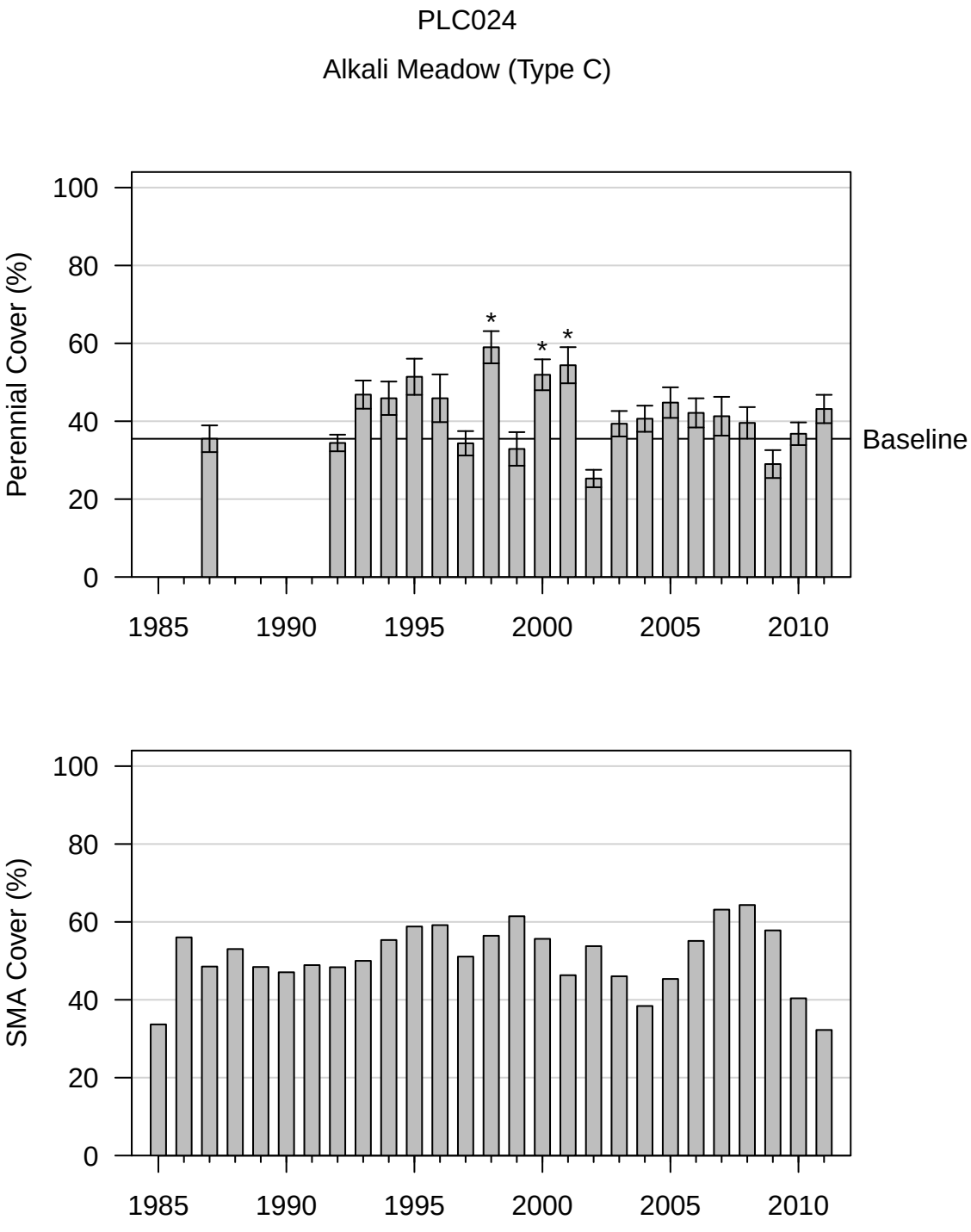


Figure 124: 2011 Control

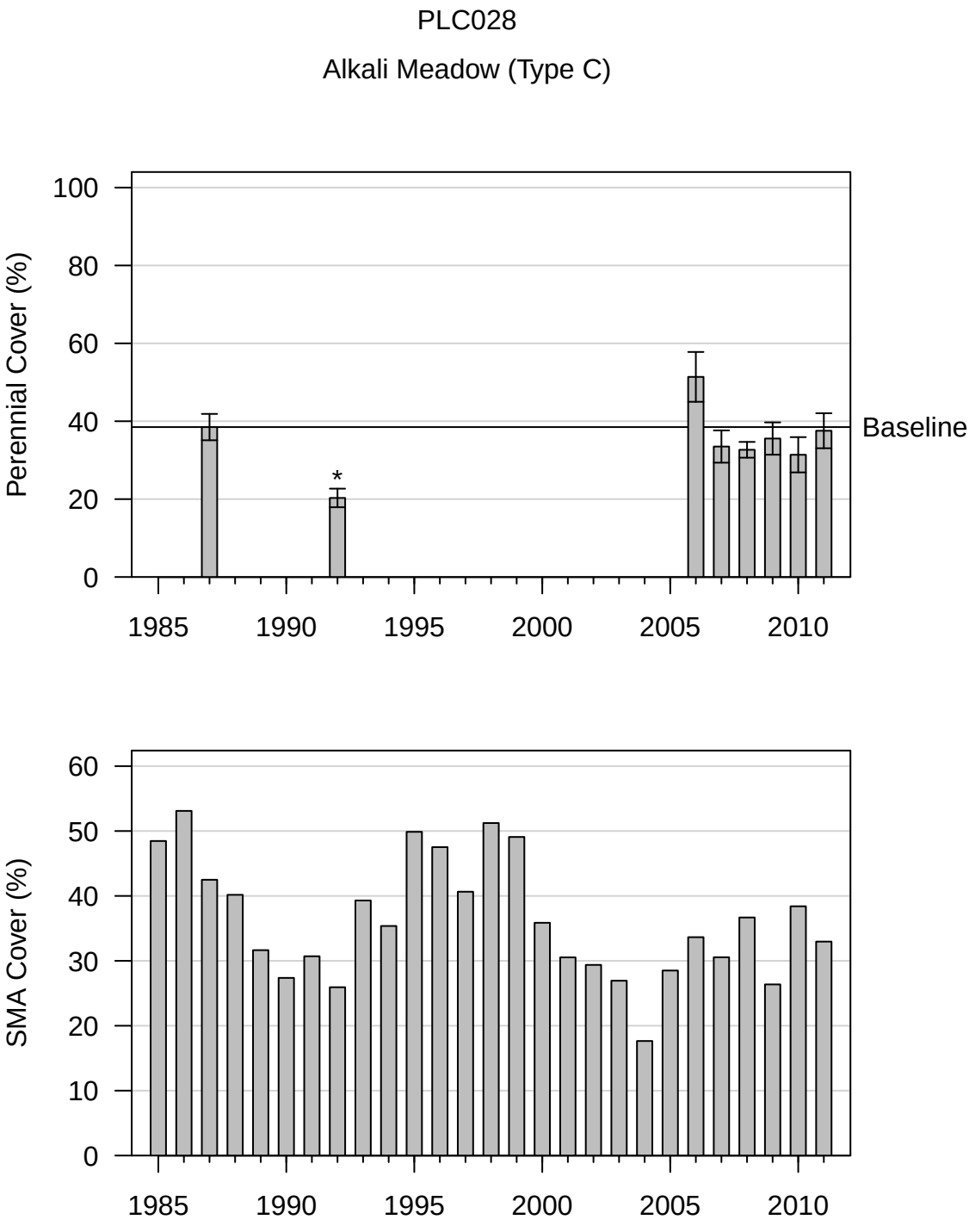


Figure 125: 2011 Control

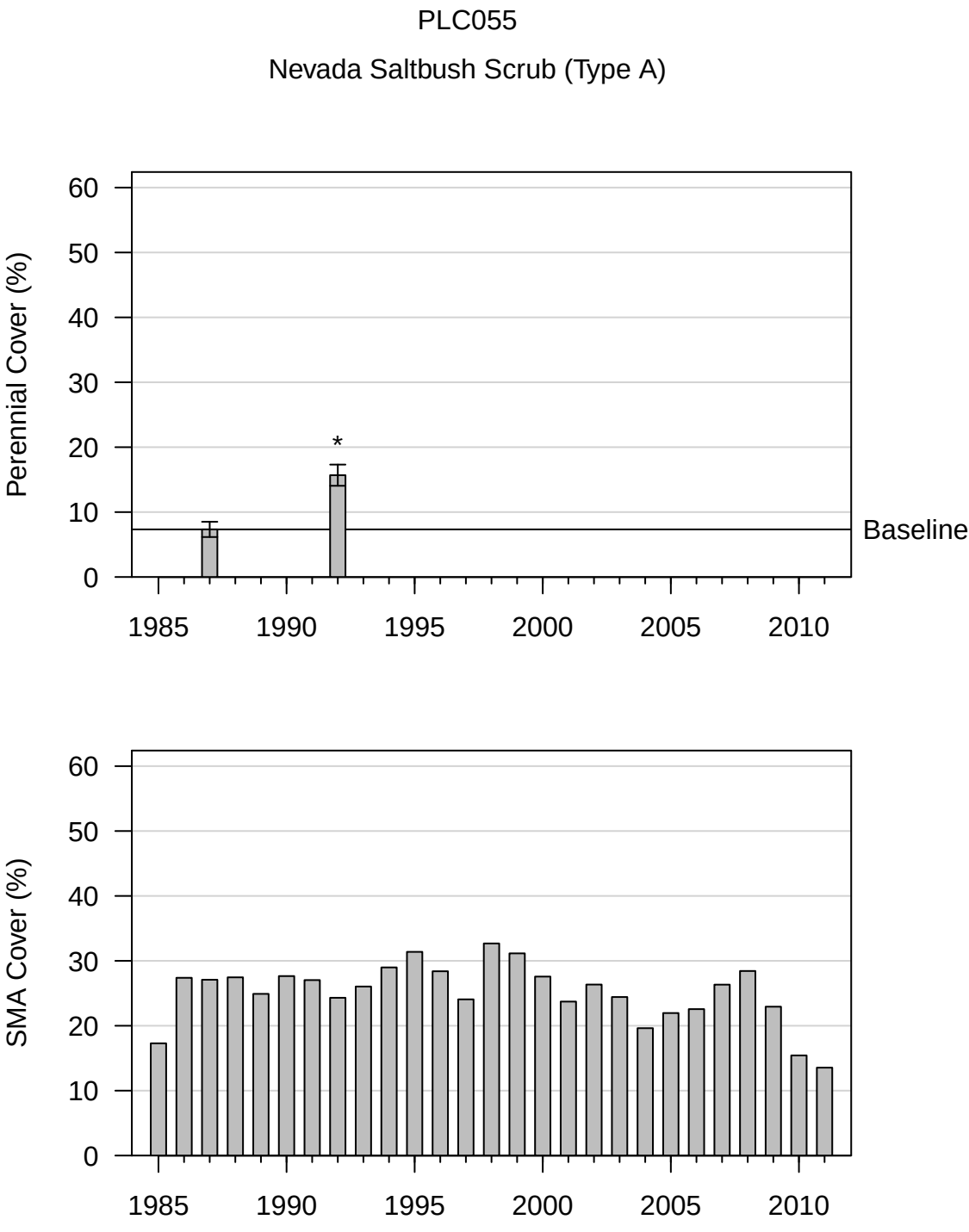


Figure 126: 1992 Control

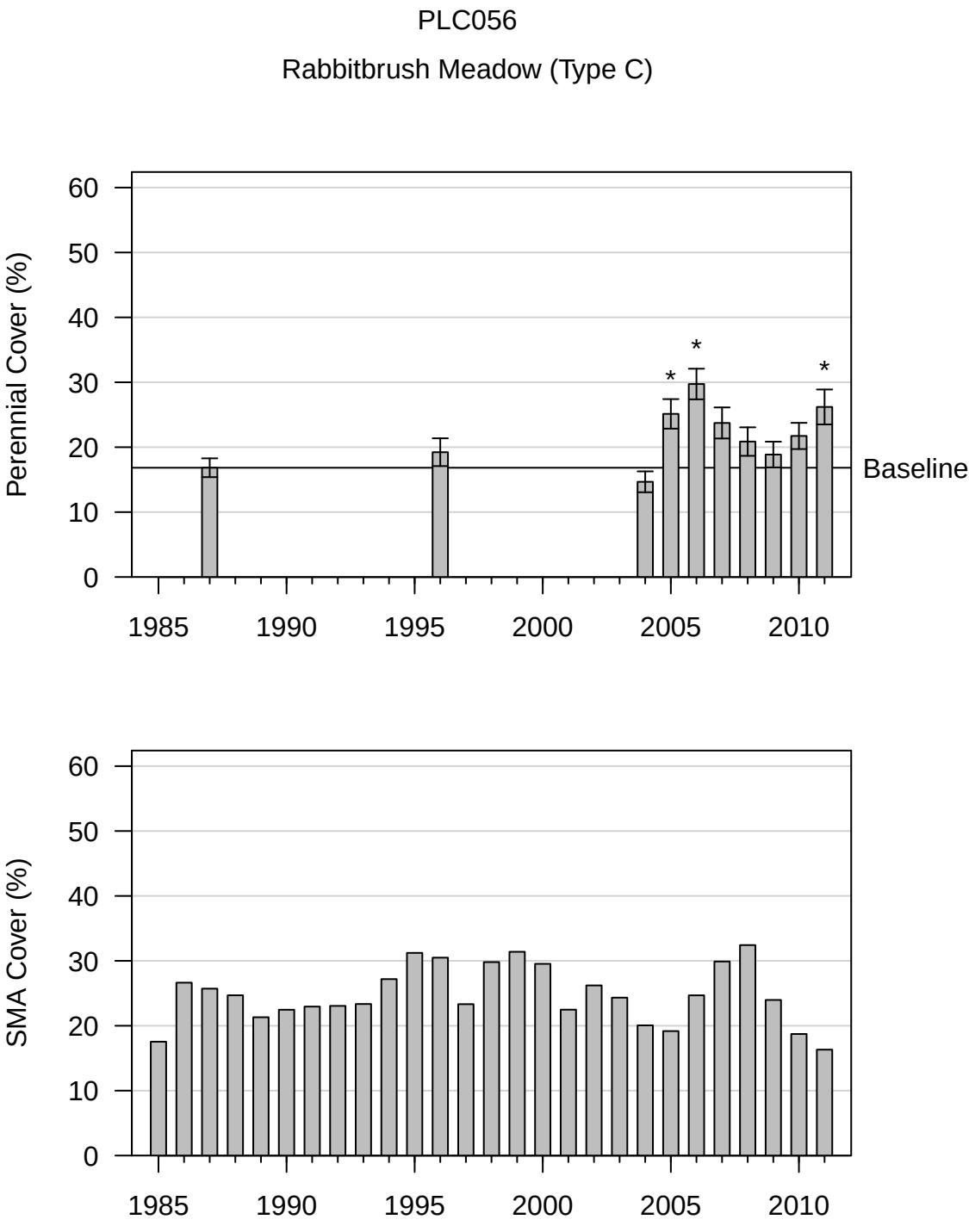


Figure 127: 2011 Control

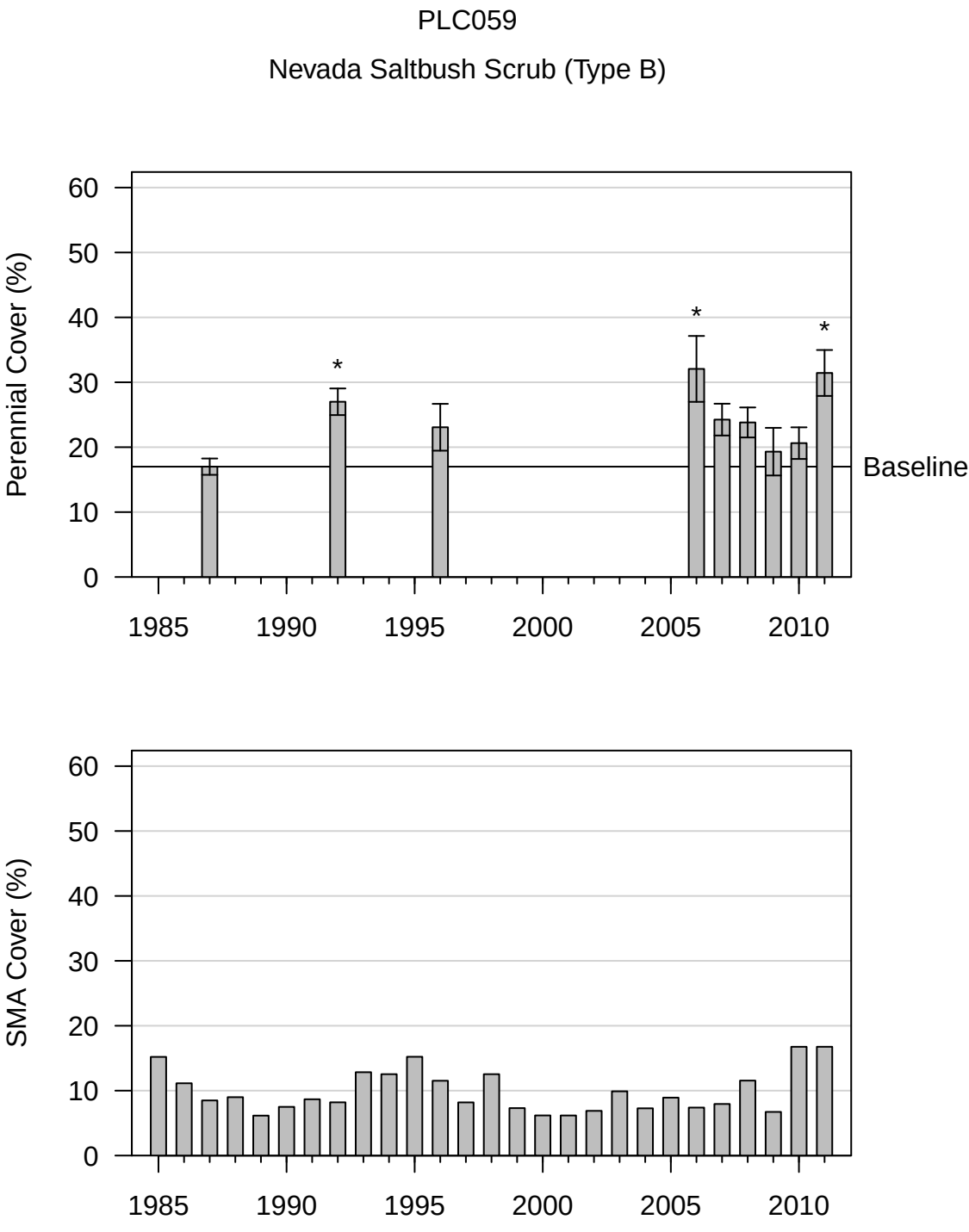


Figure 128: 2011 Control

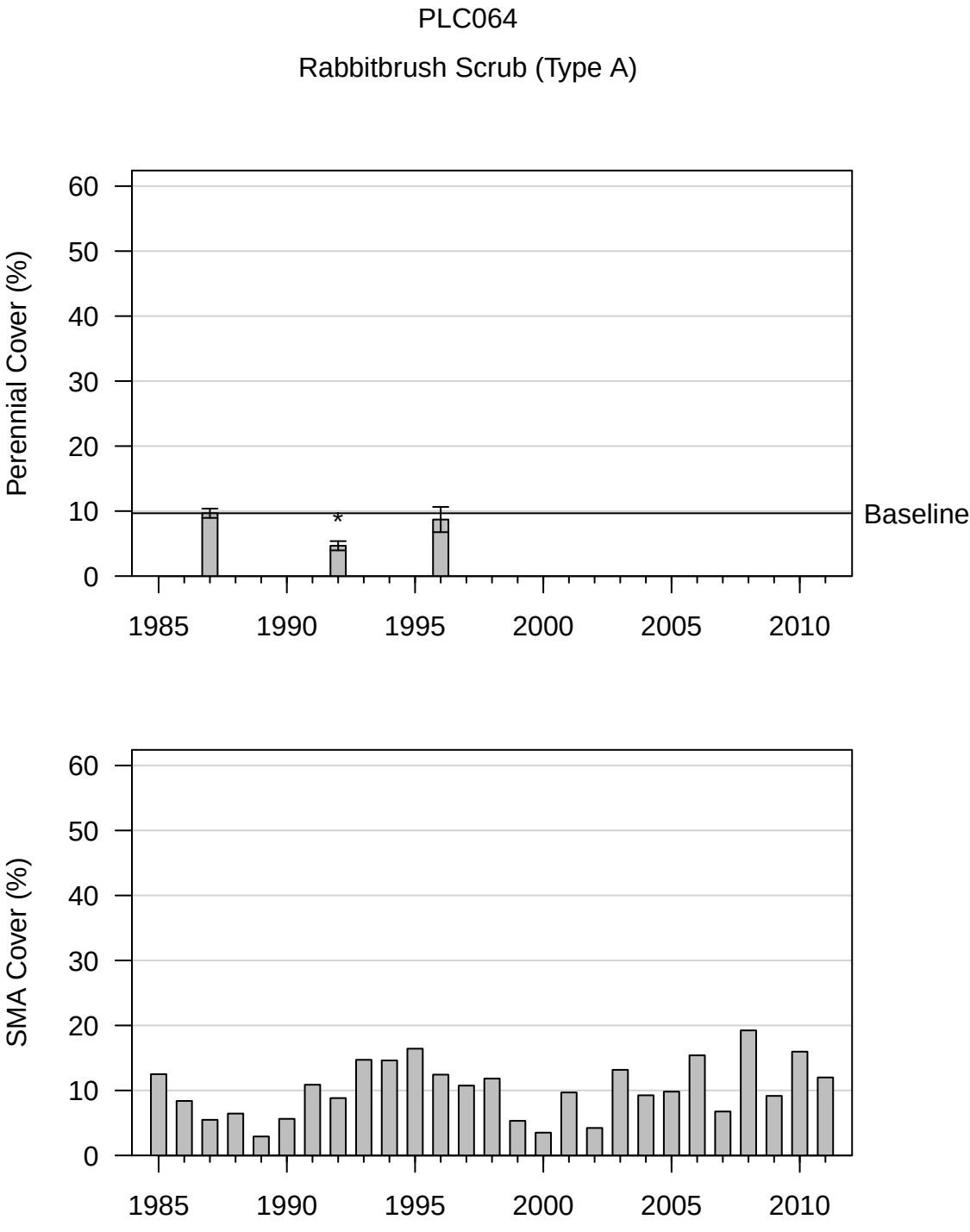


Figure 129: 1996 Control

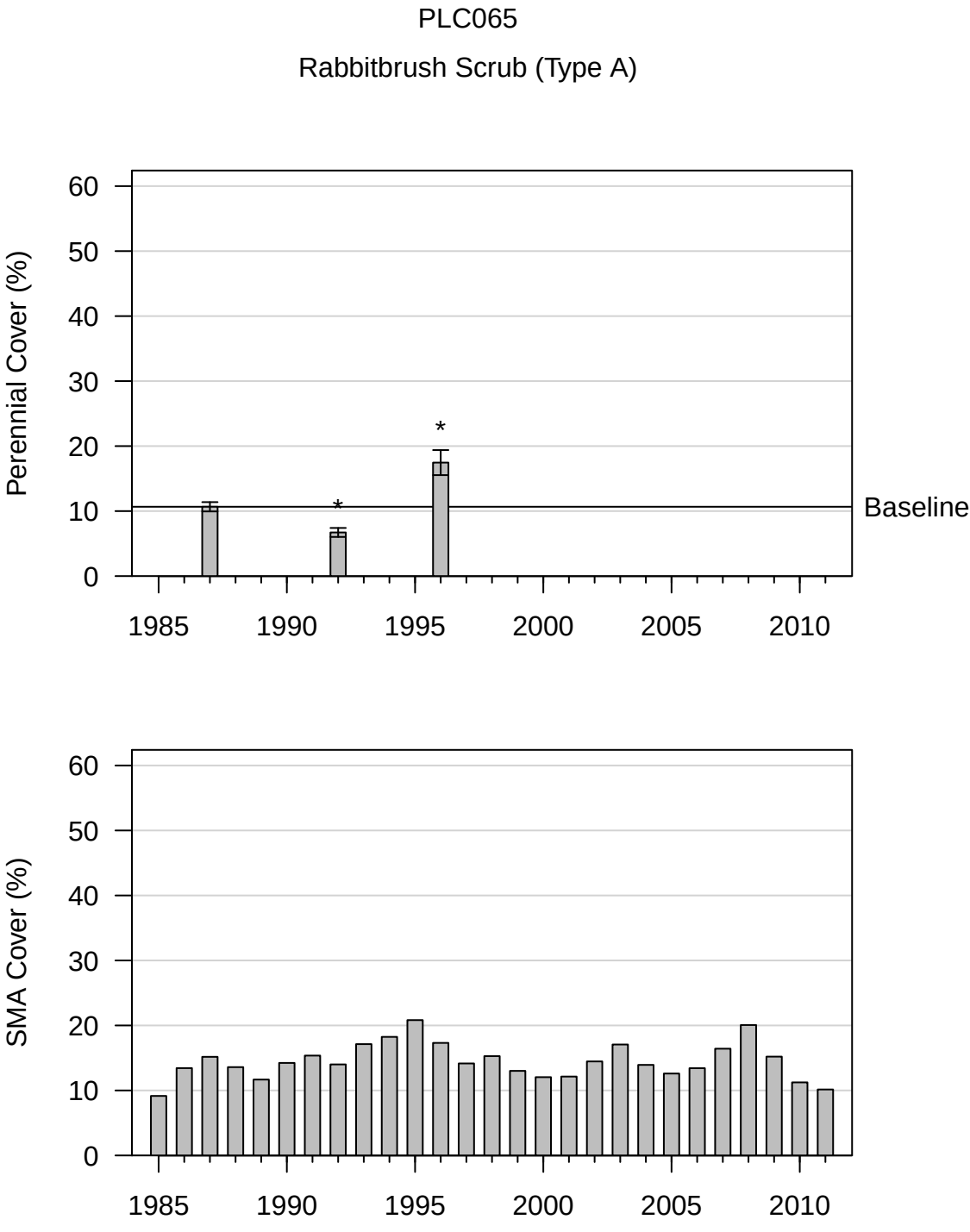


Figure 130: 1996 Control

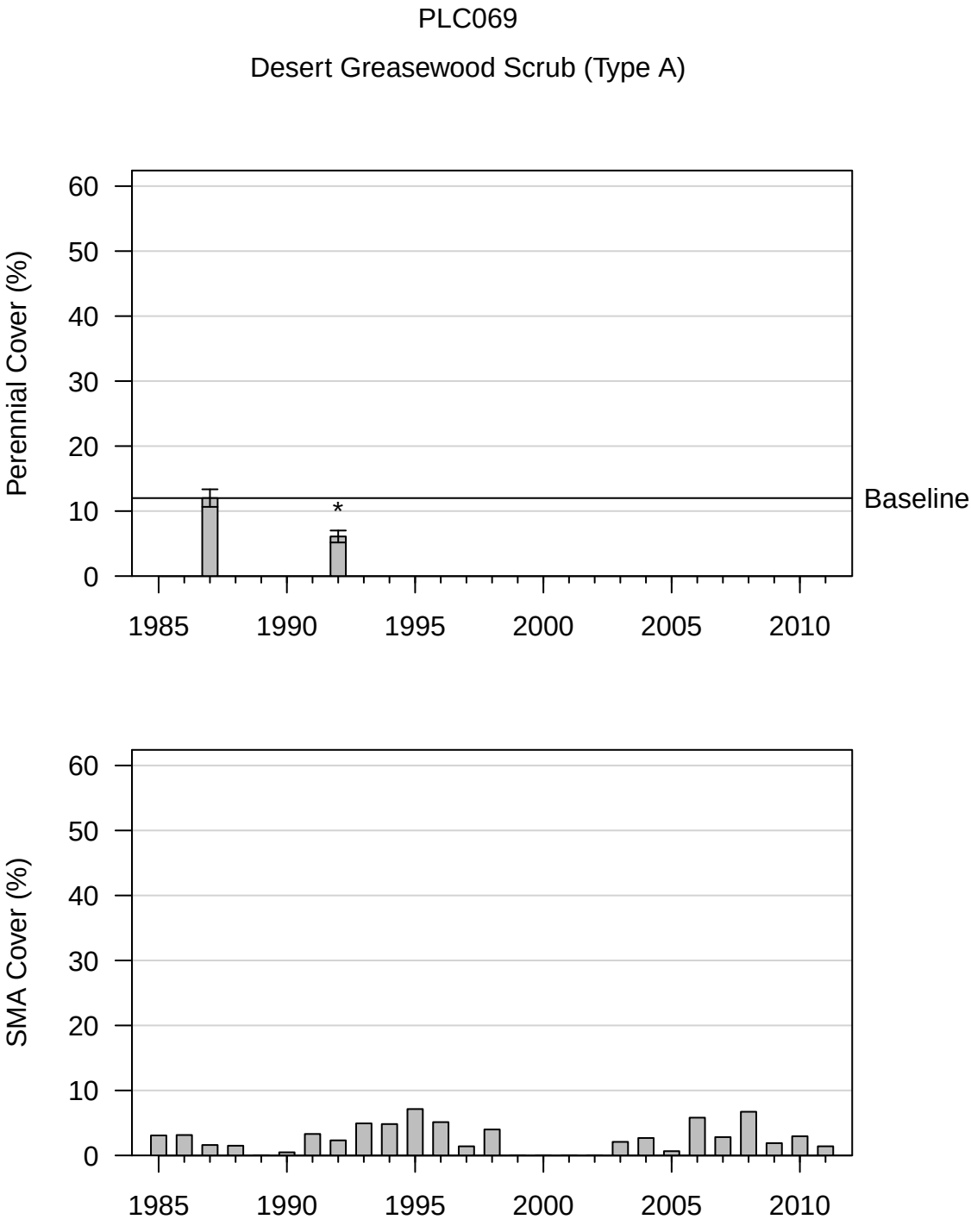


Figure 131: 1992 Control

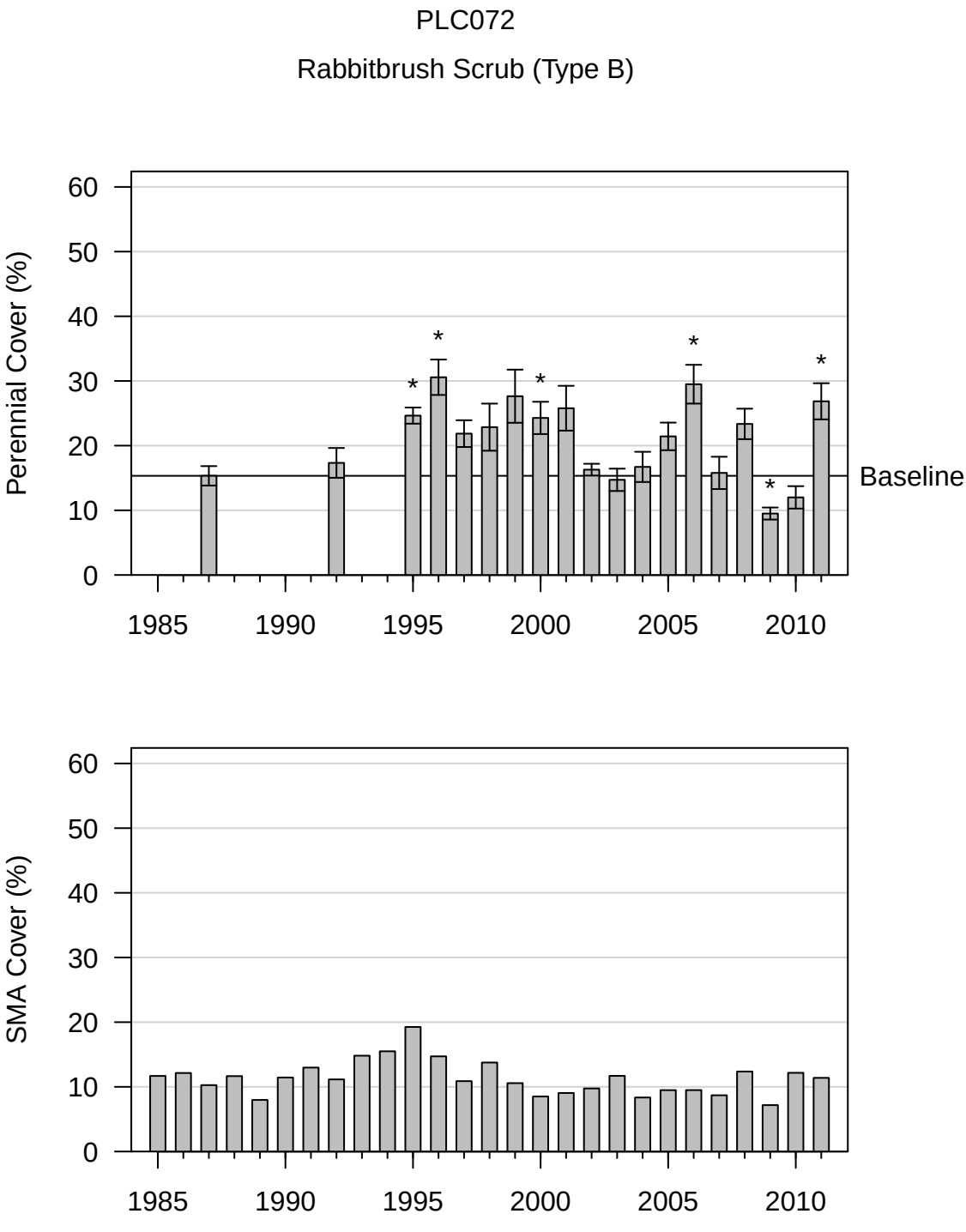


Figure 132: 2011 Control

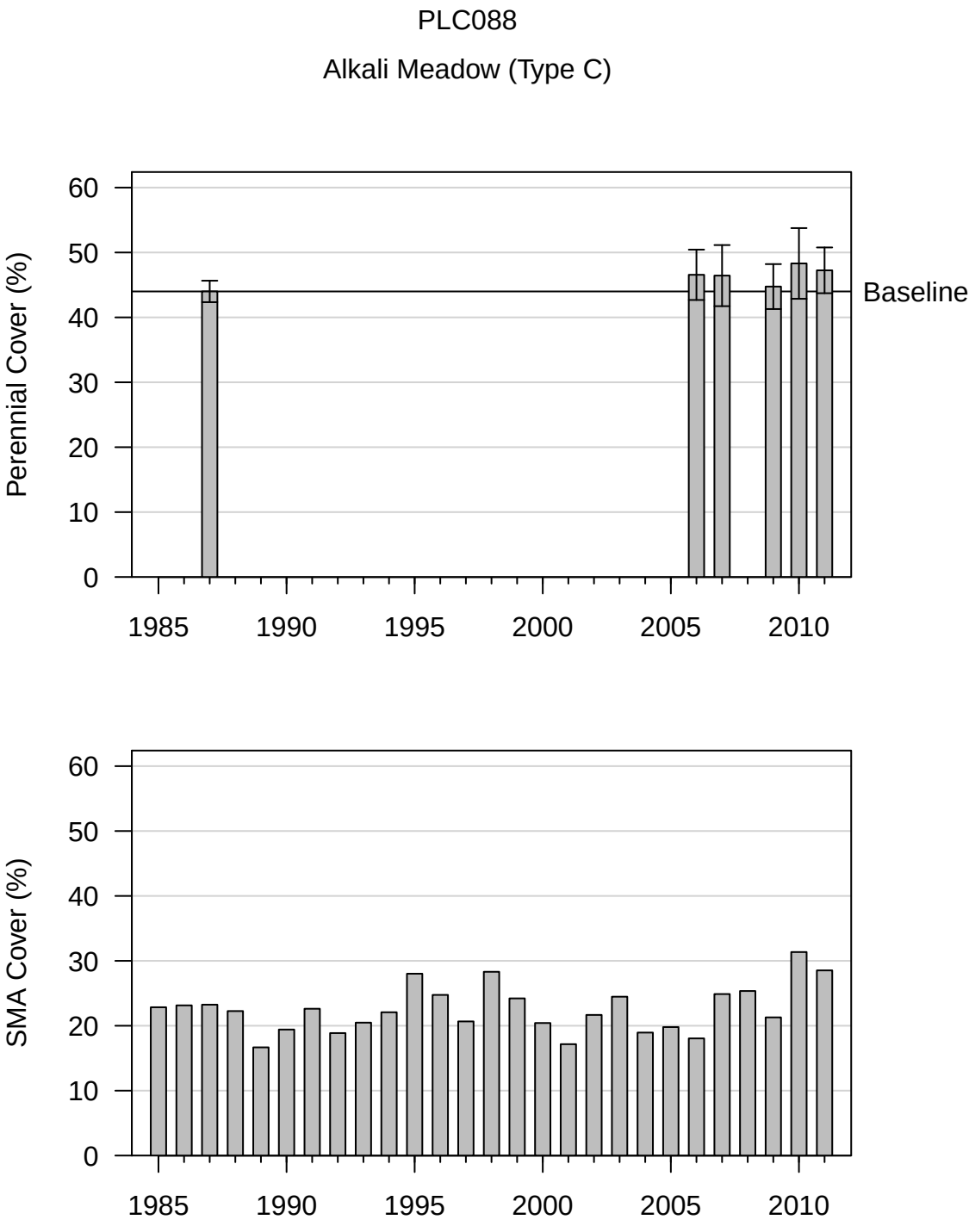


Figure 133: 2011 Control

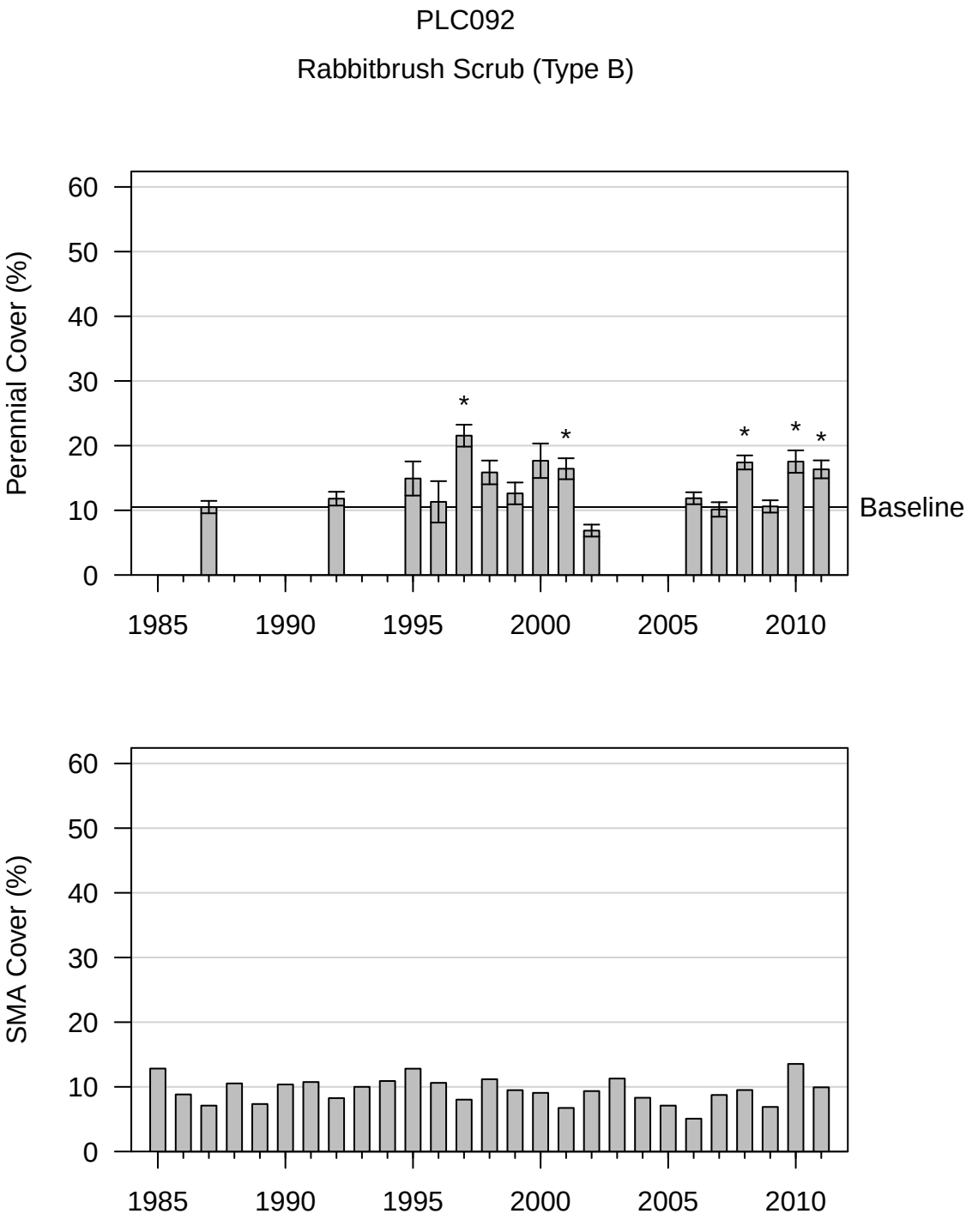


Figure 134: 2011 Control

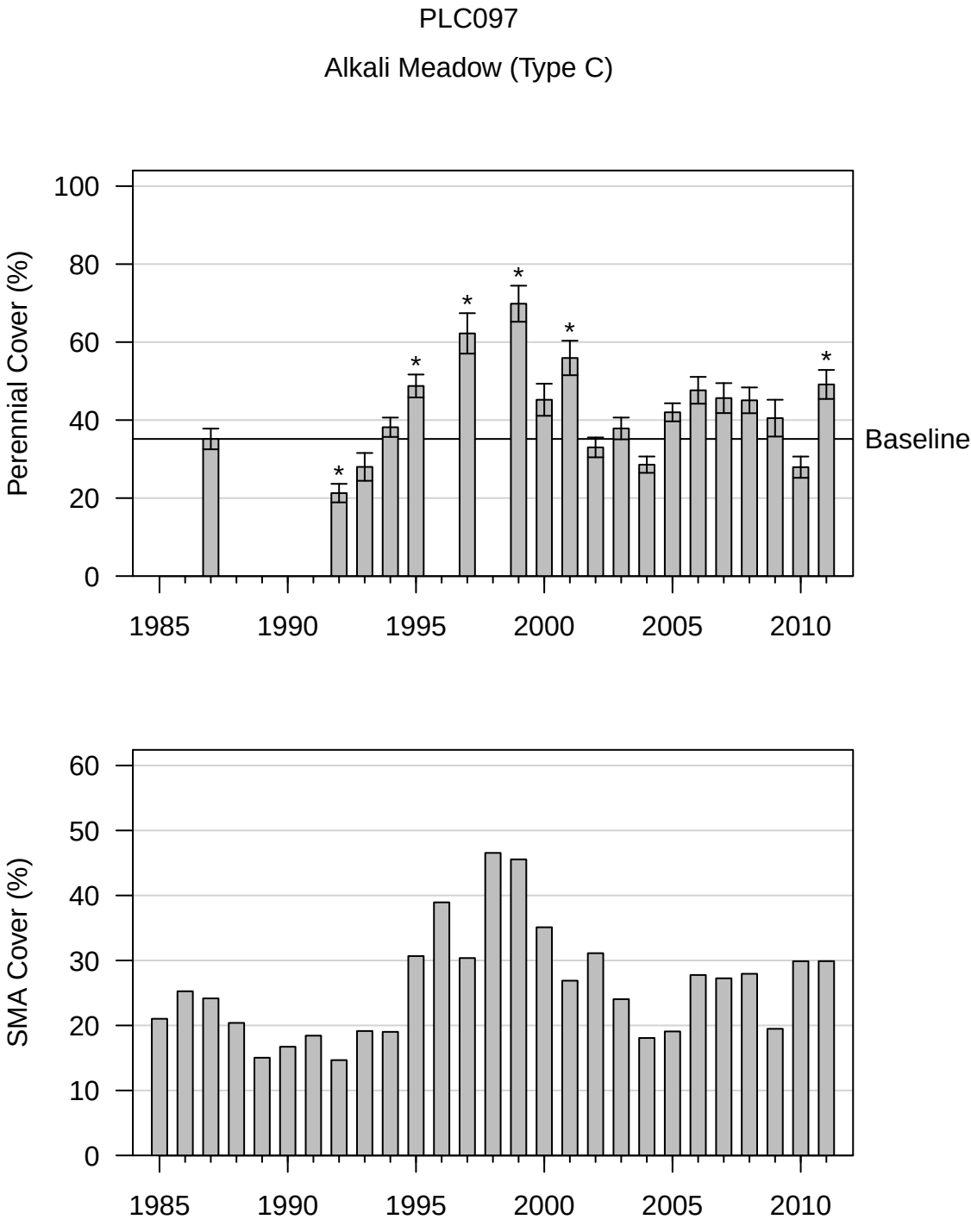


Figure 135: 2011 Control

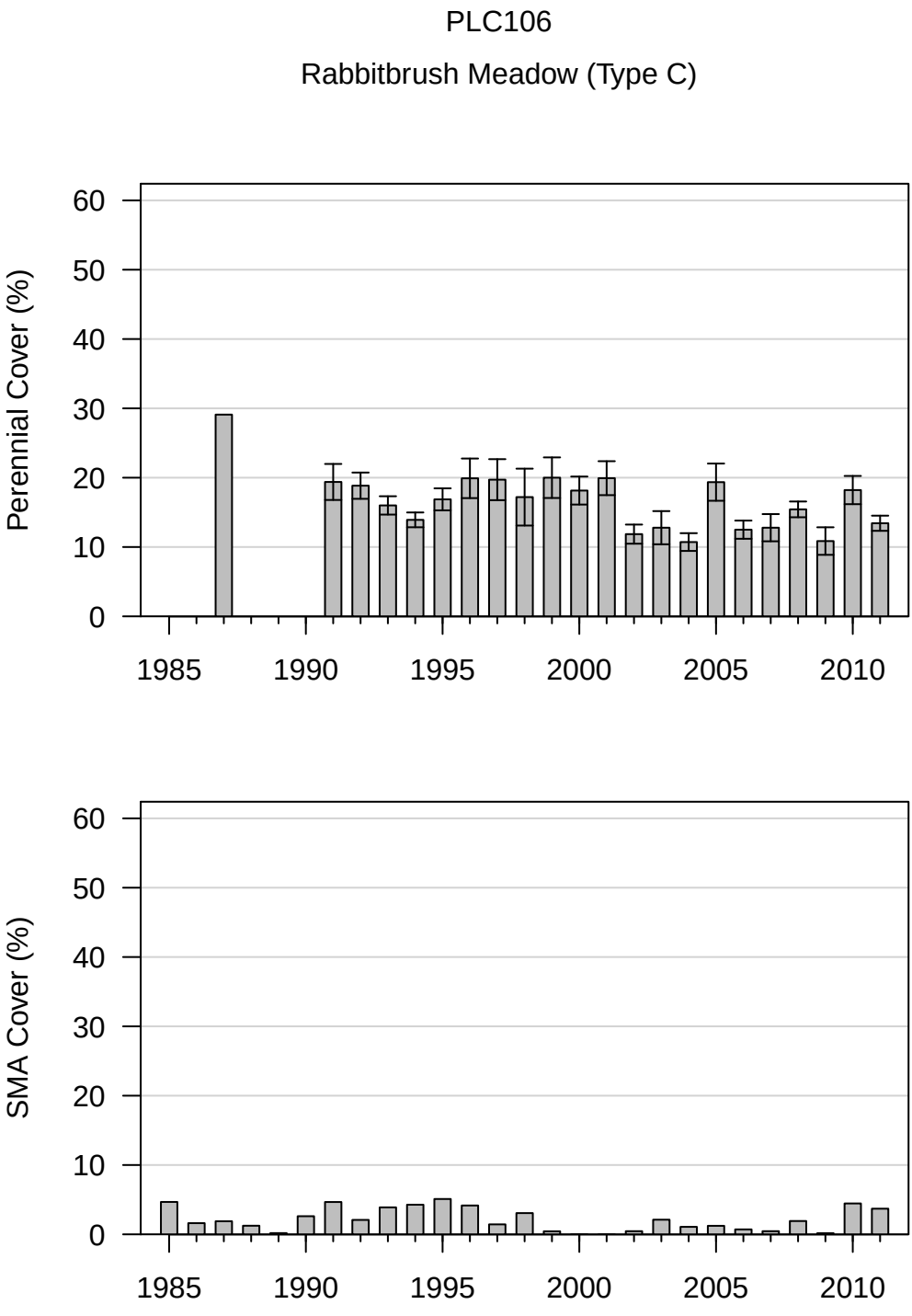


Figure 136: 2011 Control

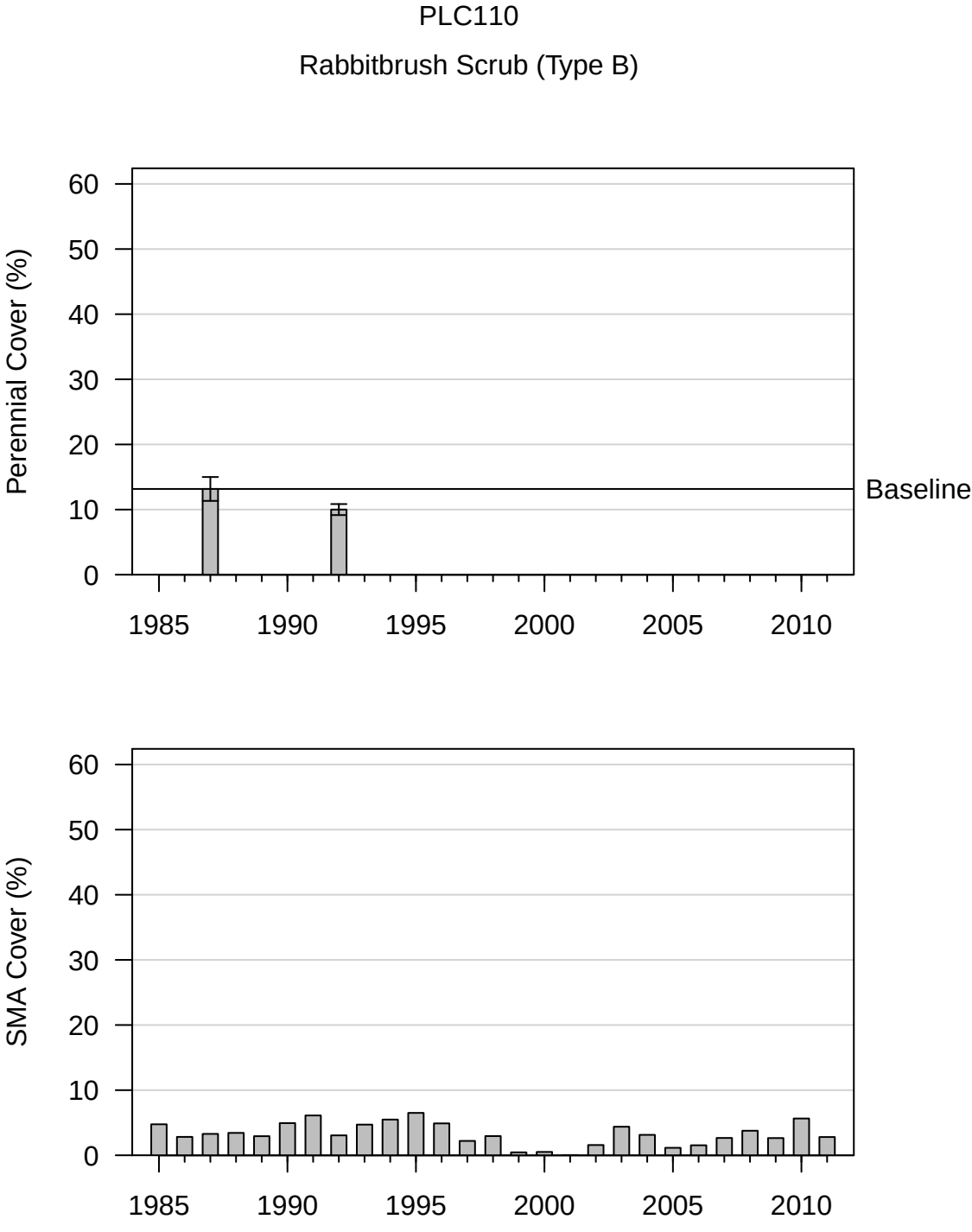


Figure 137: 1992 Control

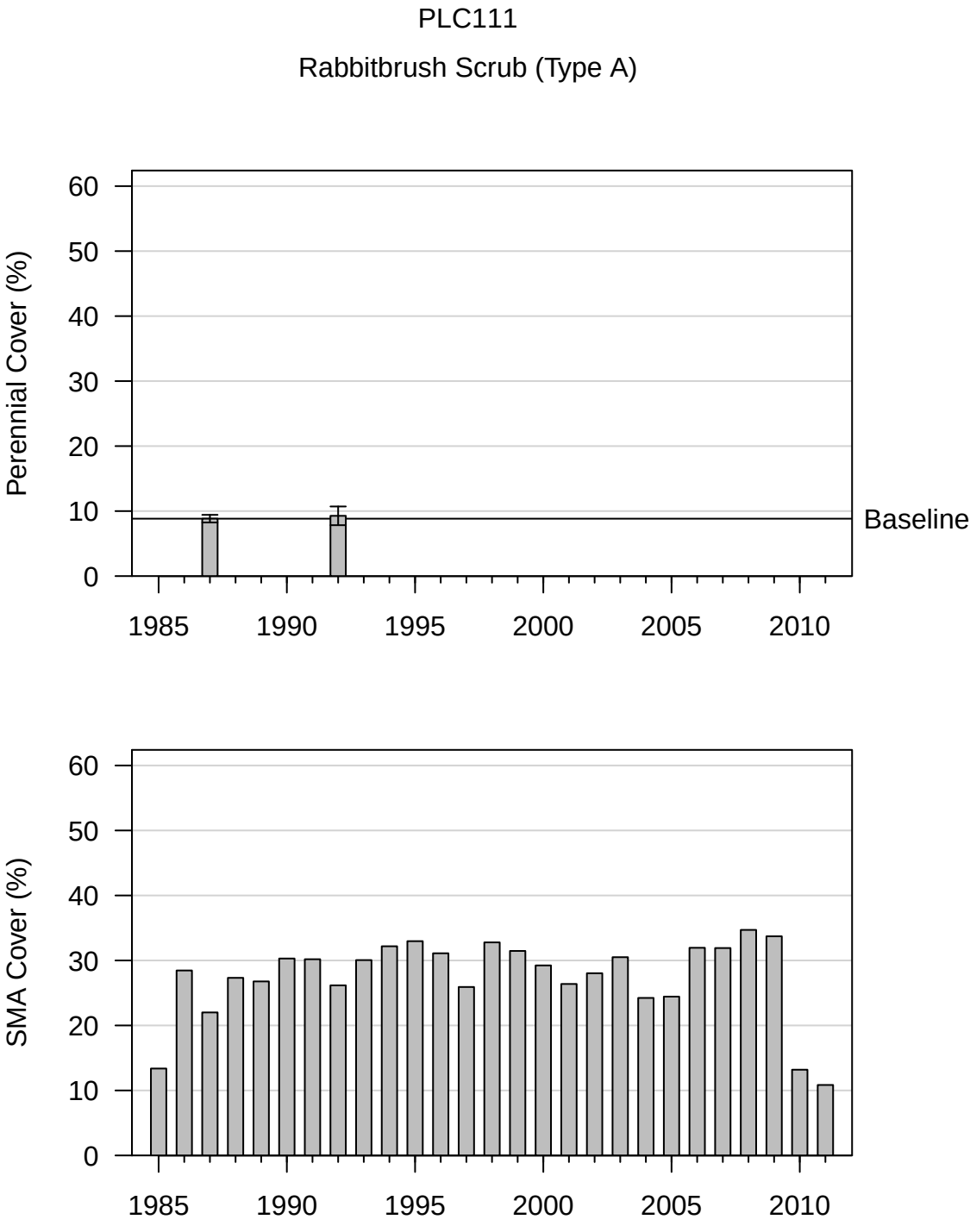


Figure 138: 1992 Control

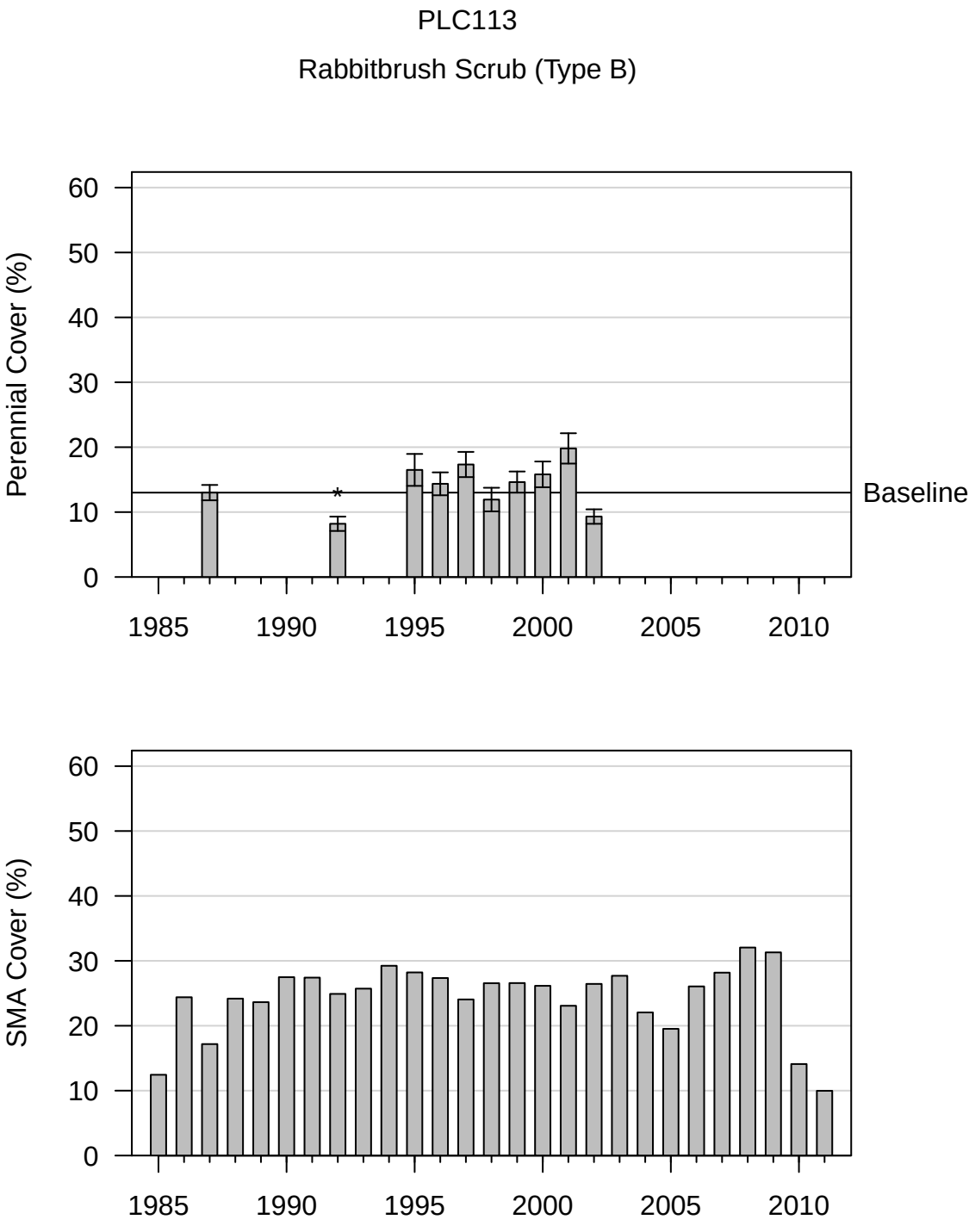


Figure 139: 2002 Control

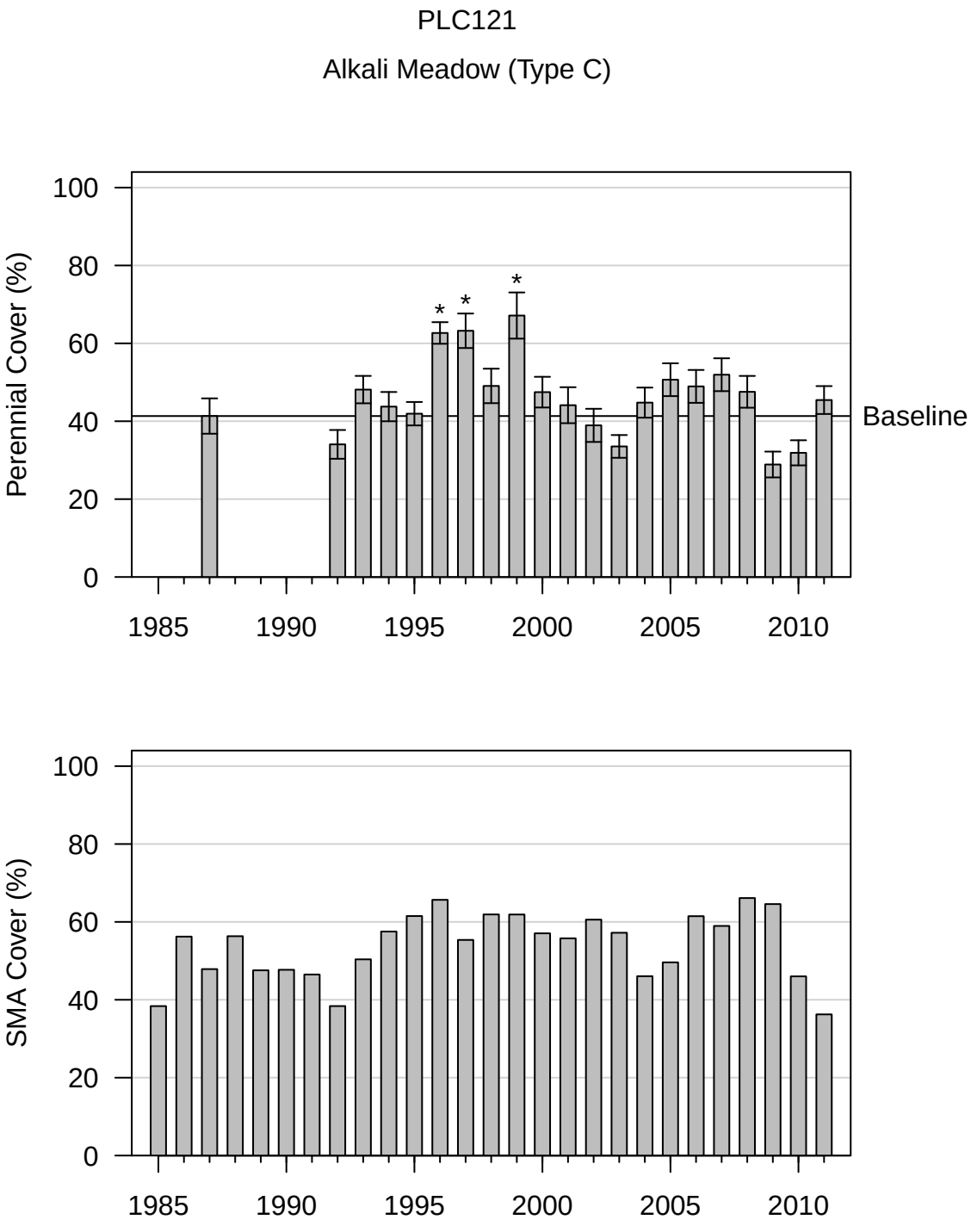


Figure 140: 2011 Control

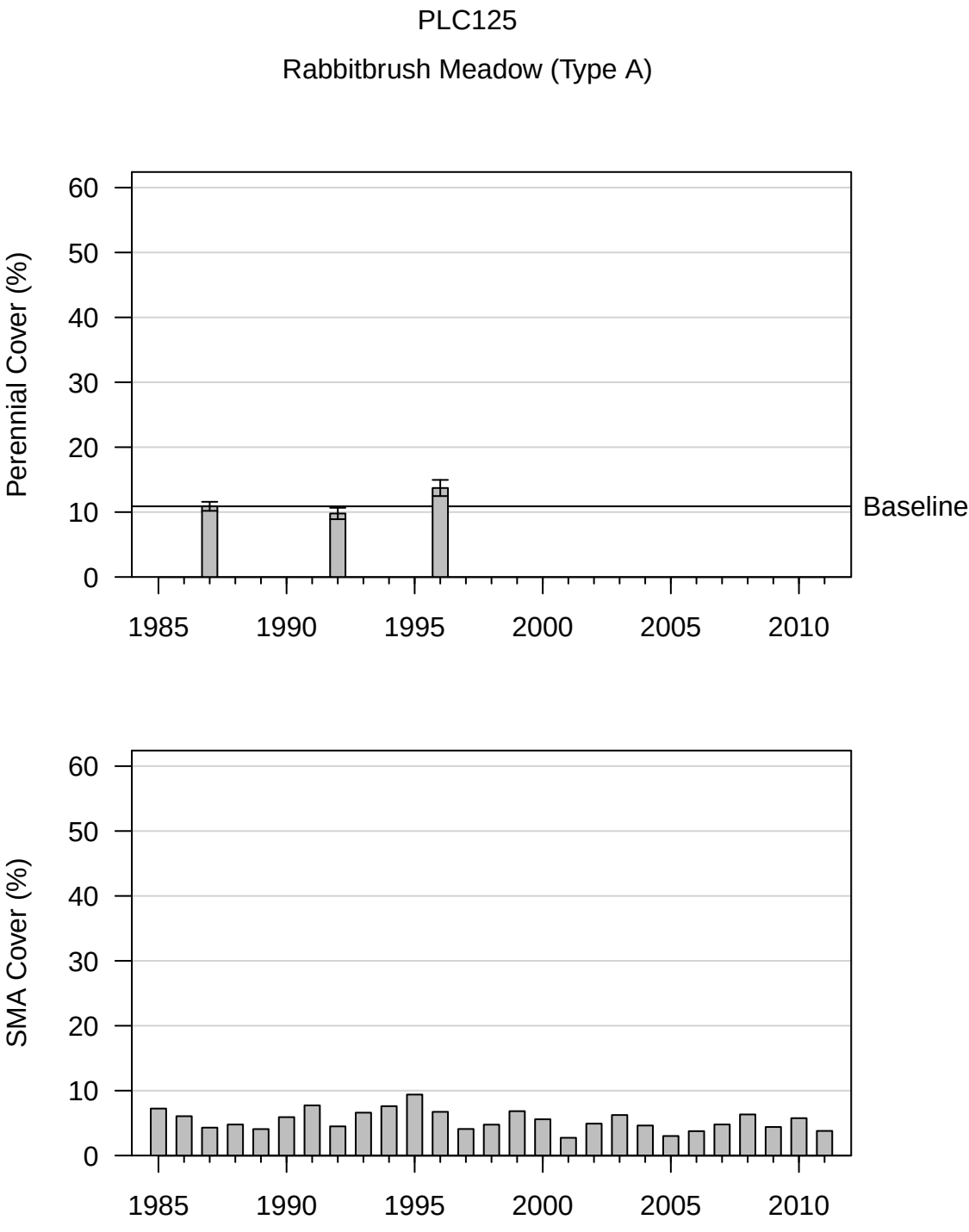


Figure 141: 1996 Control

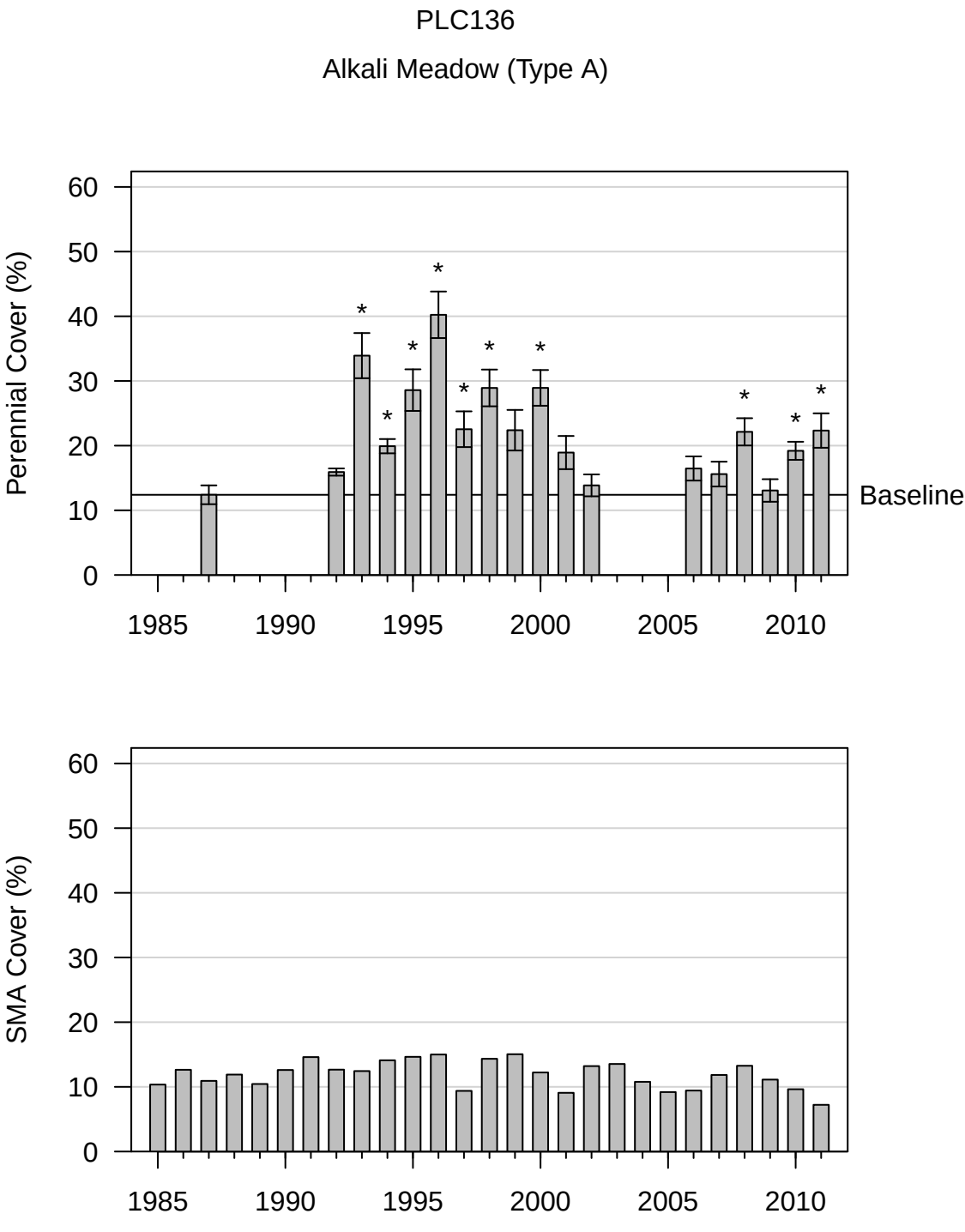


Figure 142: 2011 Control

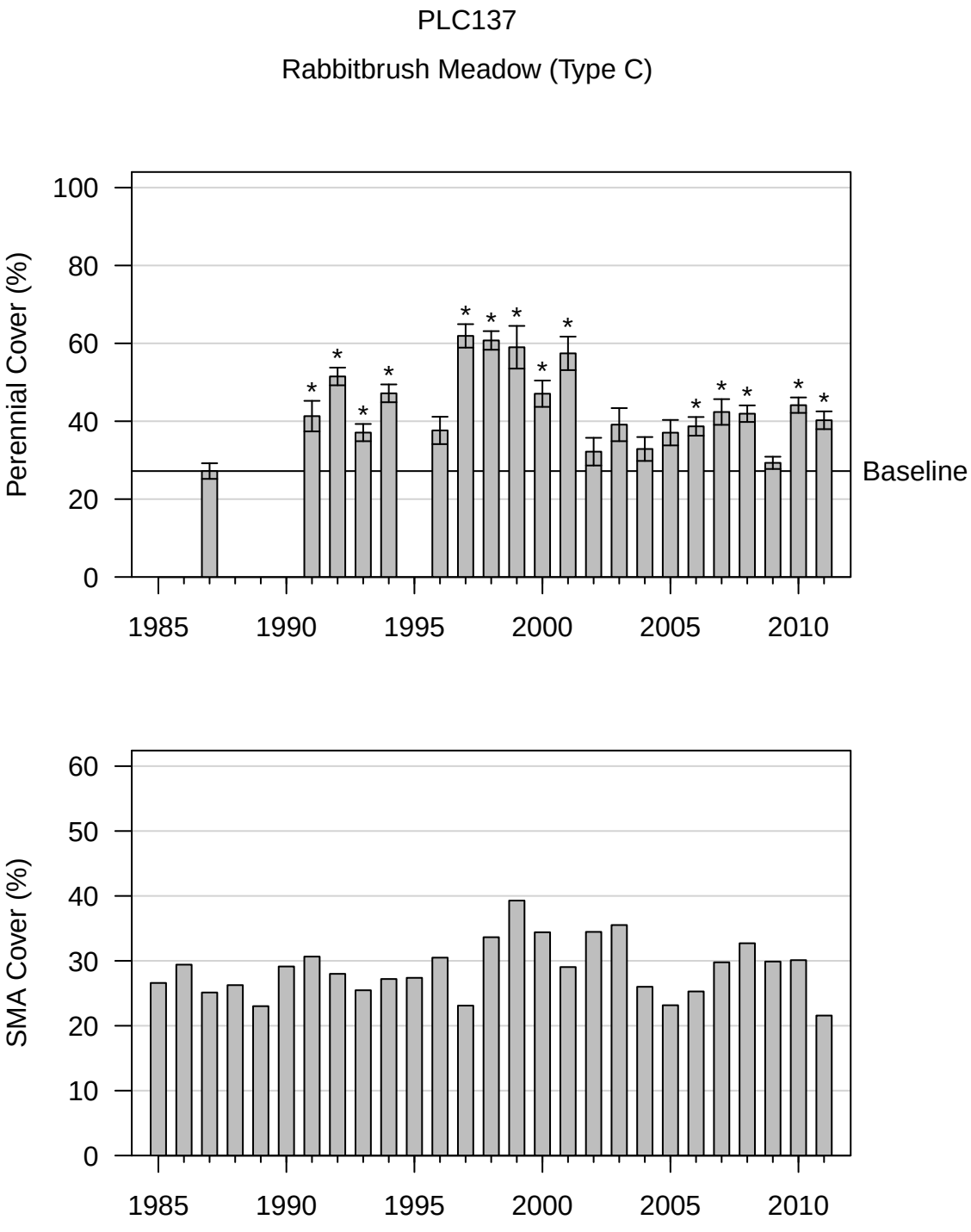


Figure 143: 2011 Control

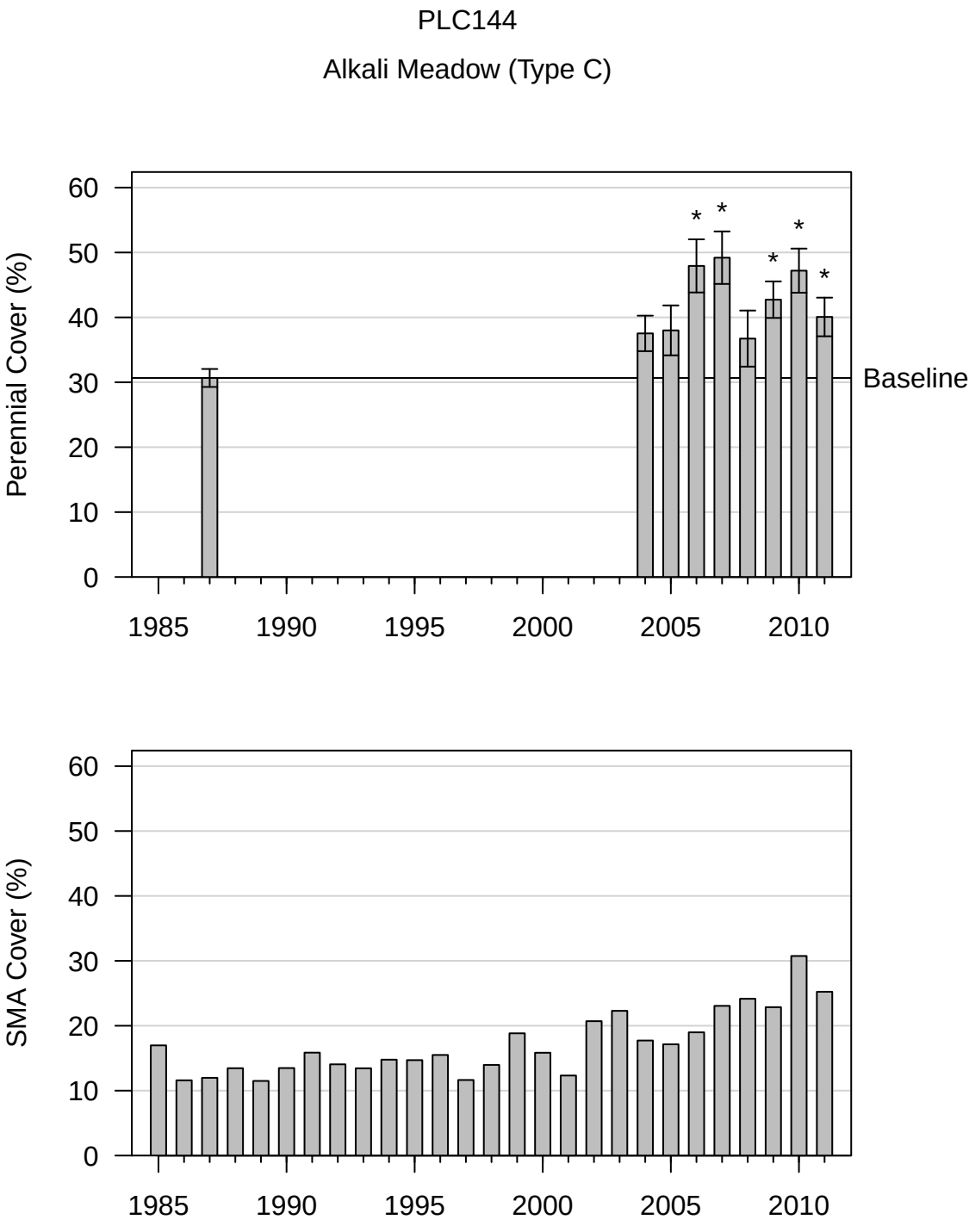


Figure 144: 2011 Control

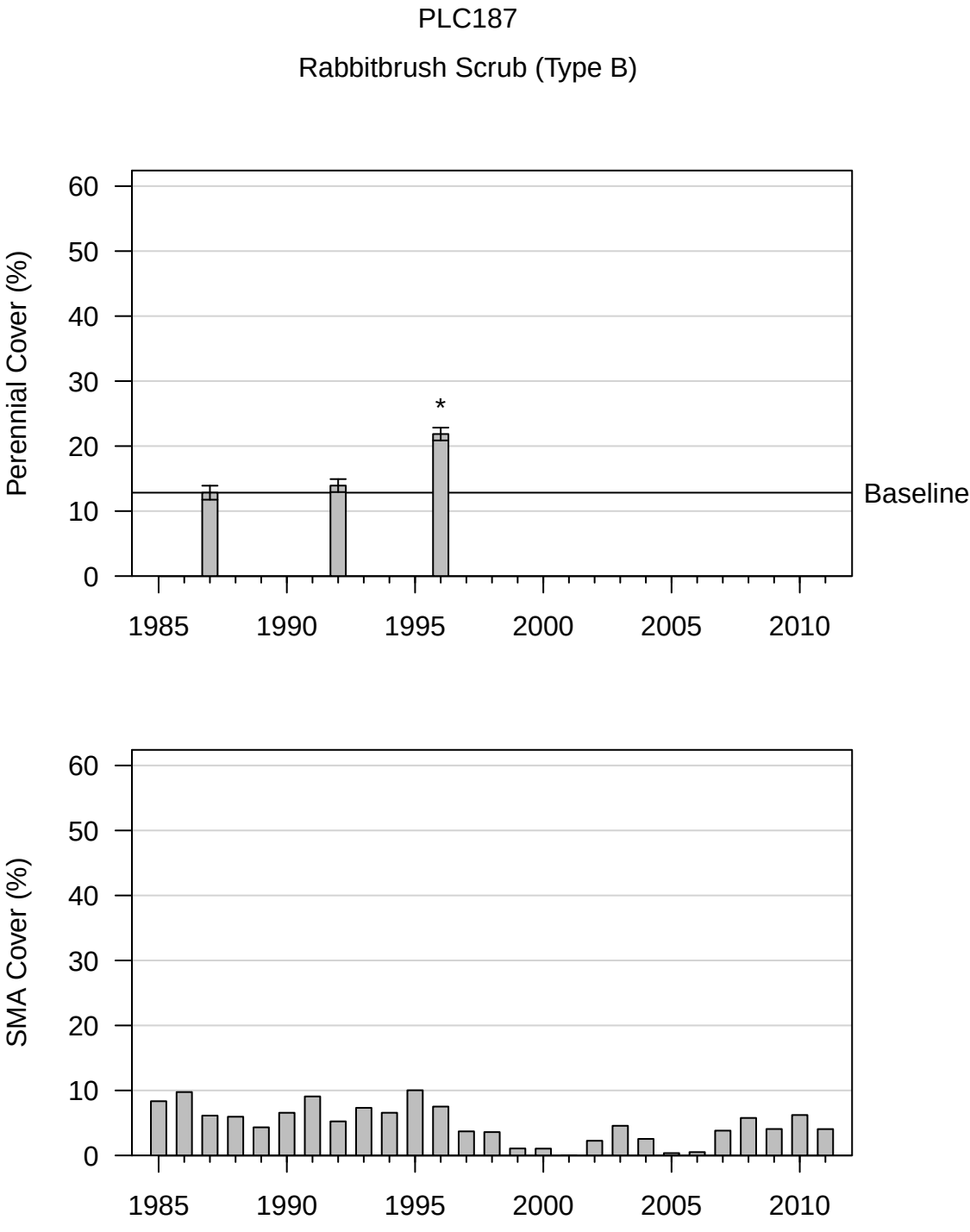


Figure 145: 1996 Control

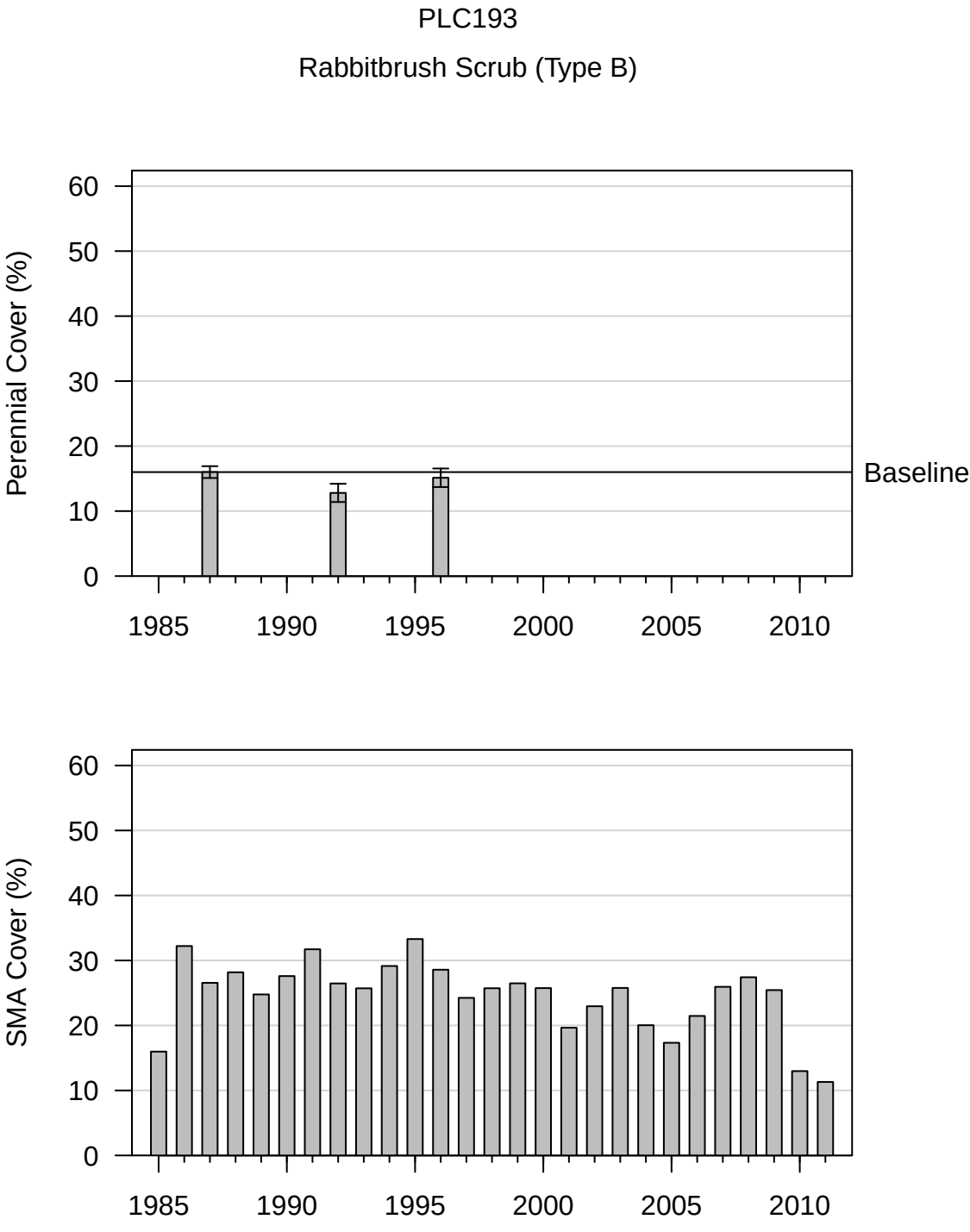


Figure 146: 1996 Control

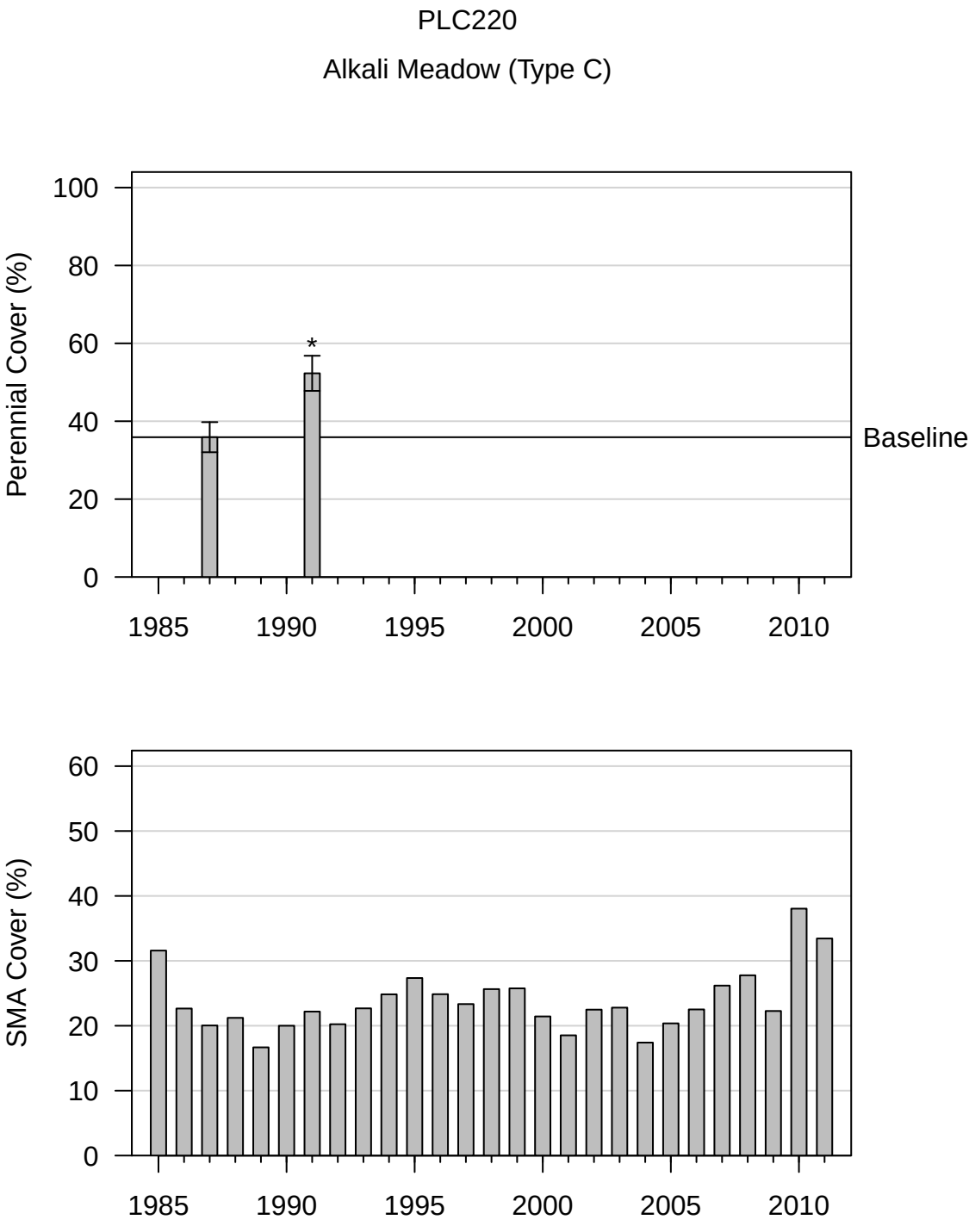


Figure 147: 1991 Control

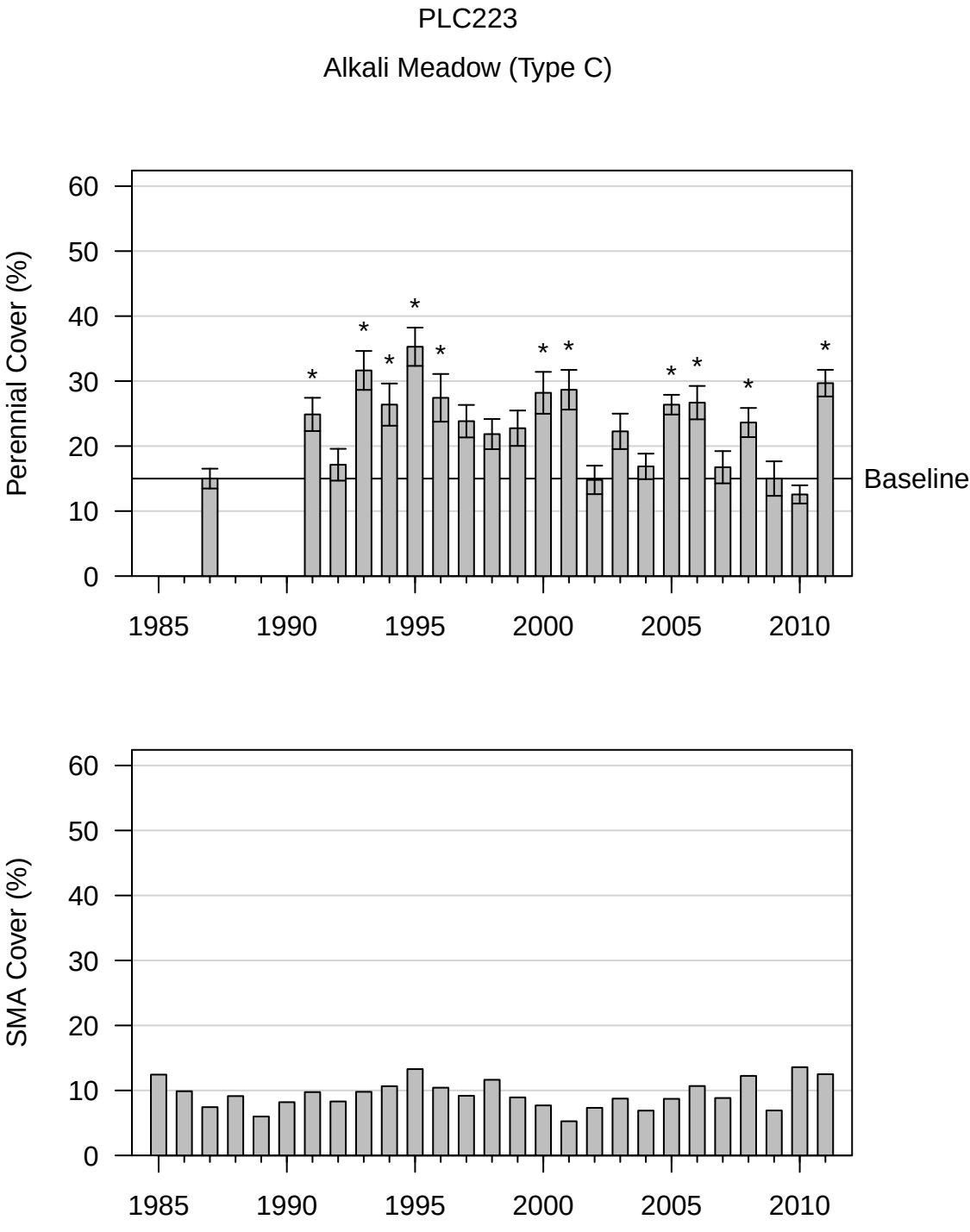


Figure 148: 2011 Control

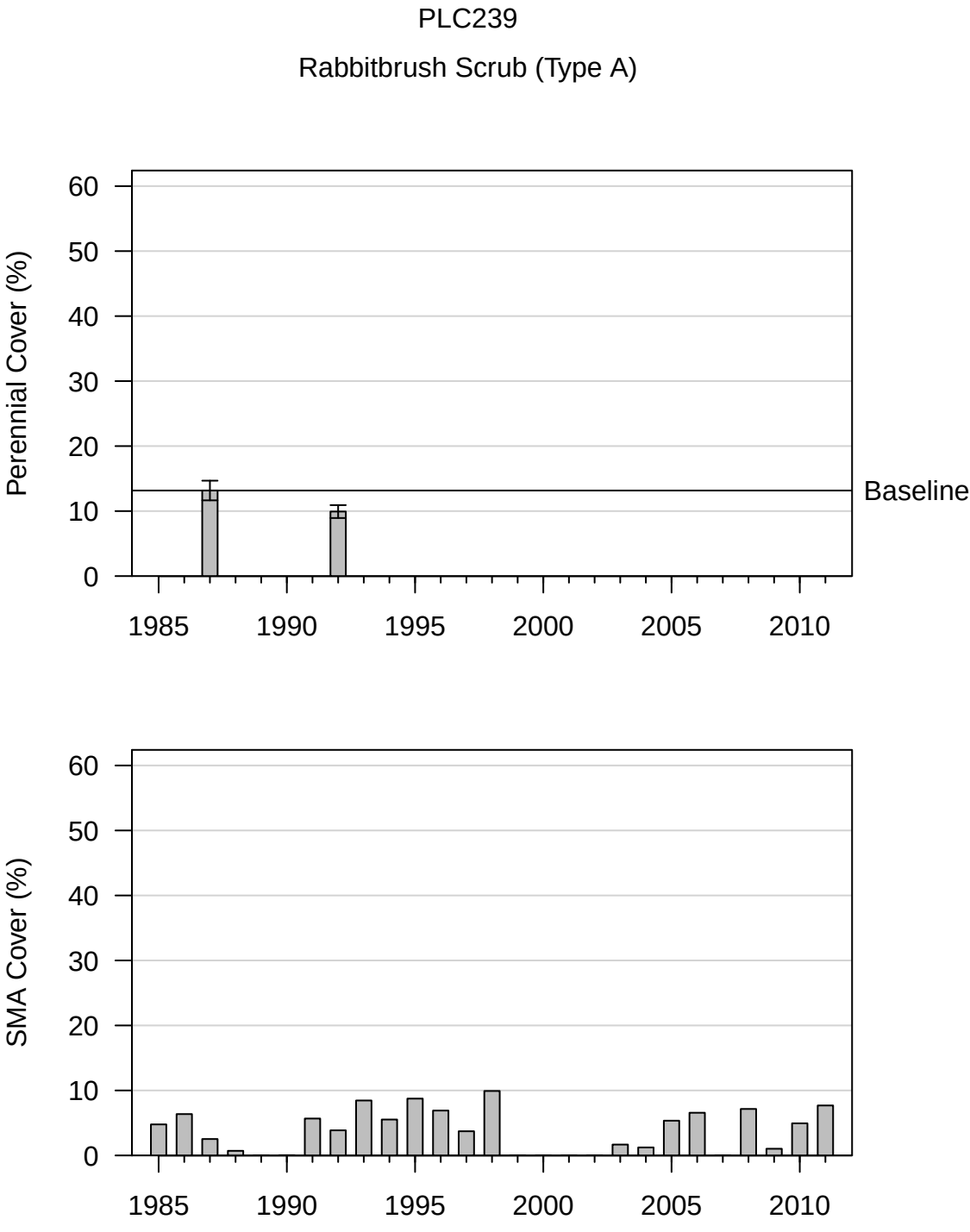


Figure 149: 1992 Control

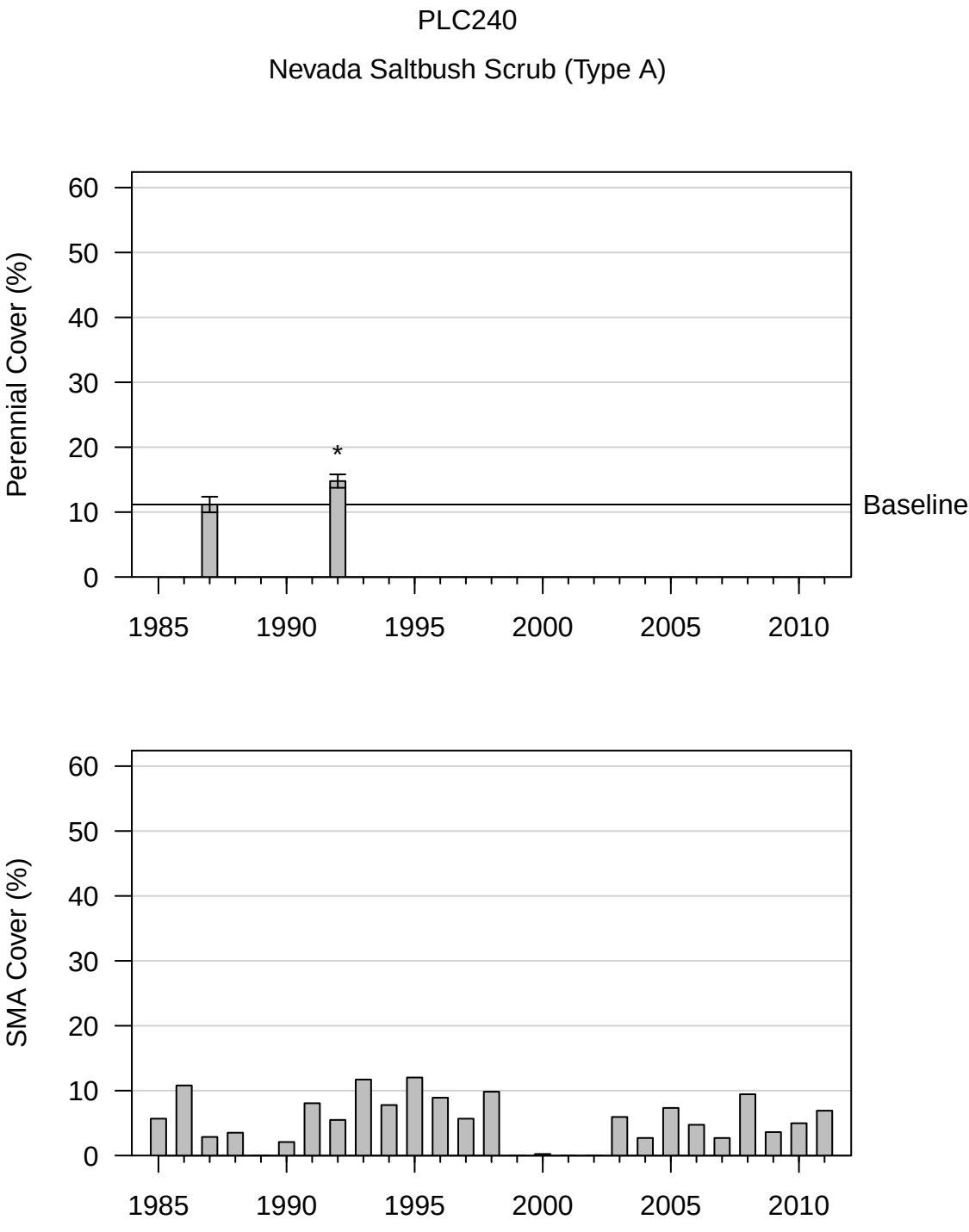


Figure 150: 1992 Control

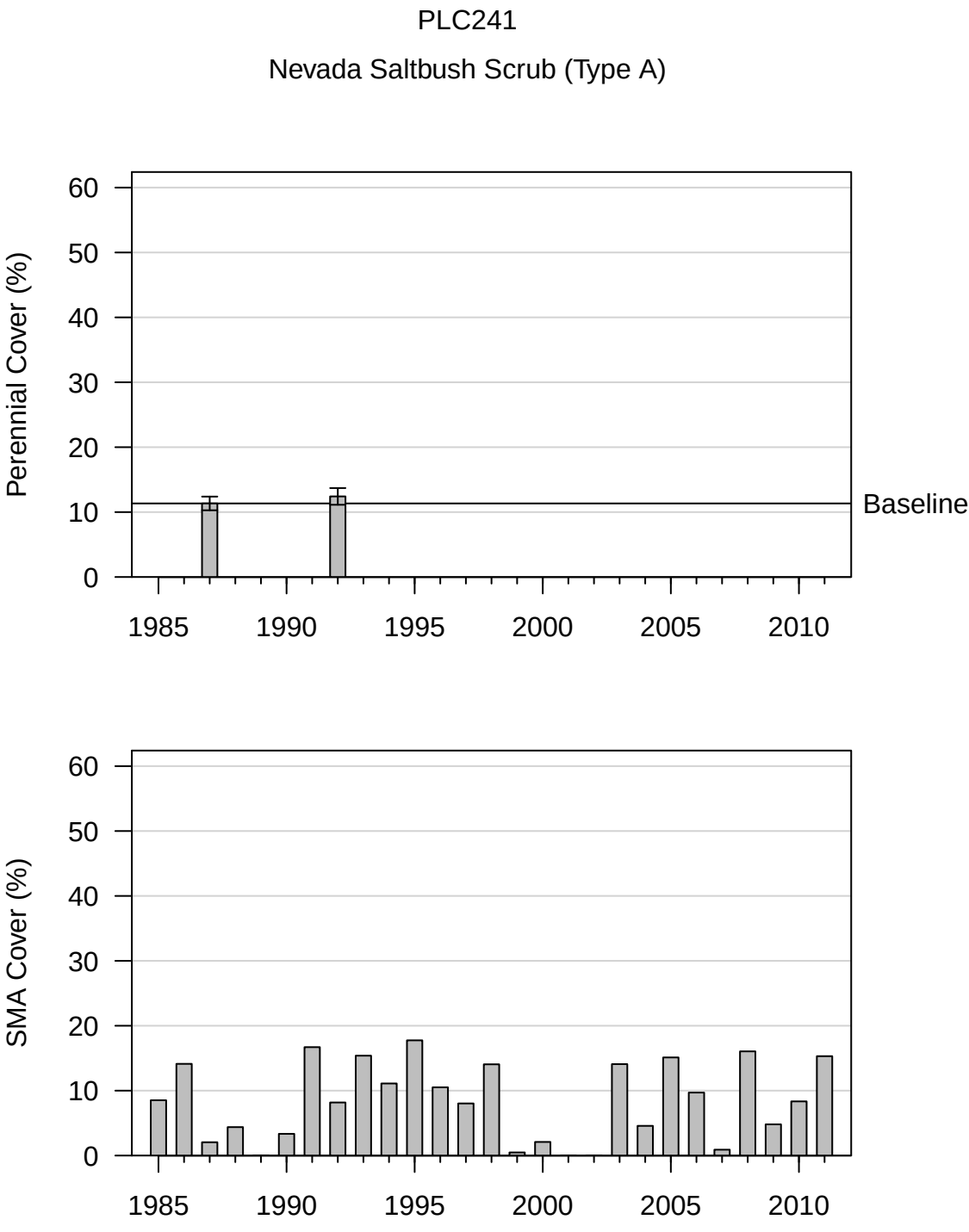


Figure 151: 1992 Control

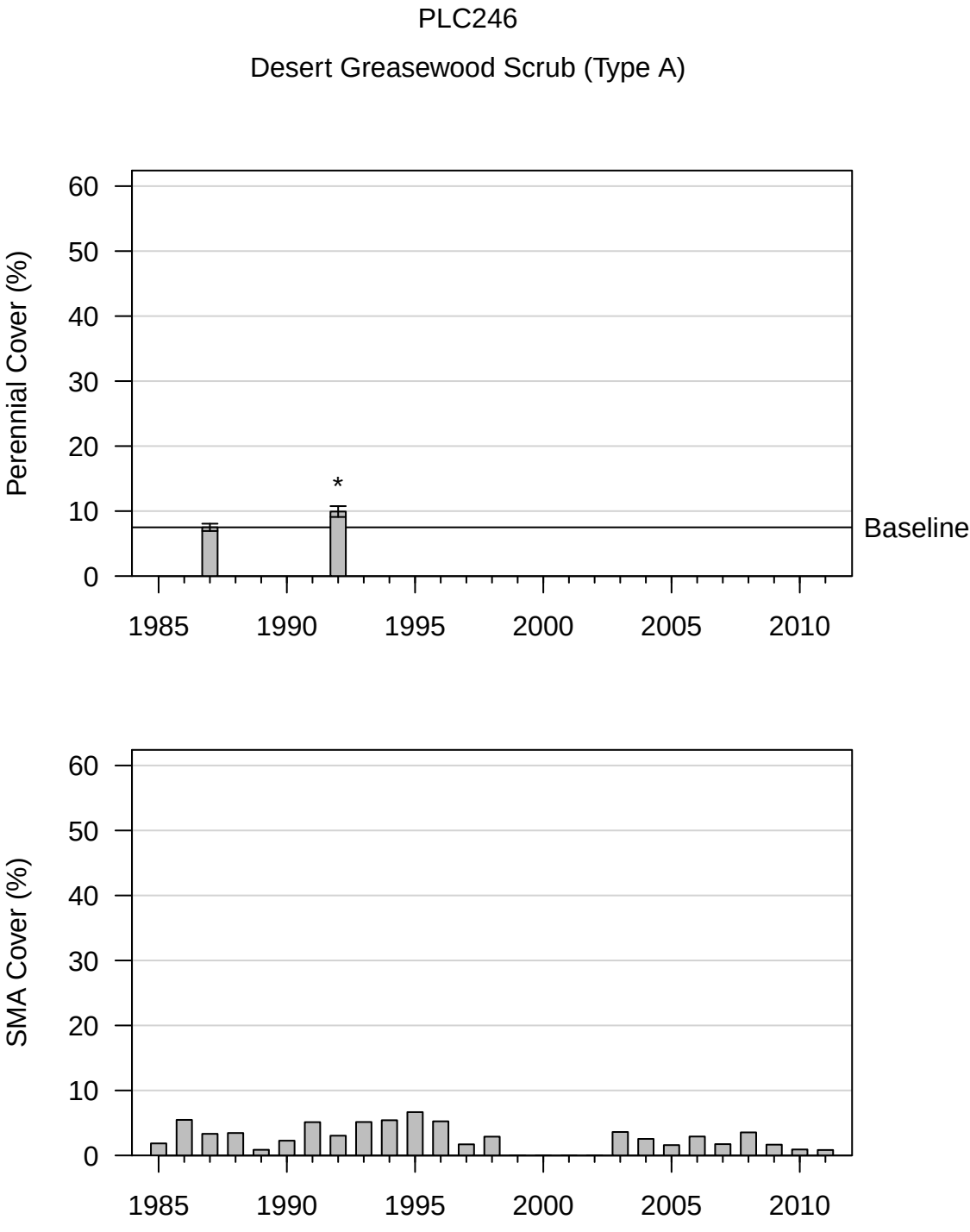


Figure 152: 1992 Control

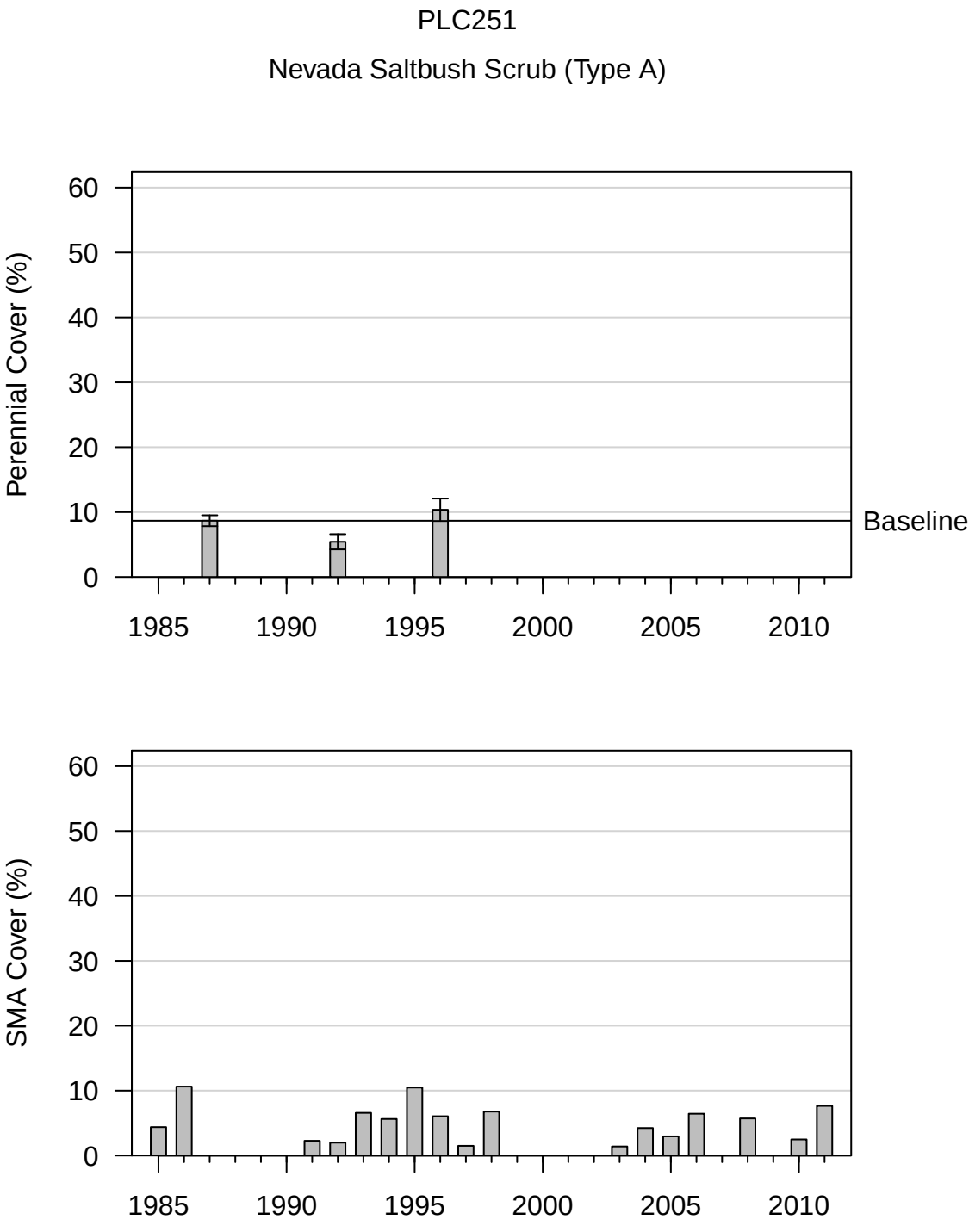


Figure 153: 1996 Control

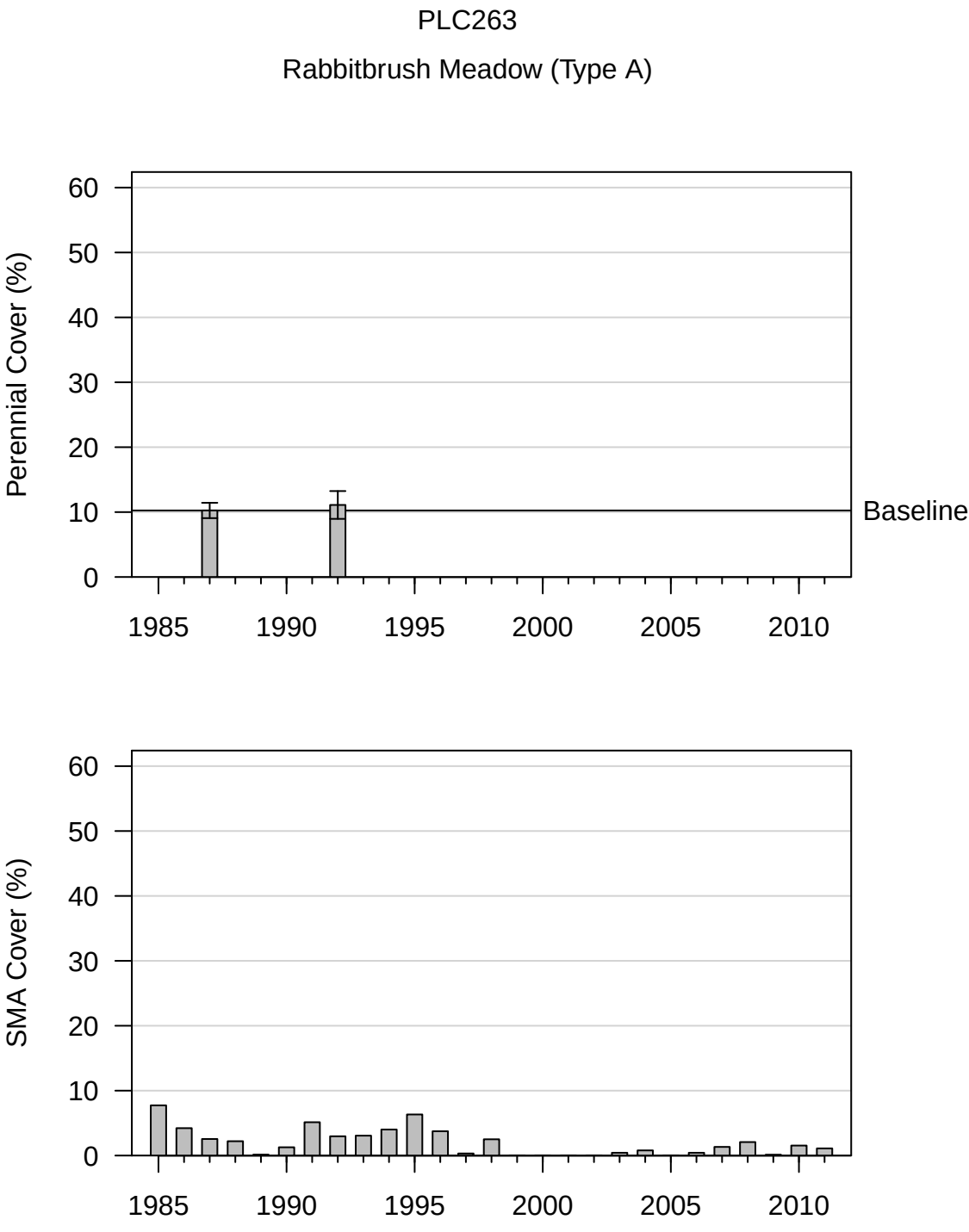


Figure 154: 1992 Control

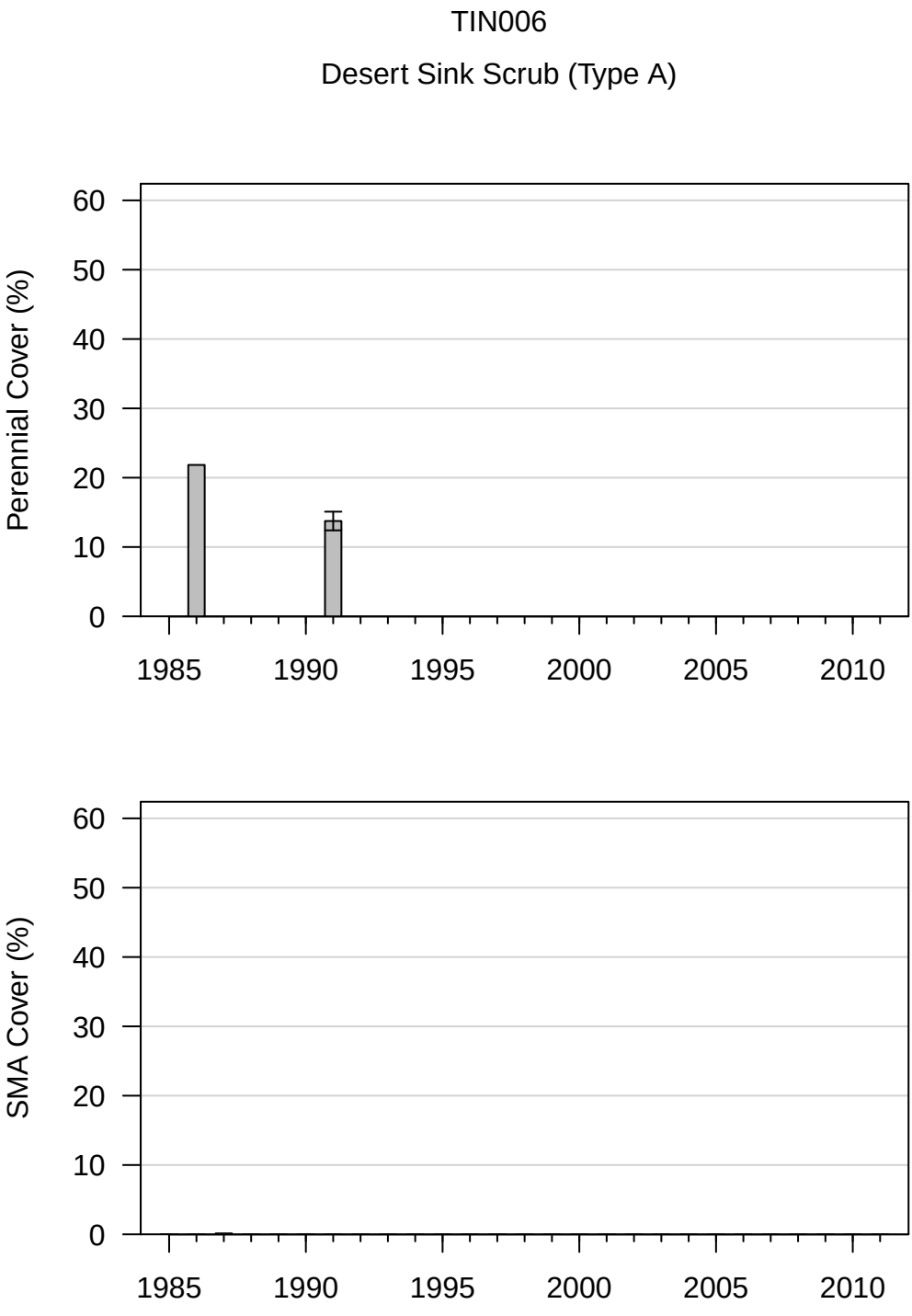


Figure 155: 1991 Wellfield

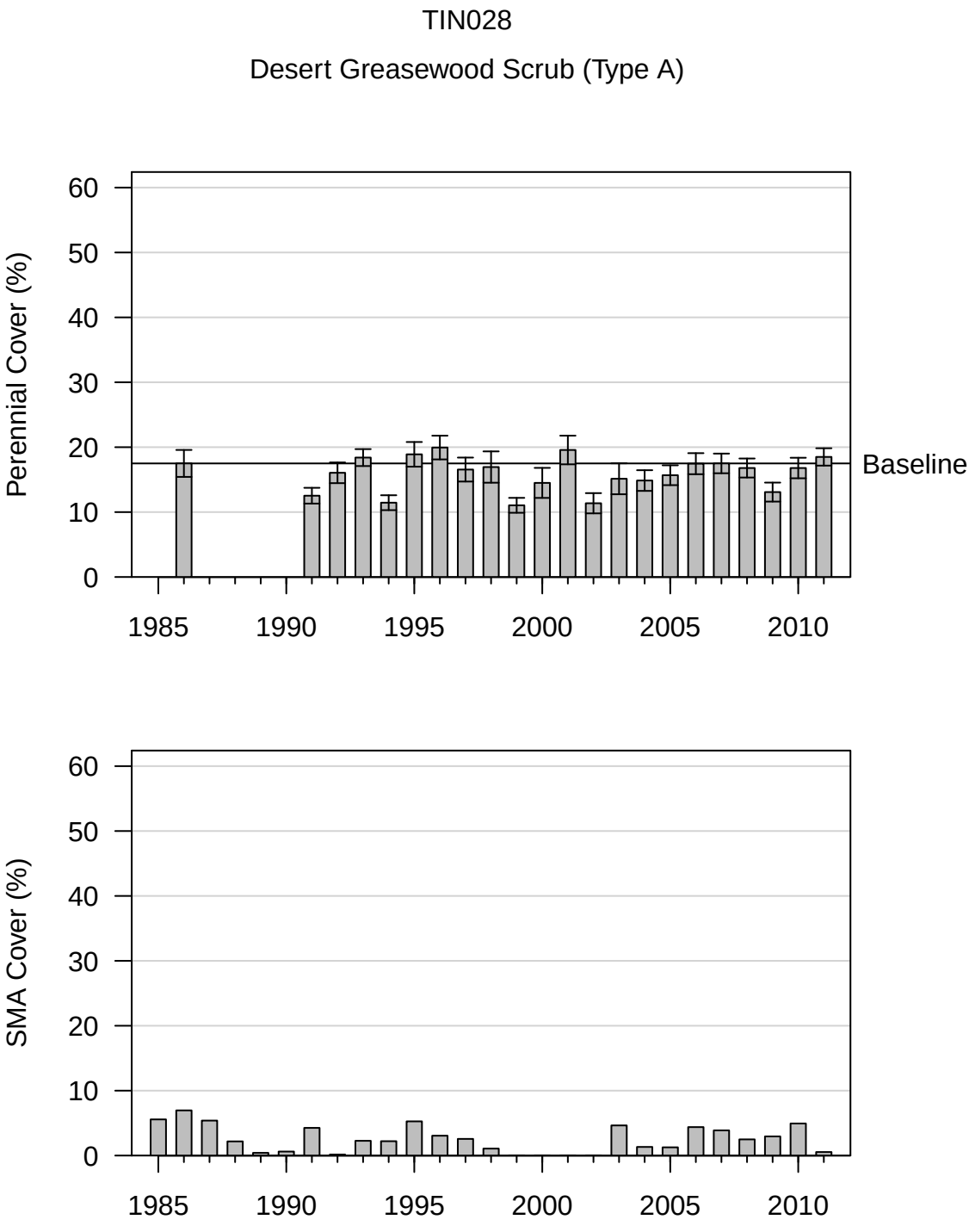


Figure 156: 2011 Wellfield

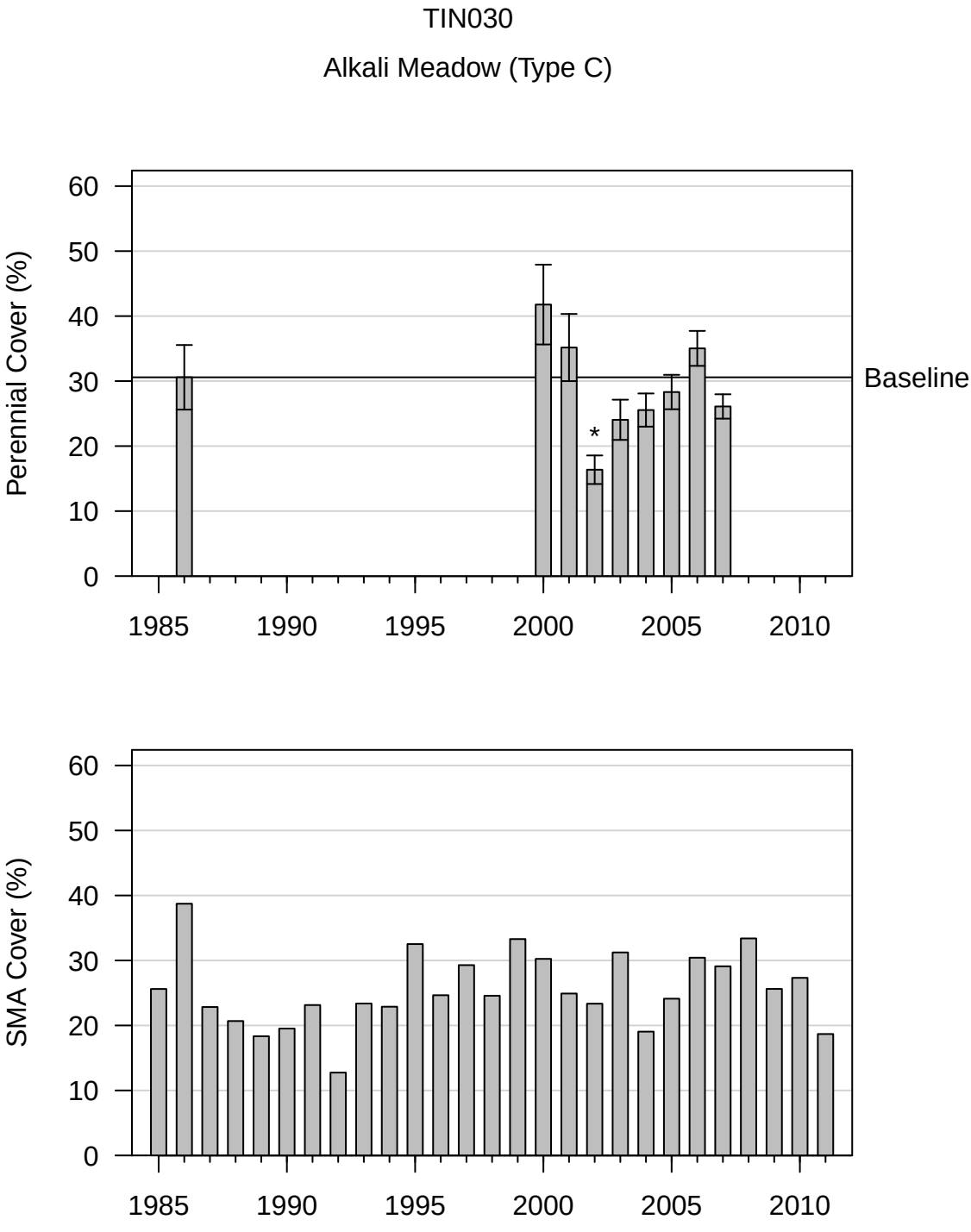


Figure 157: 2007 Wellfield

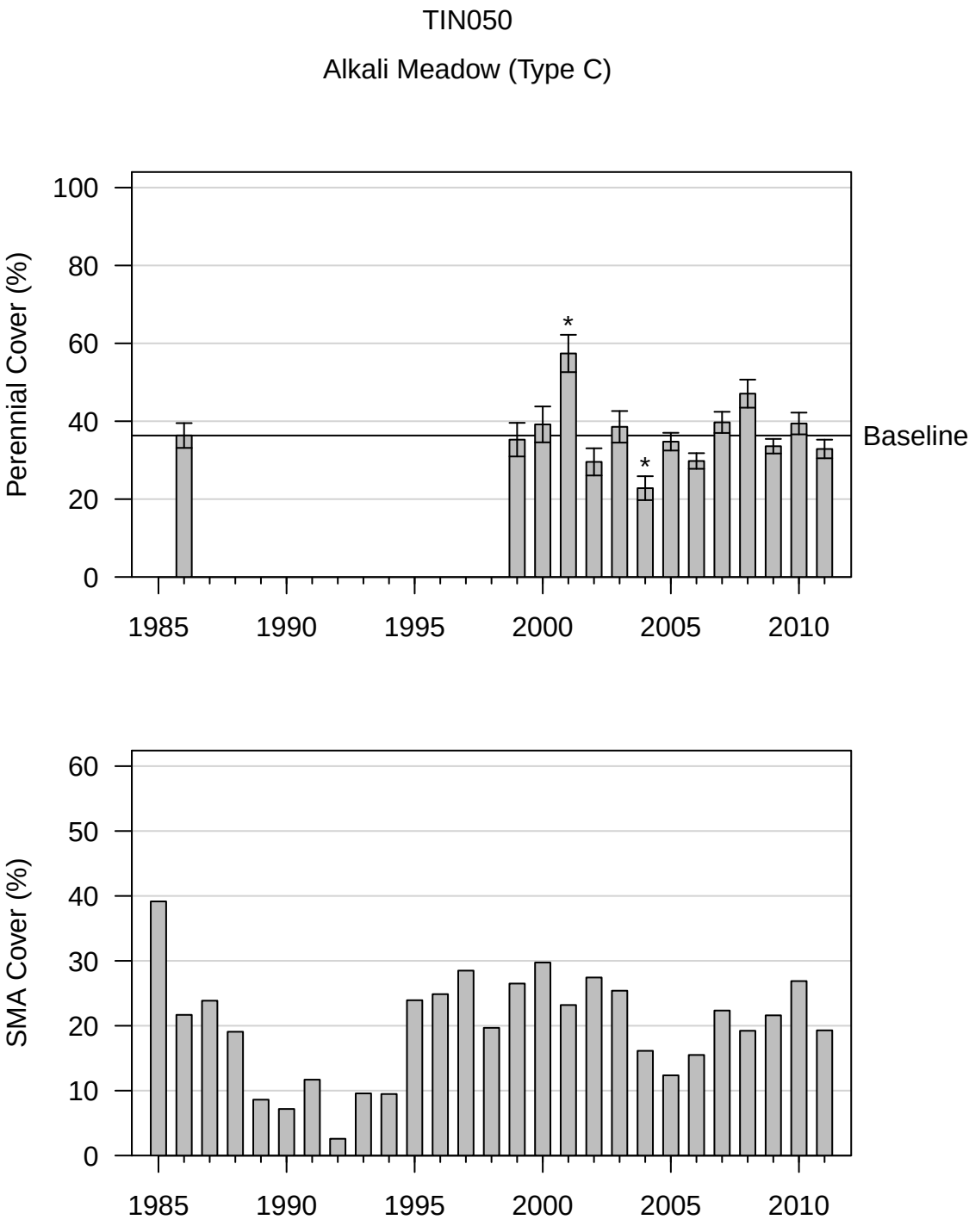


Figure 158: 2011 Wellfield

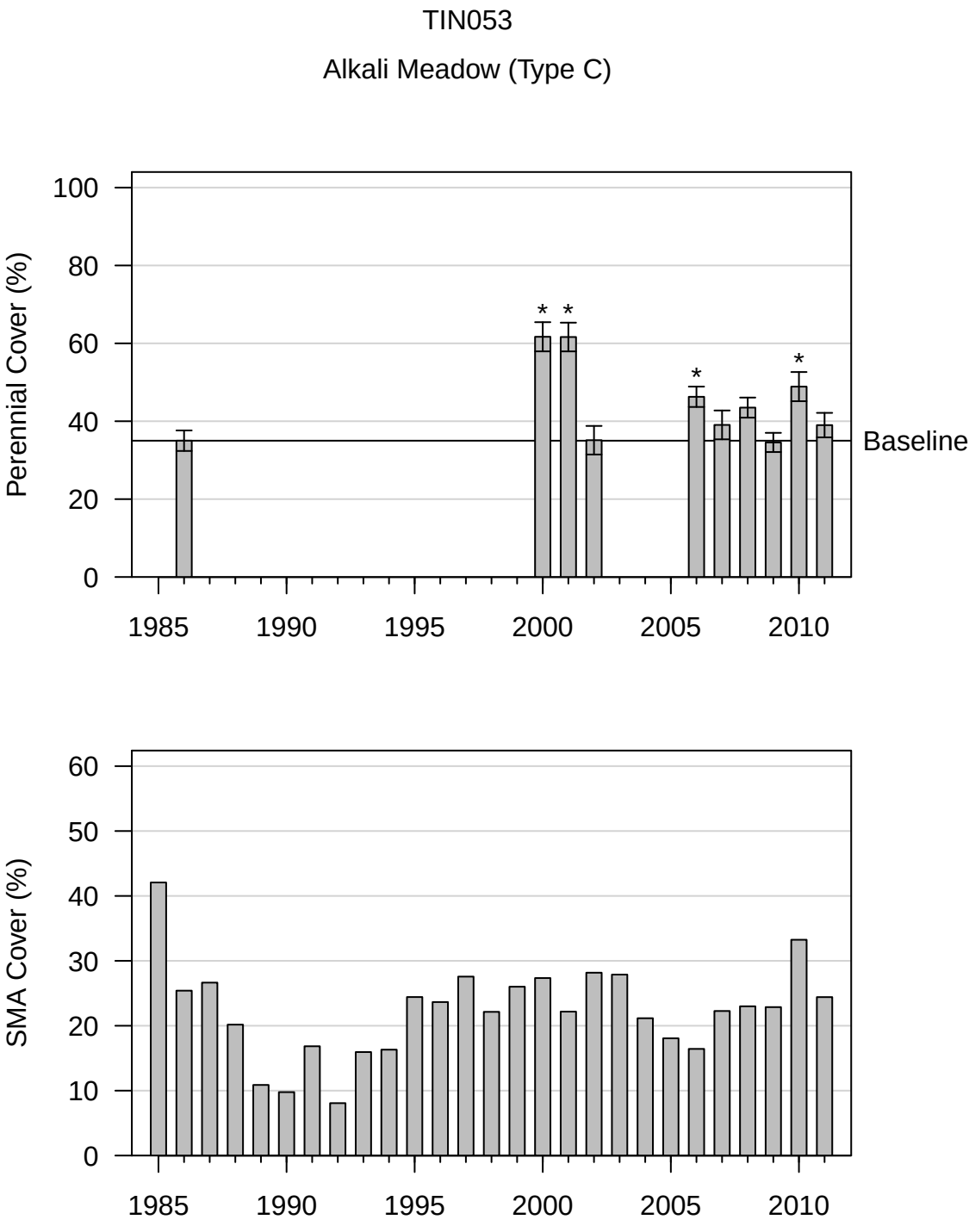


Figure 159: 2011 Wellfield

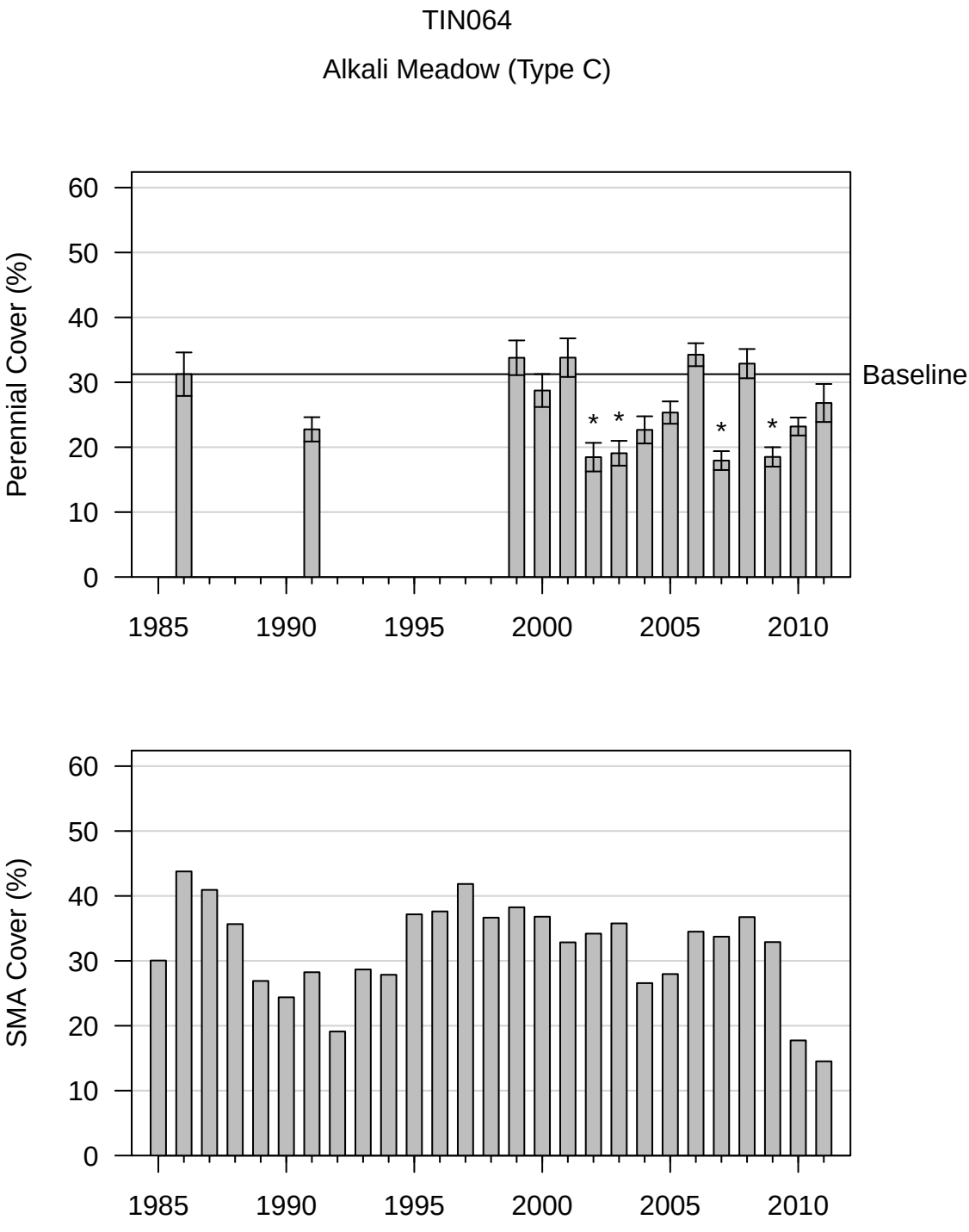


Figure 160: 2011 Wellfield

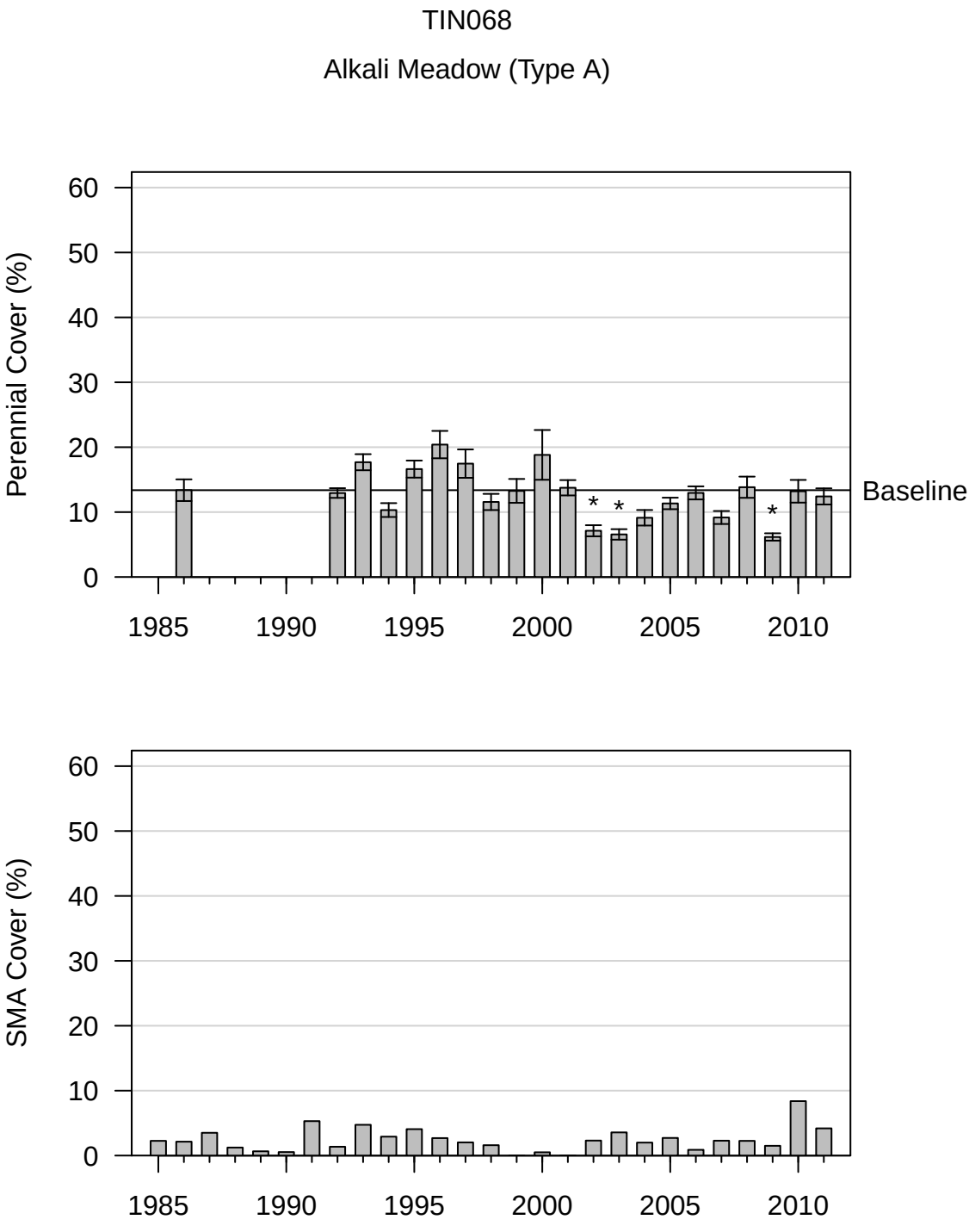


Figure 161: 2011 Wellfield

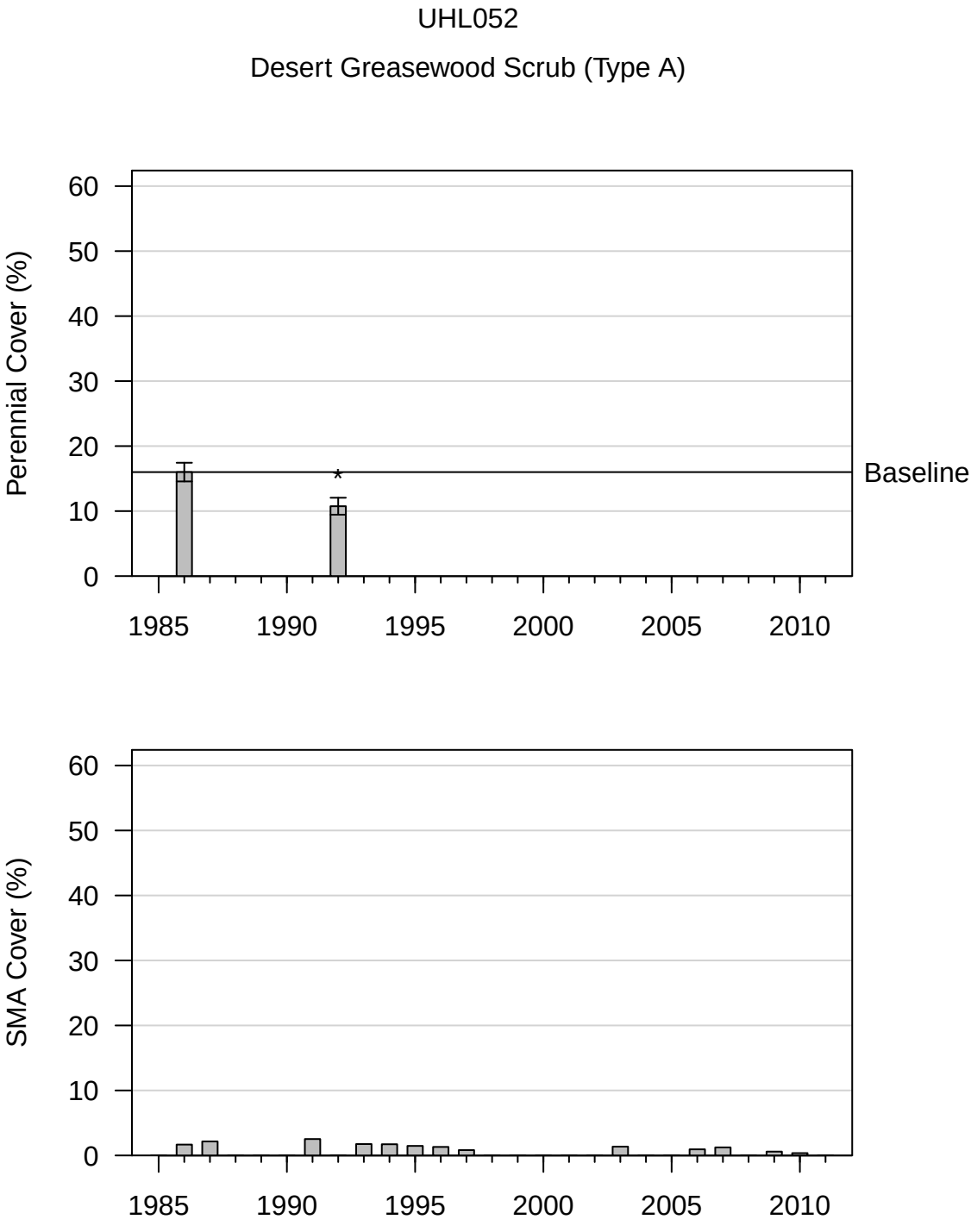


Figure 162: 1992 Wellfield

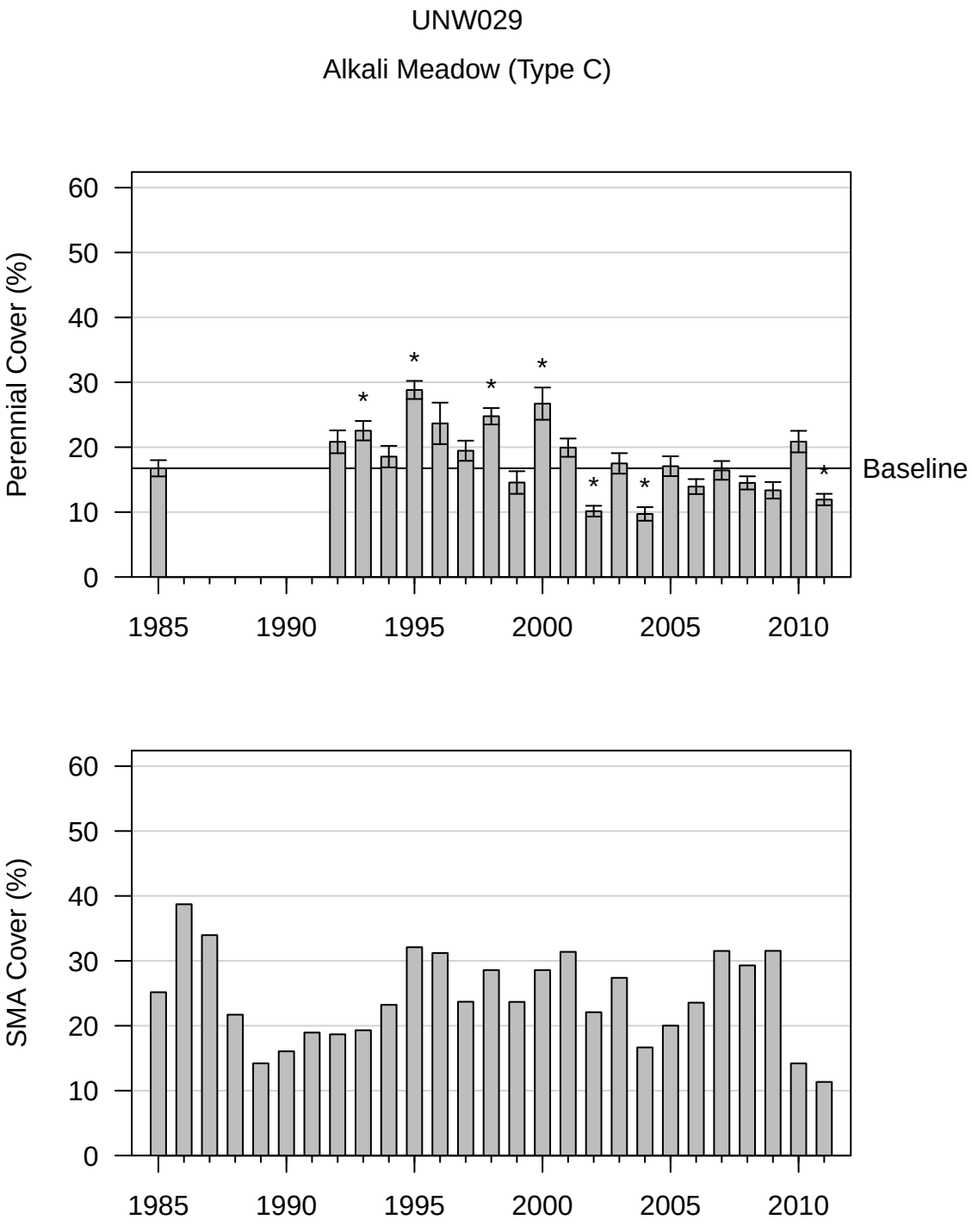


Figure 163: 2011 Control

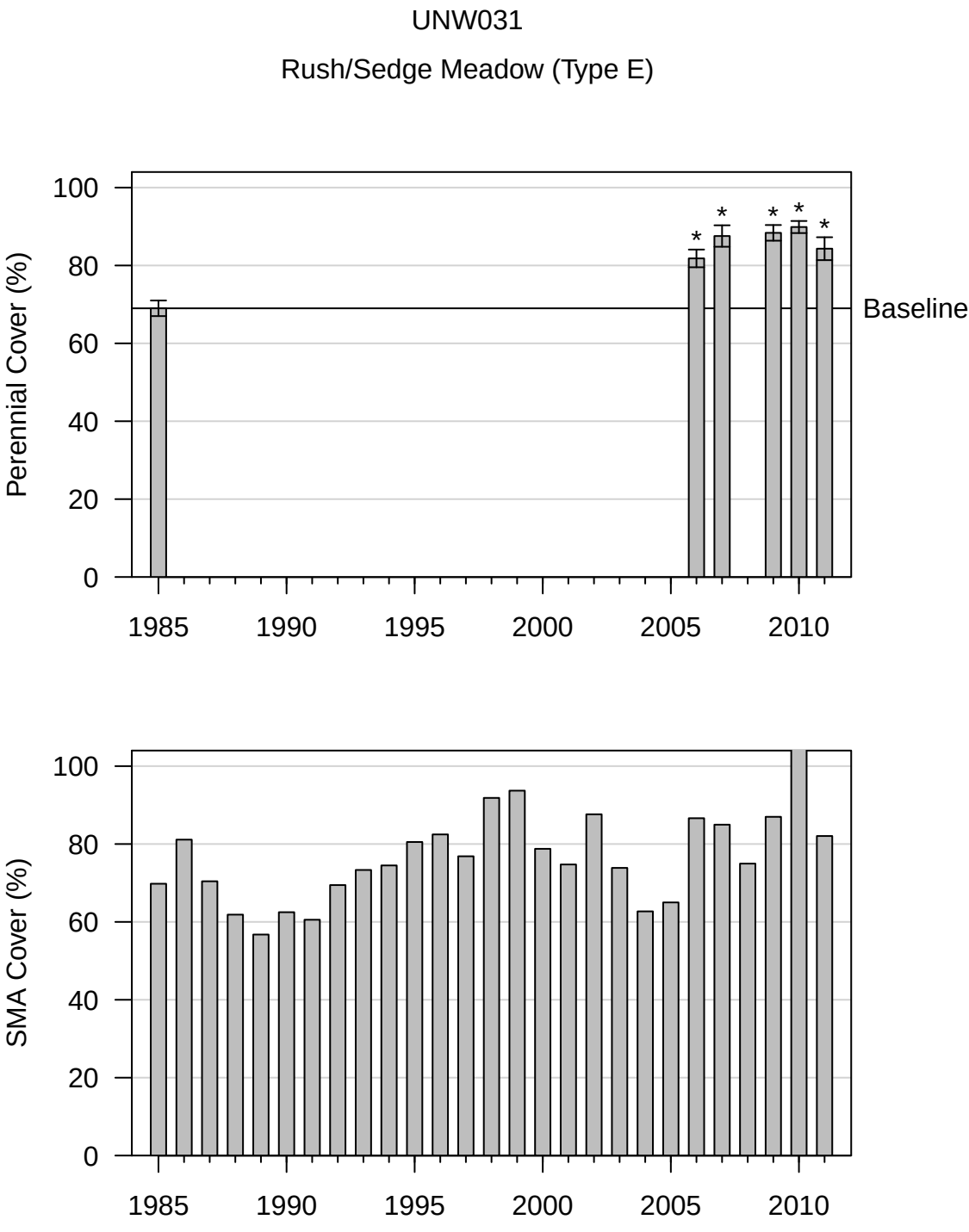


Figure 164: 2011 Control

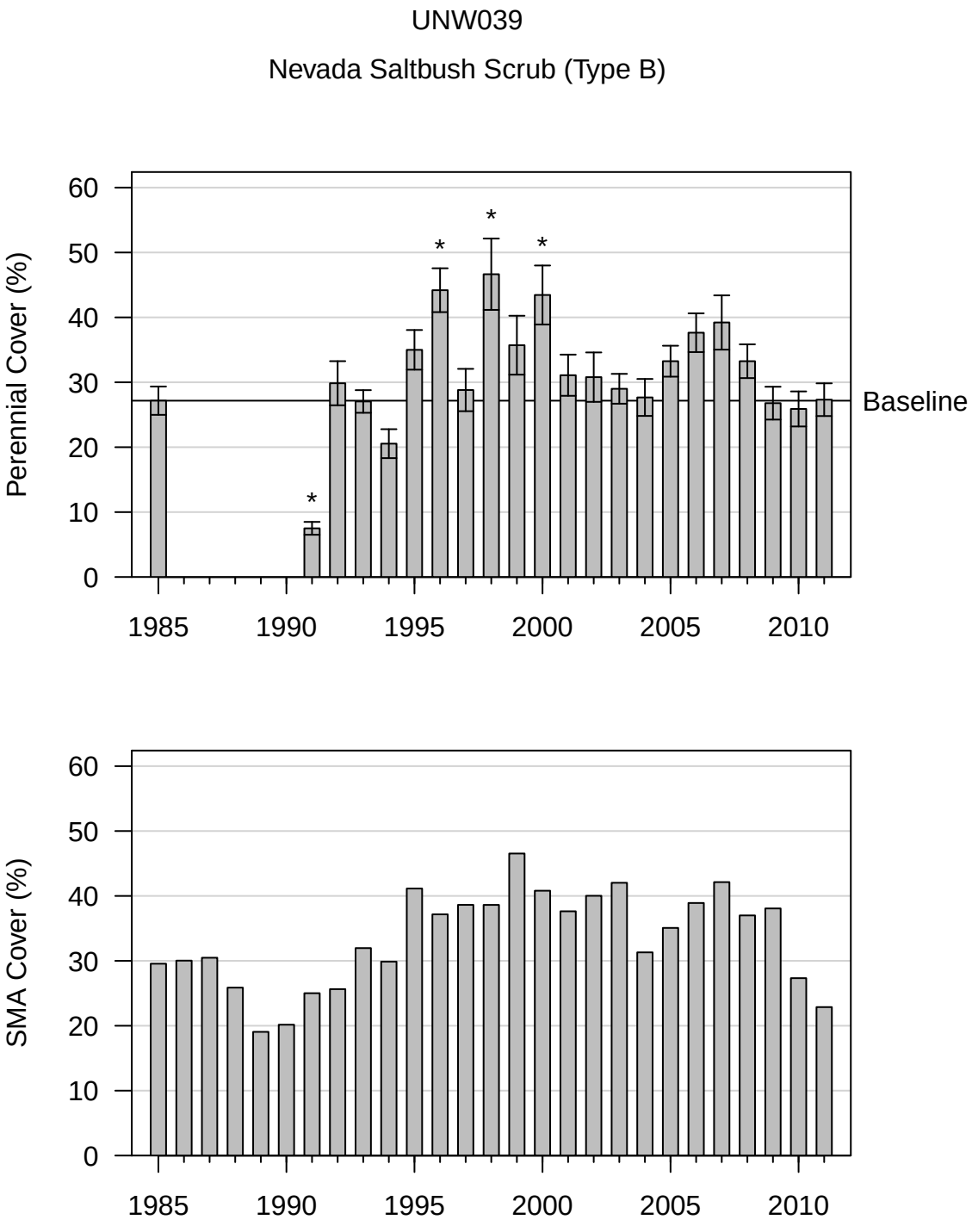


Figure 165: 2011 Control

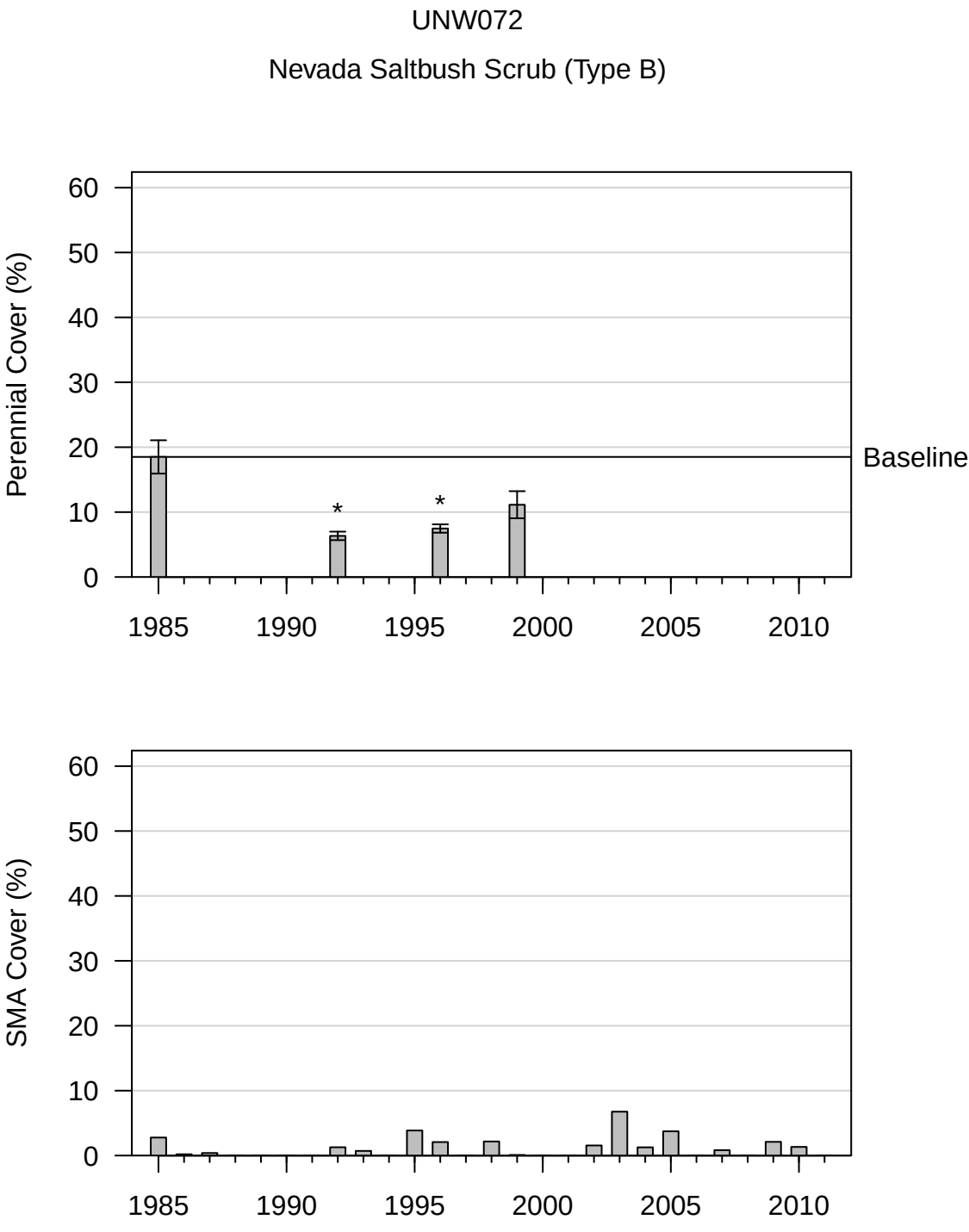


Figure 166: 1999 Control

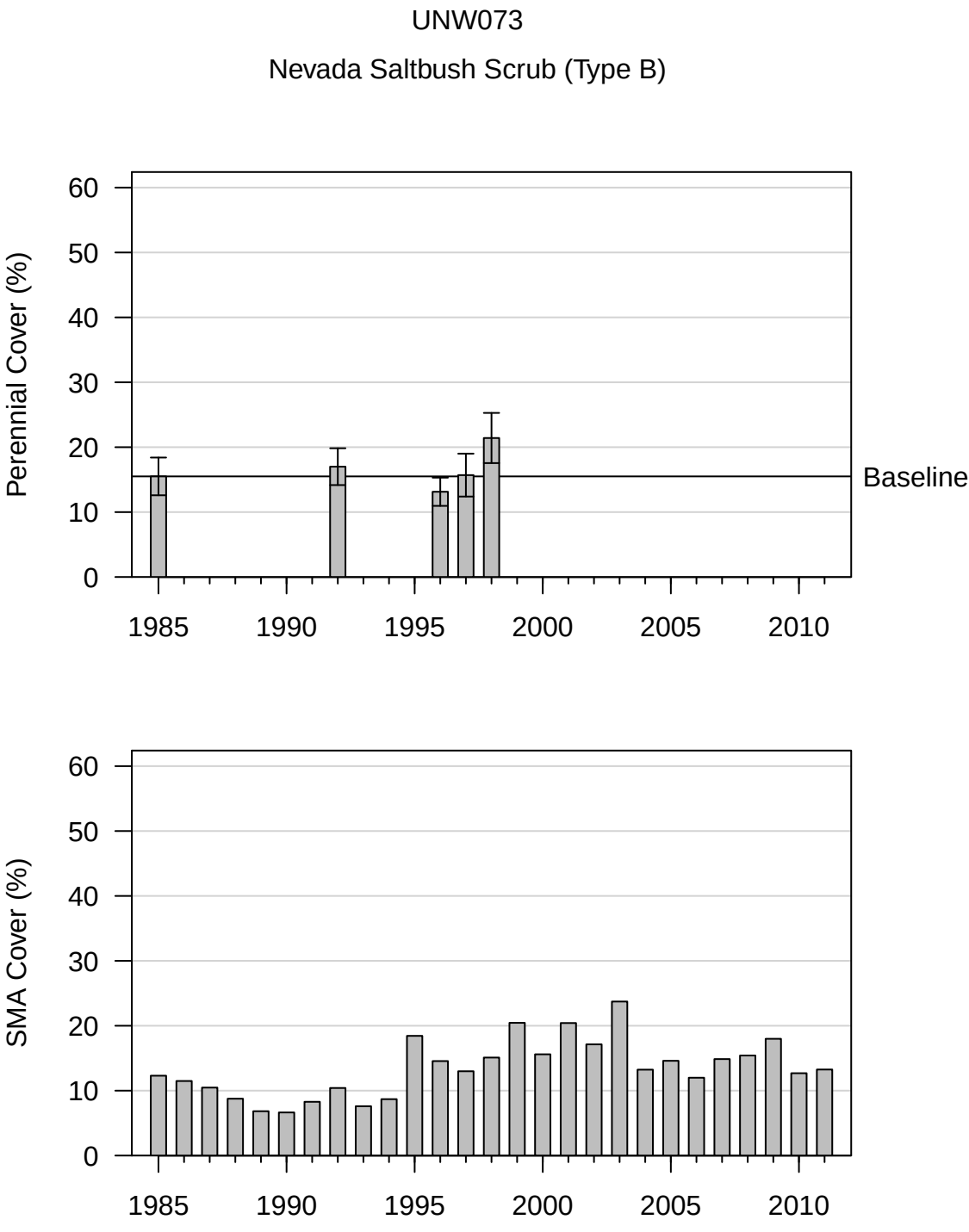


Figure 167: 1998 Control

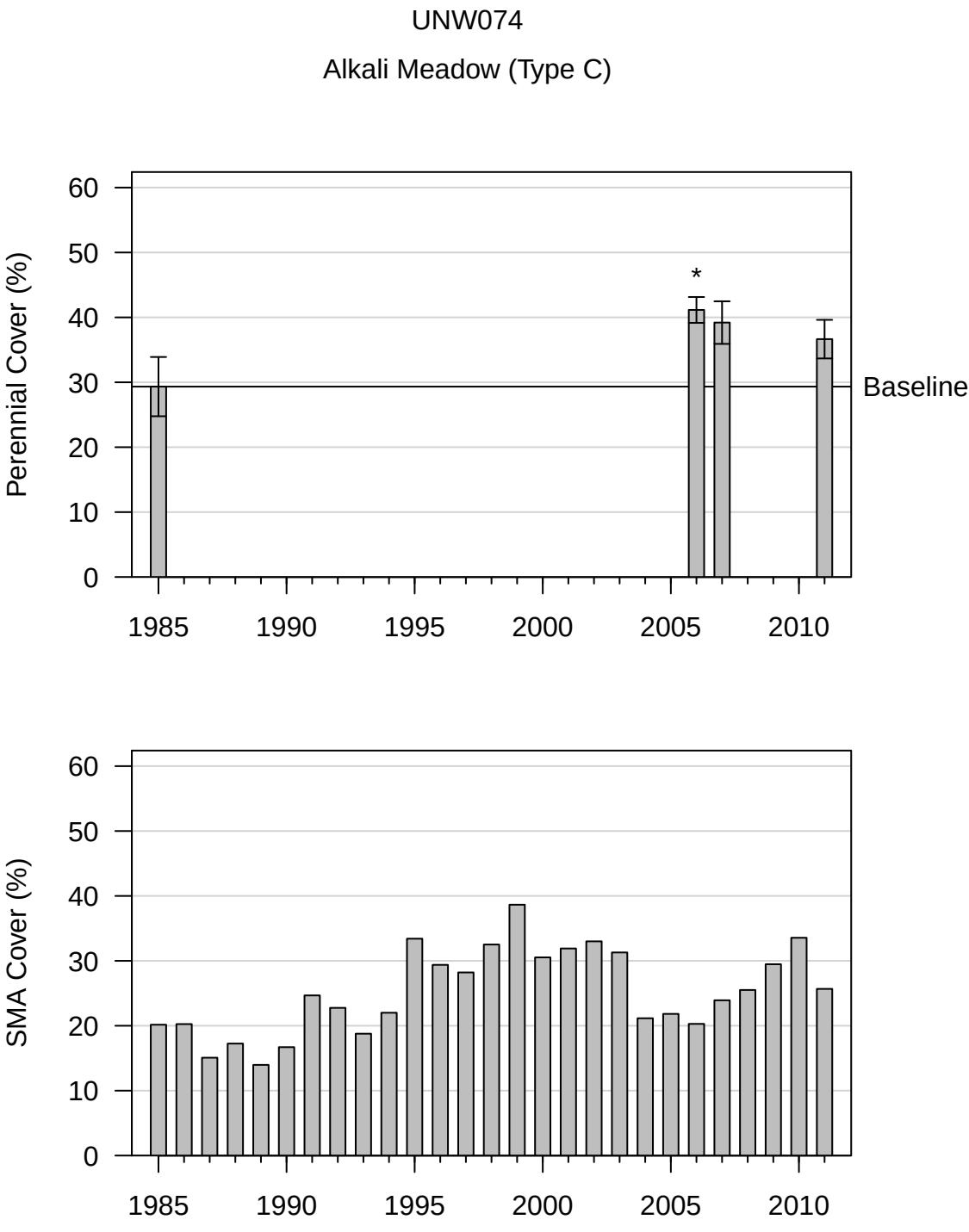


Figure 168: 2011 Control

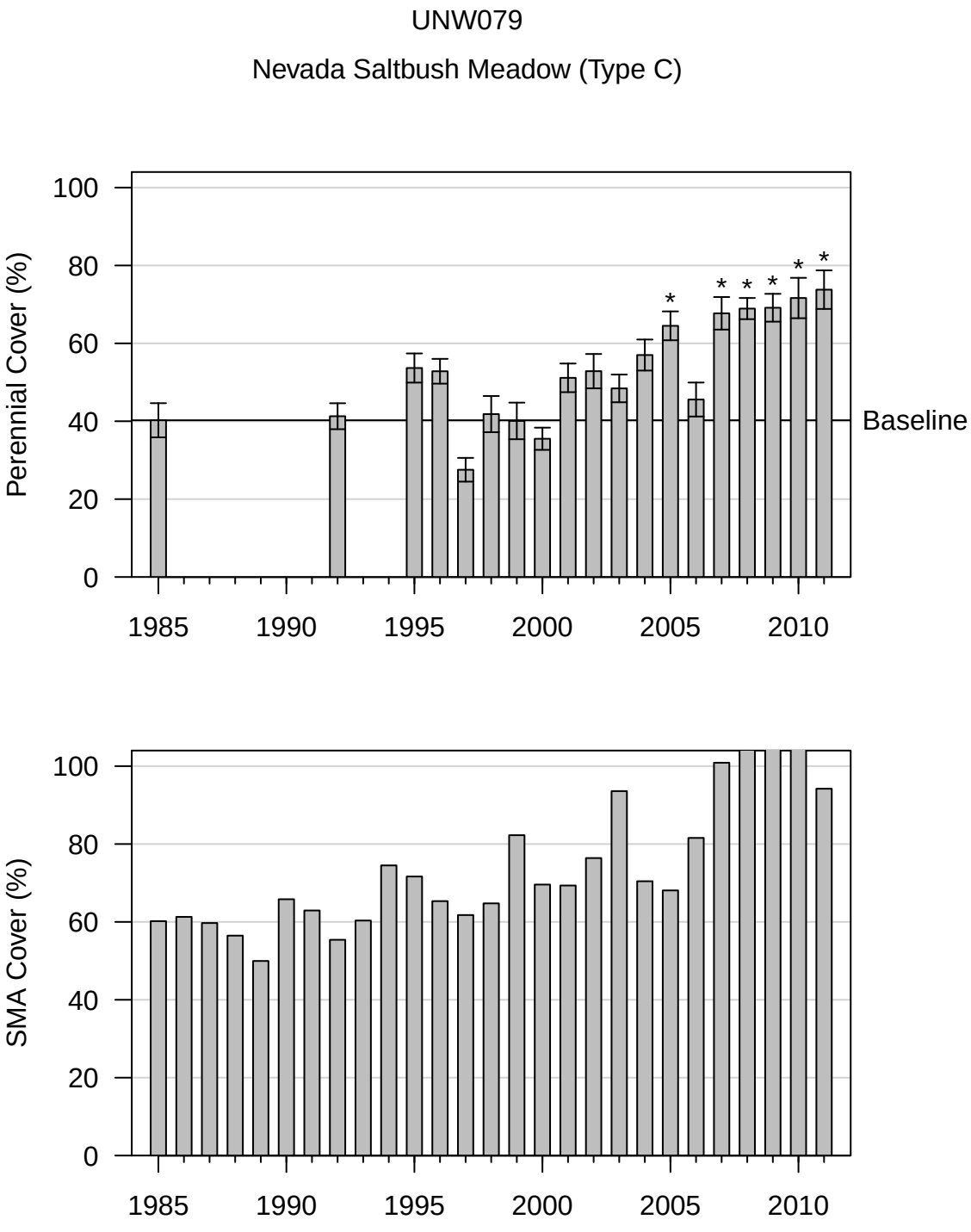
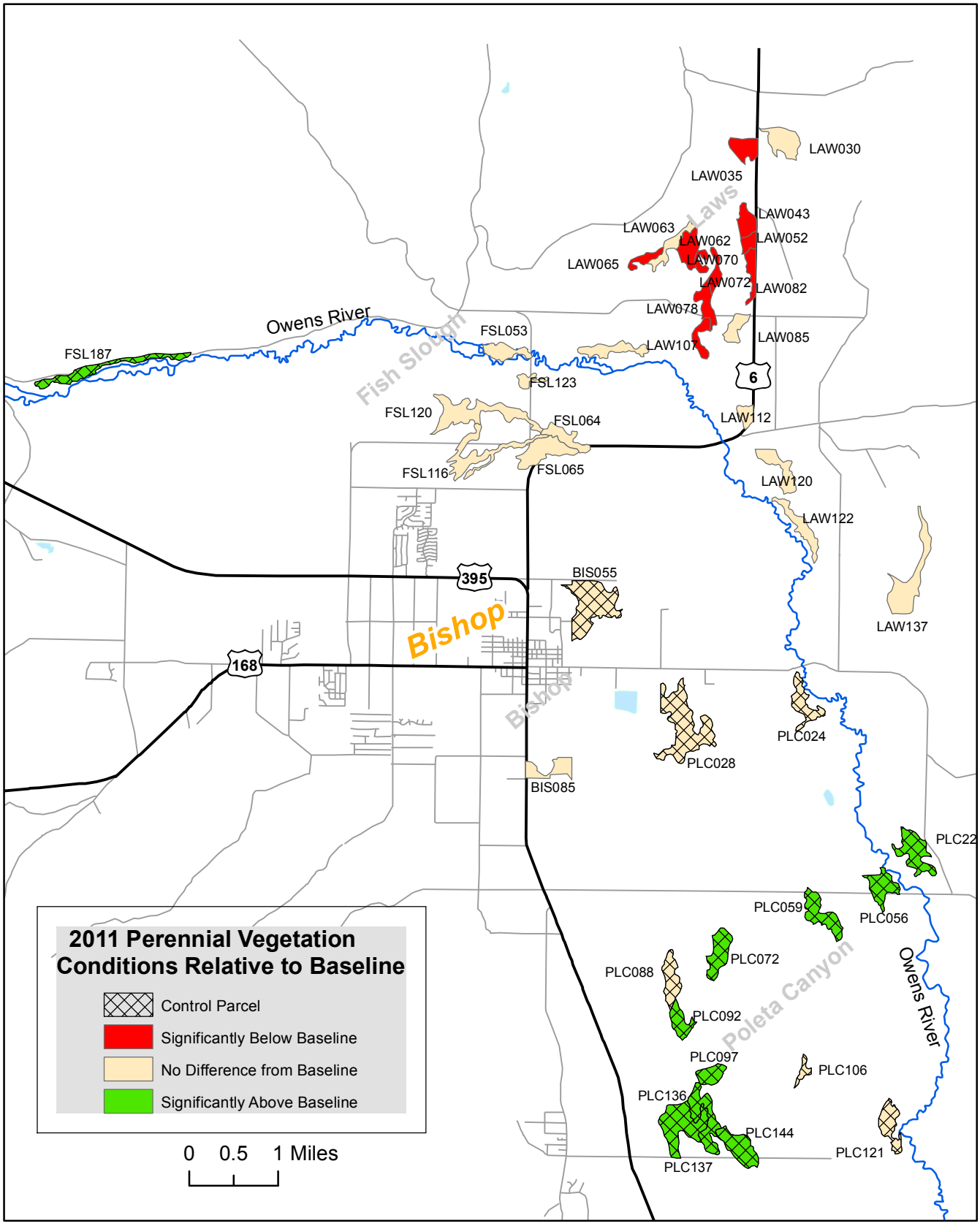
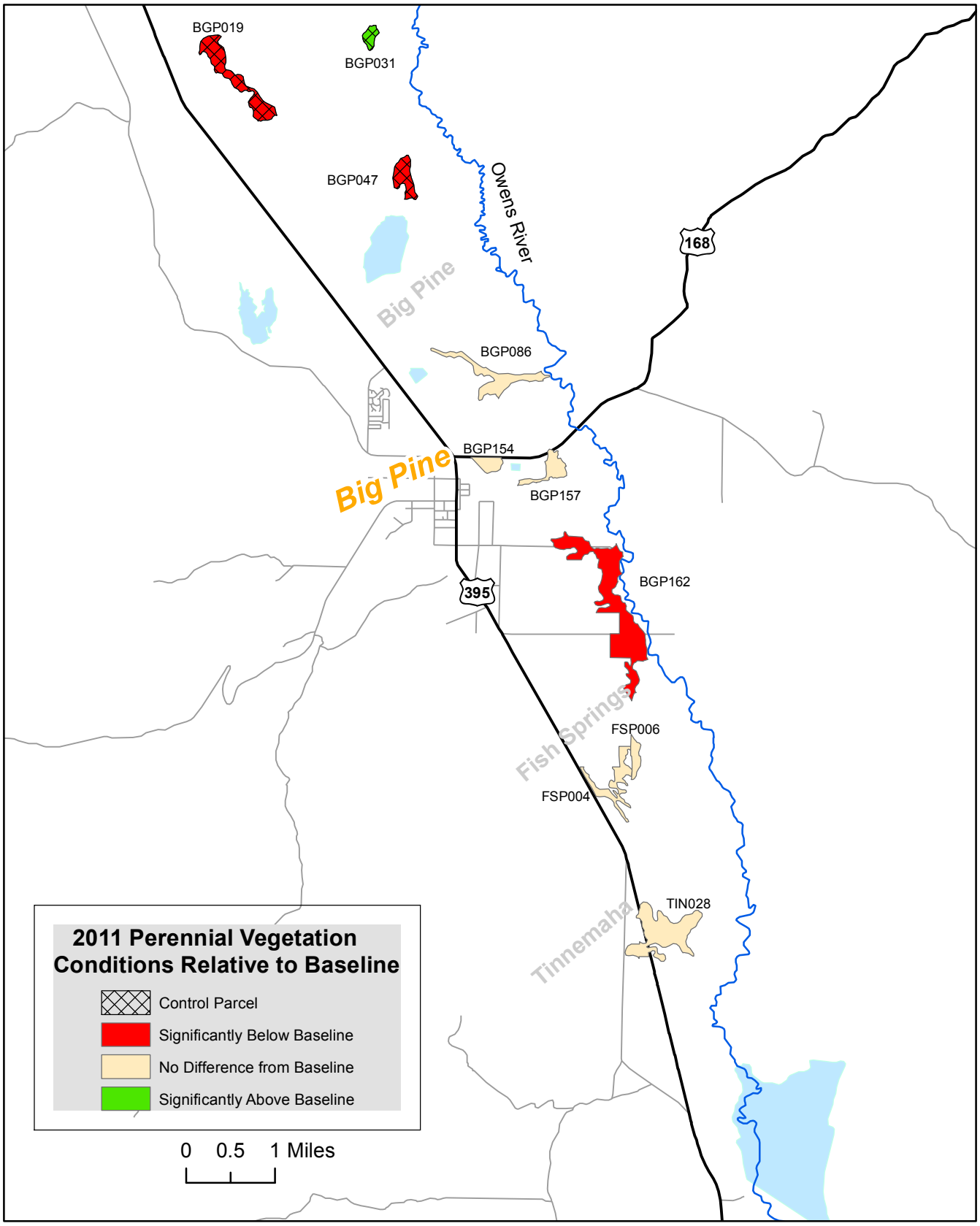


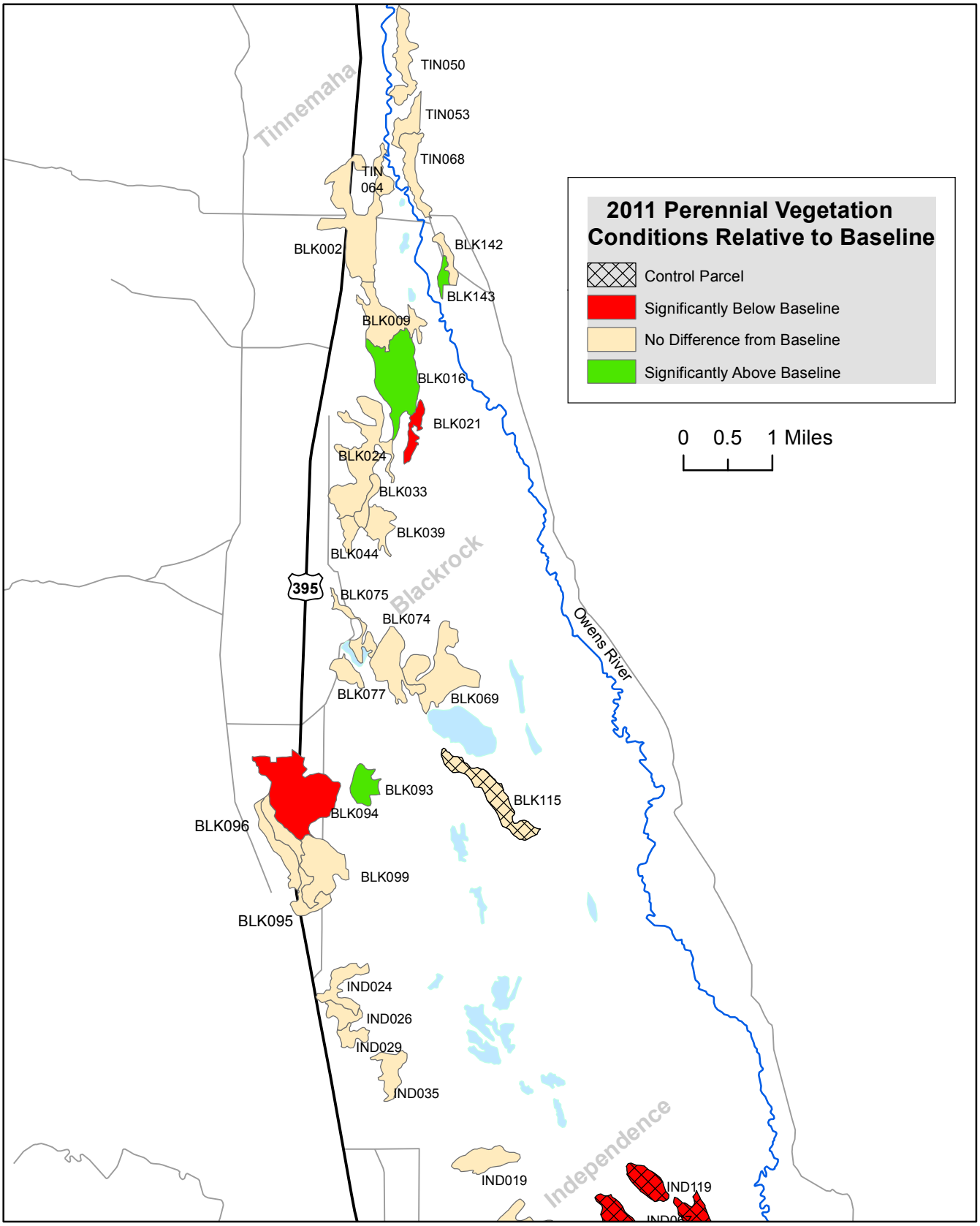
Figure 169: 2011 Control

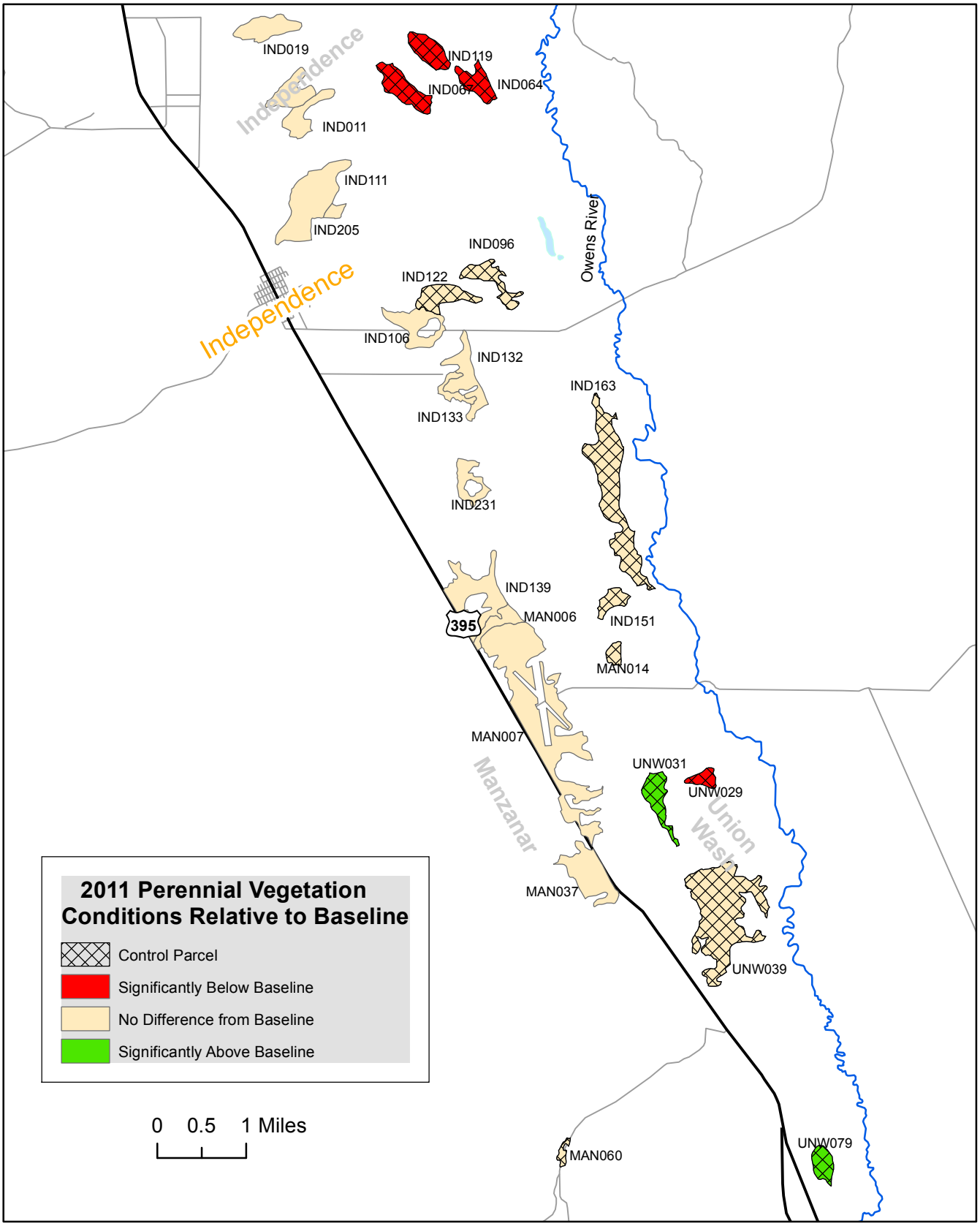
Appendix 2 –

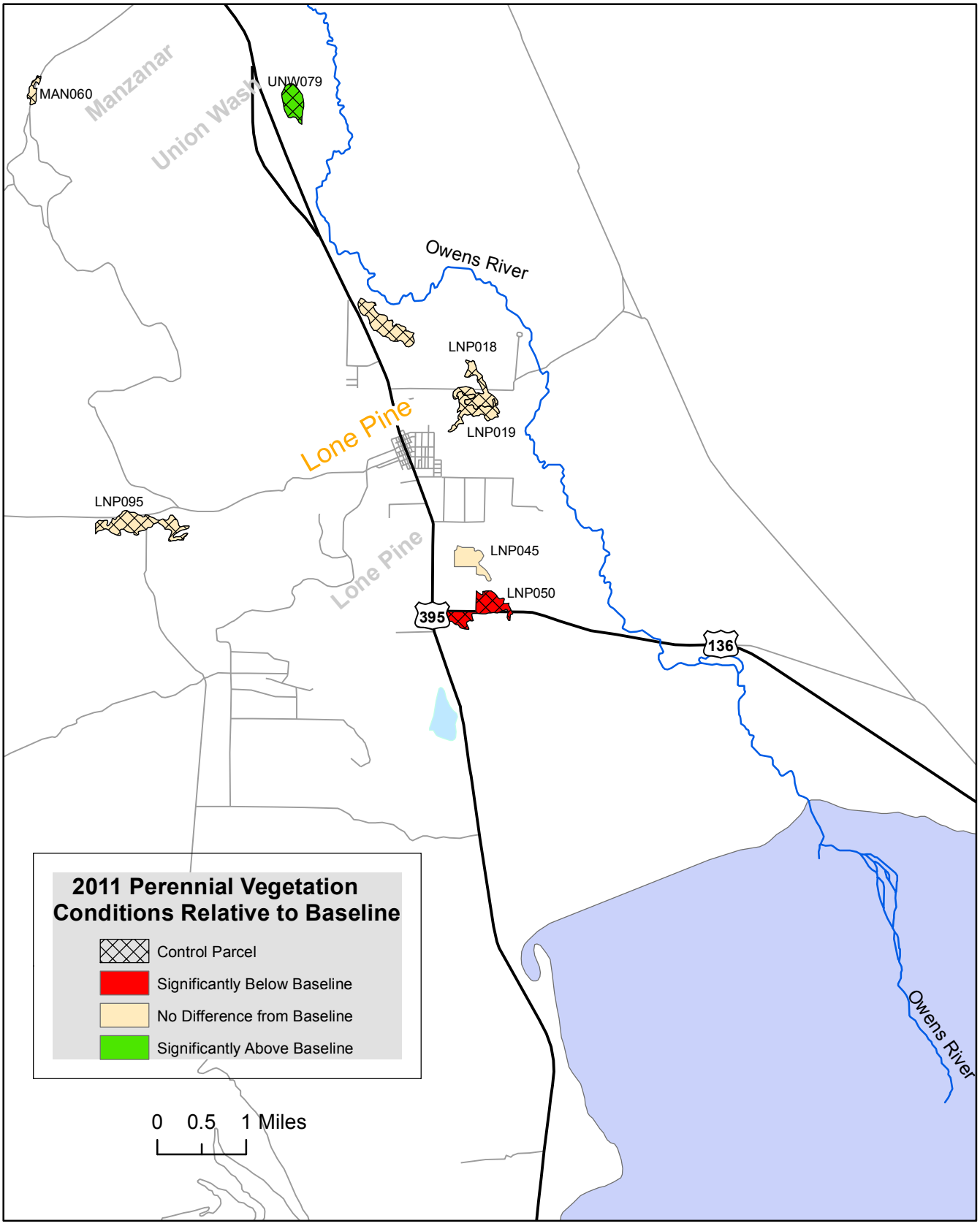
Maps of 2011 vegetation conditions in the Owens Valley from Laws to Lone Pine. Parcels are color-coded by statistical difference relative to baseline according to 2011 results using a weighted ANOVA followed by Dunnett's comparisons to a control group method. Vegetation parcels highlighted in red indicate conditions were significantly below baseline in 2011, while parcels highlighted in tan indicate no difference from baseline and those colored in green were significantly above baseline in 2011.


LAW030
LAW035
LAW043
LAW063
LAW062
LAW052
LAW065
LAW070
LAW072
LAW082
LAW078
LAW085
LAW107
Laws
Owens River
FSL187
FSL053
Fish Slough
FSL123
6
FSL120
FSL064
LAW112
FSL116
FSL065
LAW120
LAW122
LAW137
395
BIS055
Bishop
168
Bishop
PLC024
PLC028
BIS085
PLC22
PLC059
PLC056
PLC072
PLC088
Poleta Canyon
Owens River
PLC092
PLC097
PLC106
PLC136
PLC144
PLC121
PLC137
2011 Perennial Vegetation Conditions Relative to Baseline
Control Parcel
Significantly Below Baseline
No Difference from Baseline
Significantly Above Baseline
0 0.5 1 Miles


BGP019
BGP031
BGP047
Owens River
168
Big Pine
BGP086
BGP154
Big Pine
BGP157
BGP162
395
Fish Springs
FSP006
FSP004
TIN028
Tinnemaha
2011 Perennial Vegetation Conditions Relative to Baseline
Control Parcel
Significantly Below Baseline
No Difference from Baseline
Significantly Above Baseline
0 0.5 1 Miles

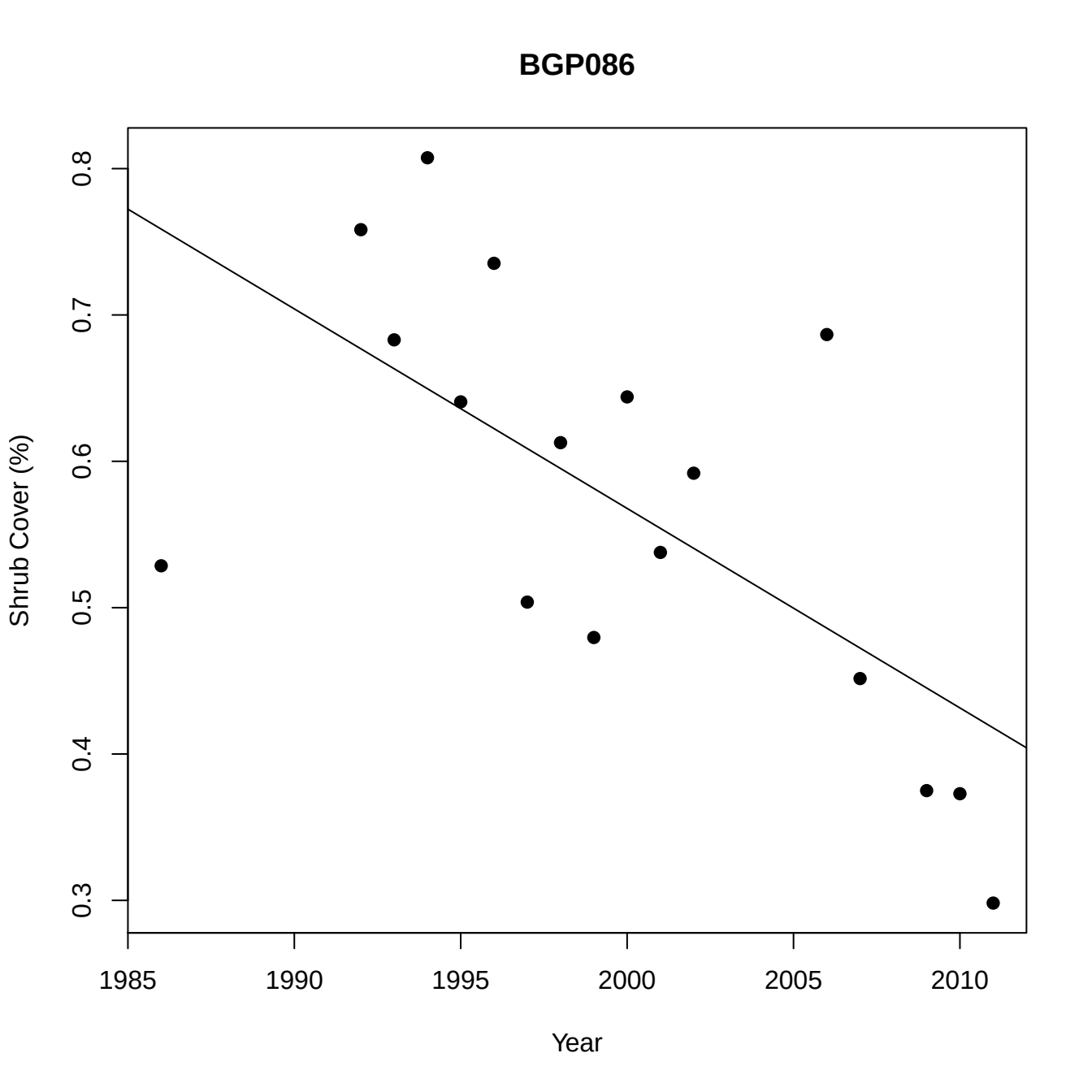

2011 Perennial Vegetation Conditions Relative to Baseline
Control Parcel
Significantly Below Baseline
No Difference from Baseline
Significantly Above Baseline
0 0.5 1 Miles
Tinnemaha
Blackrock
Owens River
Independence
395
TIN050
TIN053
TIN068
TIN 064
BLK002
BLK142
BLK143
BLK009
BLK016
BLK021
BLK024
BLK033
BLK039
BLK044
BLK075
BLK074
BLK077
BLK069
BLK093
BLK094
BLK115
BLK096
BLK099
BLK095
IND024
IND026
IND029
IND035
IND019
IND119

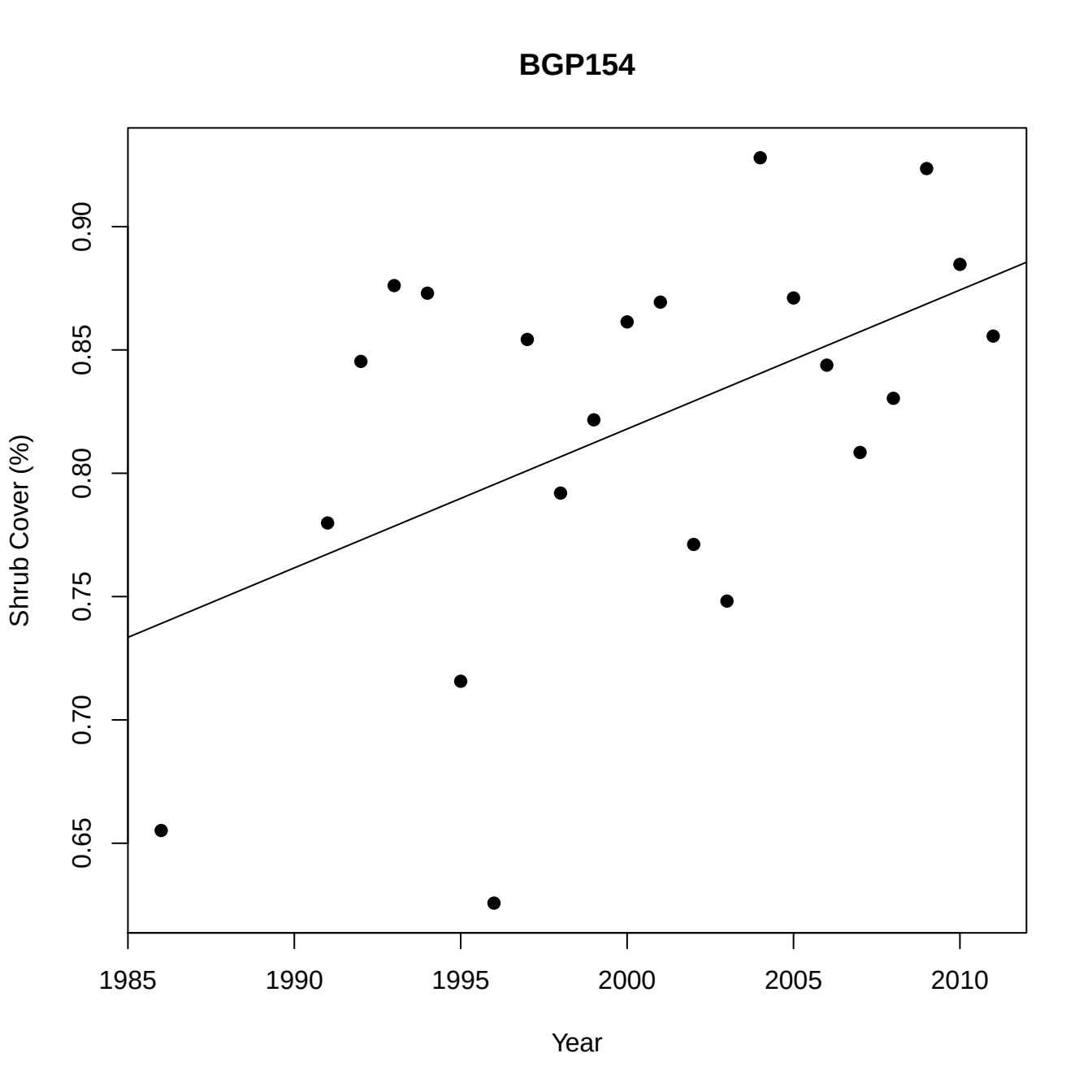

IND019
IND119
IND087
IND064
IND011
IND111
IND205
IND096
IND122
IND106
IND132
IND133
IND163
IND231
IND139
MAN006
IND151
MAN014
MAN007
UNW031
UNW029
MAN037
UNW039
MAN060
UNW079
Independence
Independence
Owens River
Manzanar
Union Wash
395
2011 Perennial Vegetation Conditions Relative to Baseline
Control Parcel
Significantly Below Baseline
No Difference from Baseline
Significantly Above Baseline
0 0.5 1 Miles

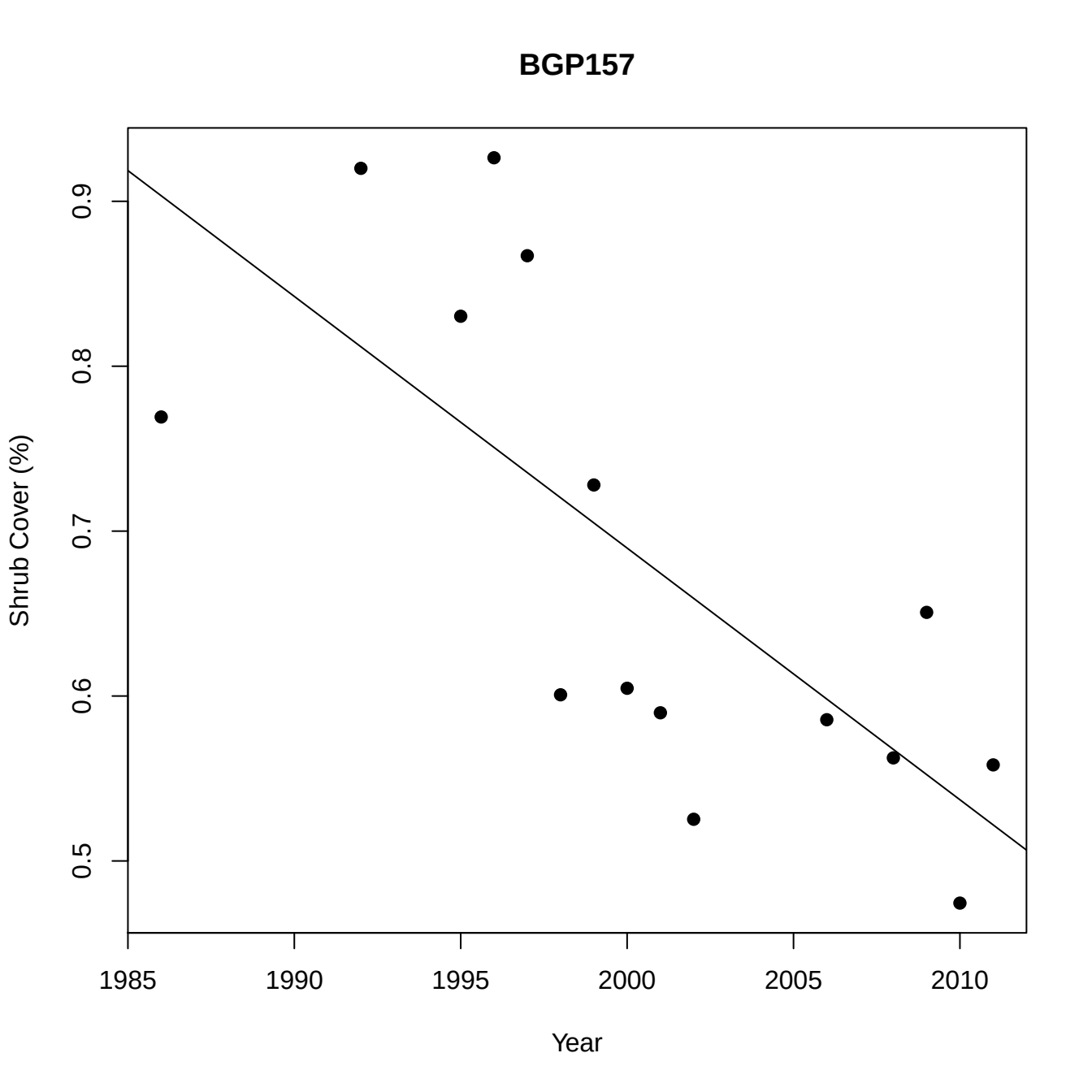

MAN060
Manzanar
Union Wash
UNW079
Owens River
LNP018
LNP019
Lone Pine
LNP095
Lone Pine
LNP045
LNP050
395
136
Owens River
2011 Perennial Vegetation Conditions Relative to Baseline
Control Parcel
Significantly Below Baseline
No Difference from Baseline
Significantly Above Baseline
0 0.5 1 Miles

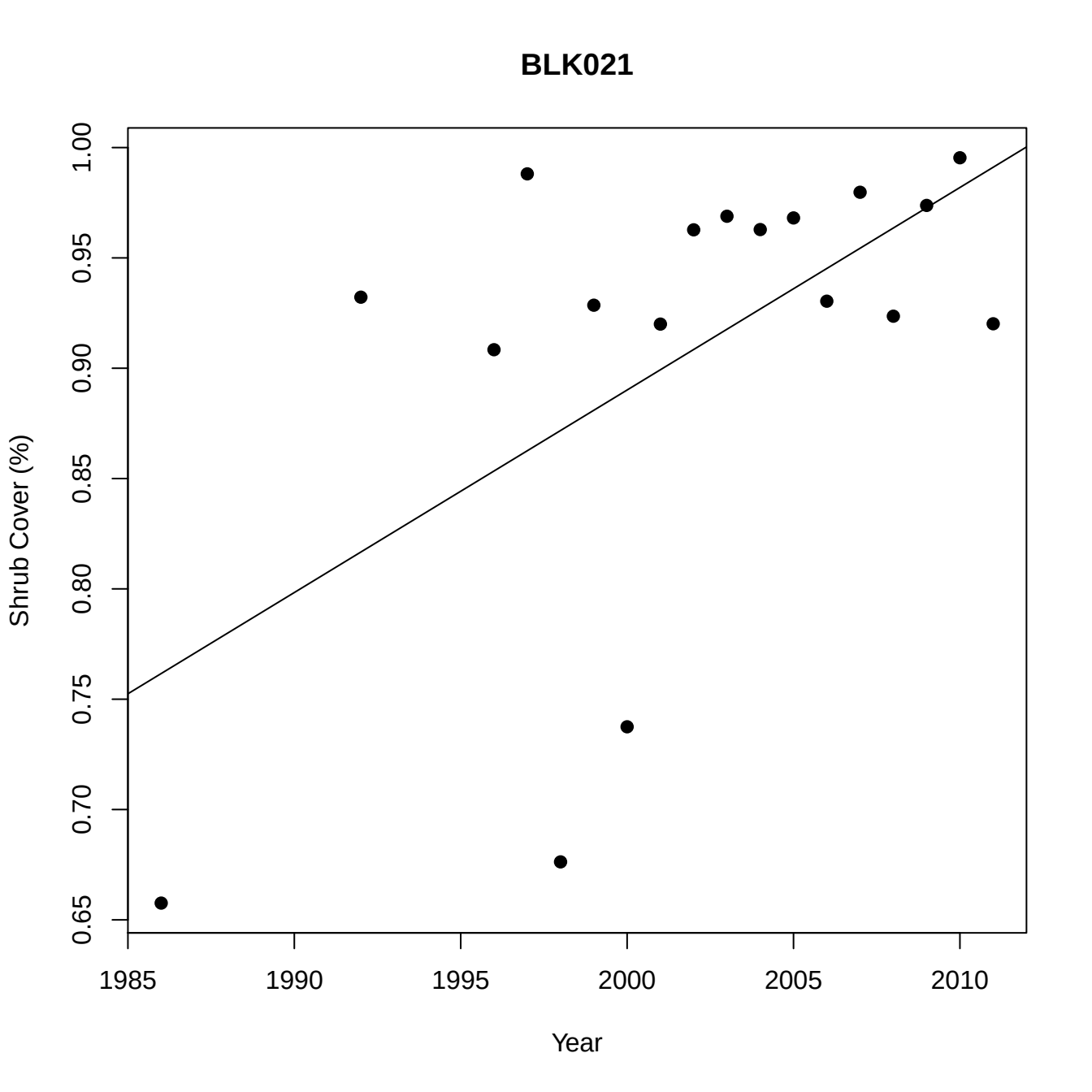
Appendix 3 –

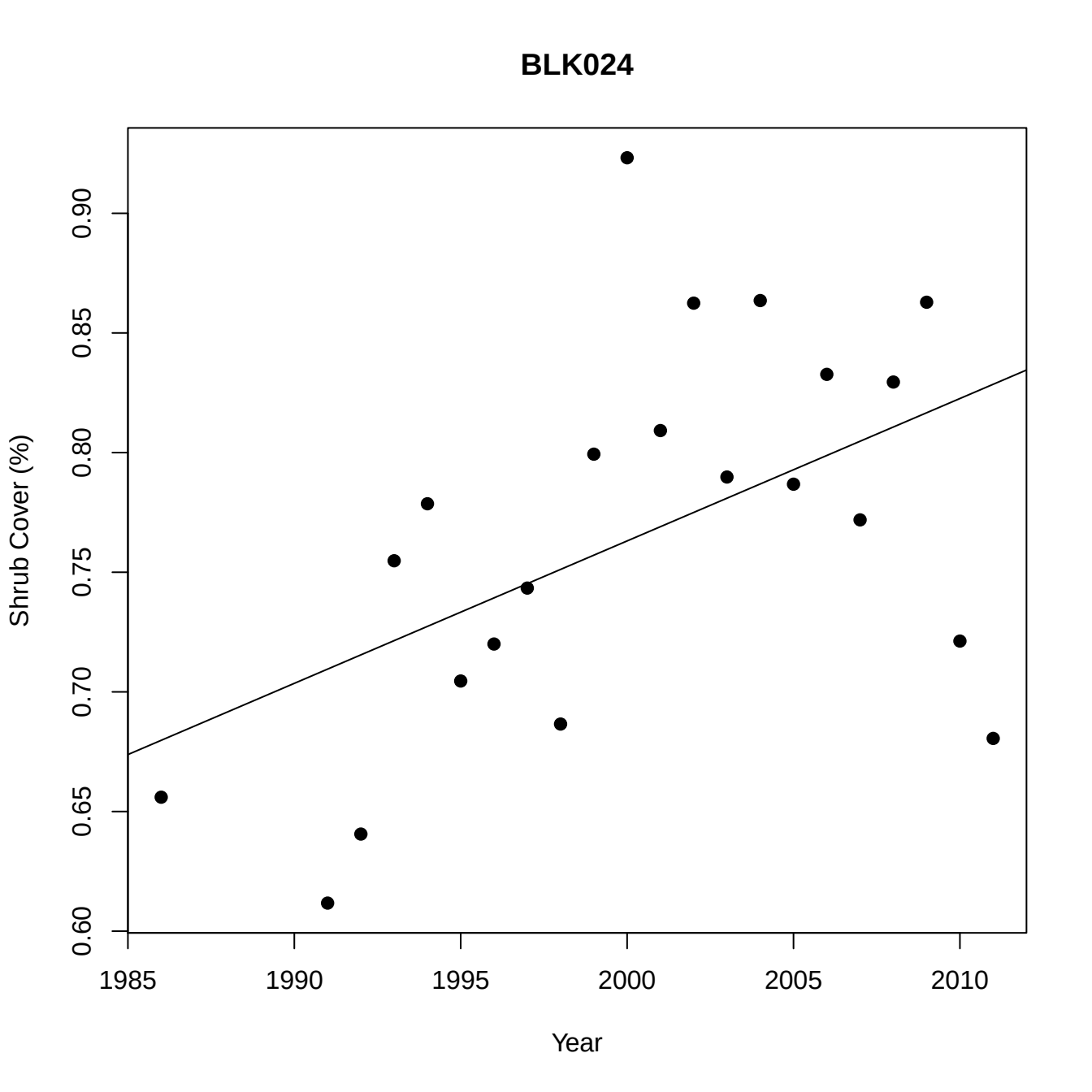
Shrub proportion plotted against time for the thirty-six vegetation parcels which had at least ten years of line point data, baseline transect data and demonstrated a significant correlation between shrub cover and time (see Table 2).

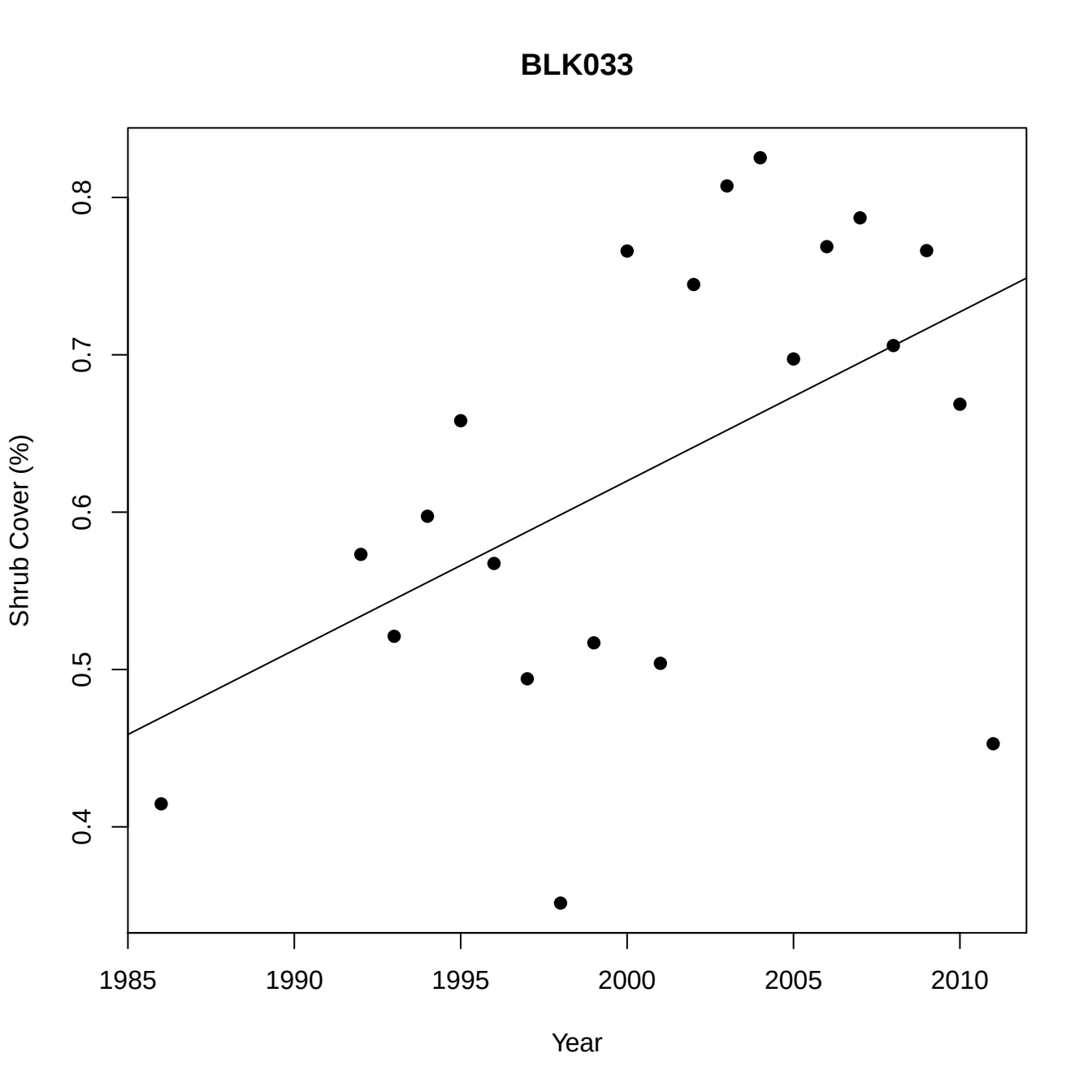

BGP086
Shrub Cover (%)
0.3
0.4
0.5
0.6
0.7
0.8
1985
1990
1995
2000
2005
2010
Year

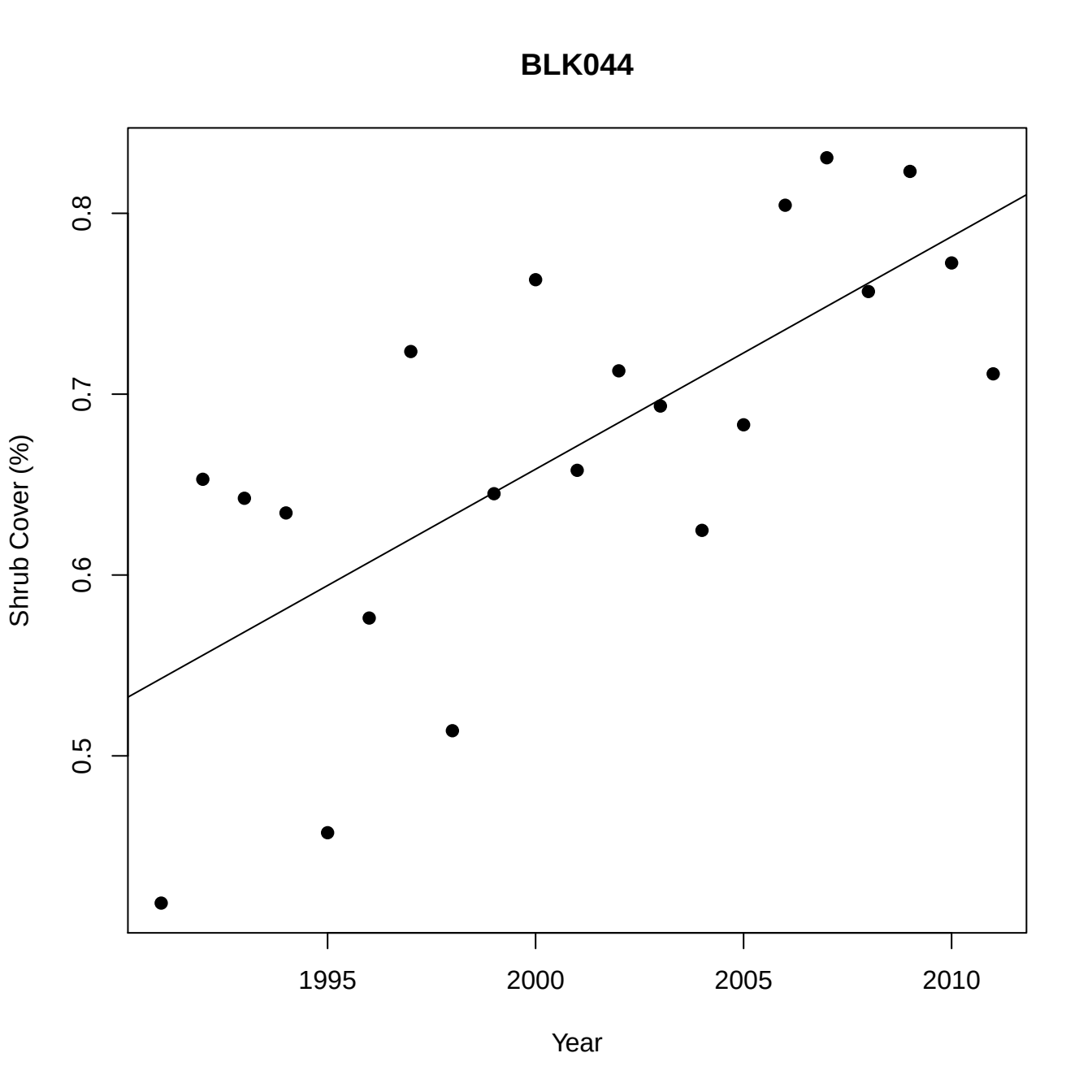

BGP154
Shrub Cover (%)
0.65
0.70
0.75
0.80
0.85
0.90
1985
1990
1995
2000
2005
2010
Year

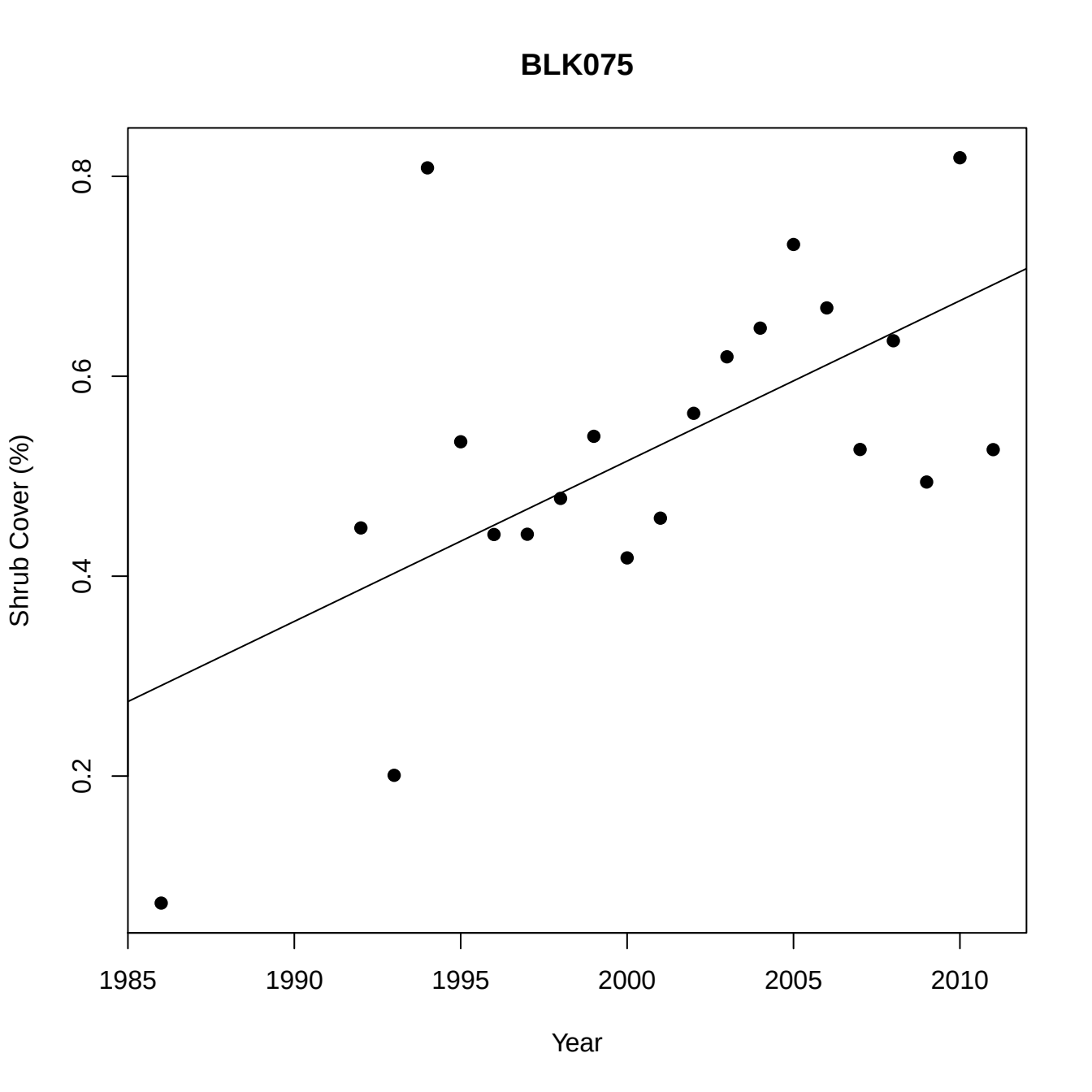

BGP157
Shrub Cover (%)
0.5
0.6
0.7
0.8
0.9
1985
1990
1995
2000
2005
2010
Year

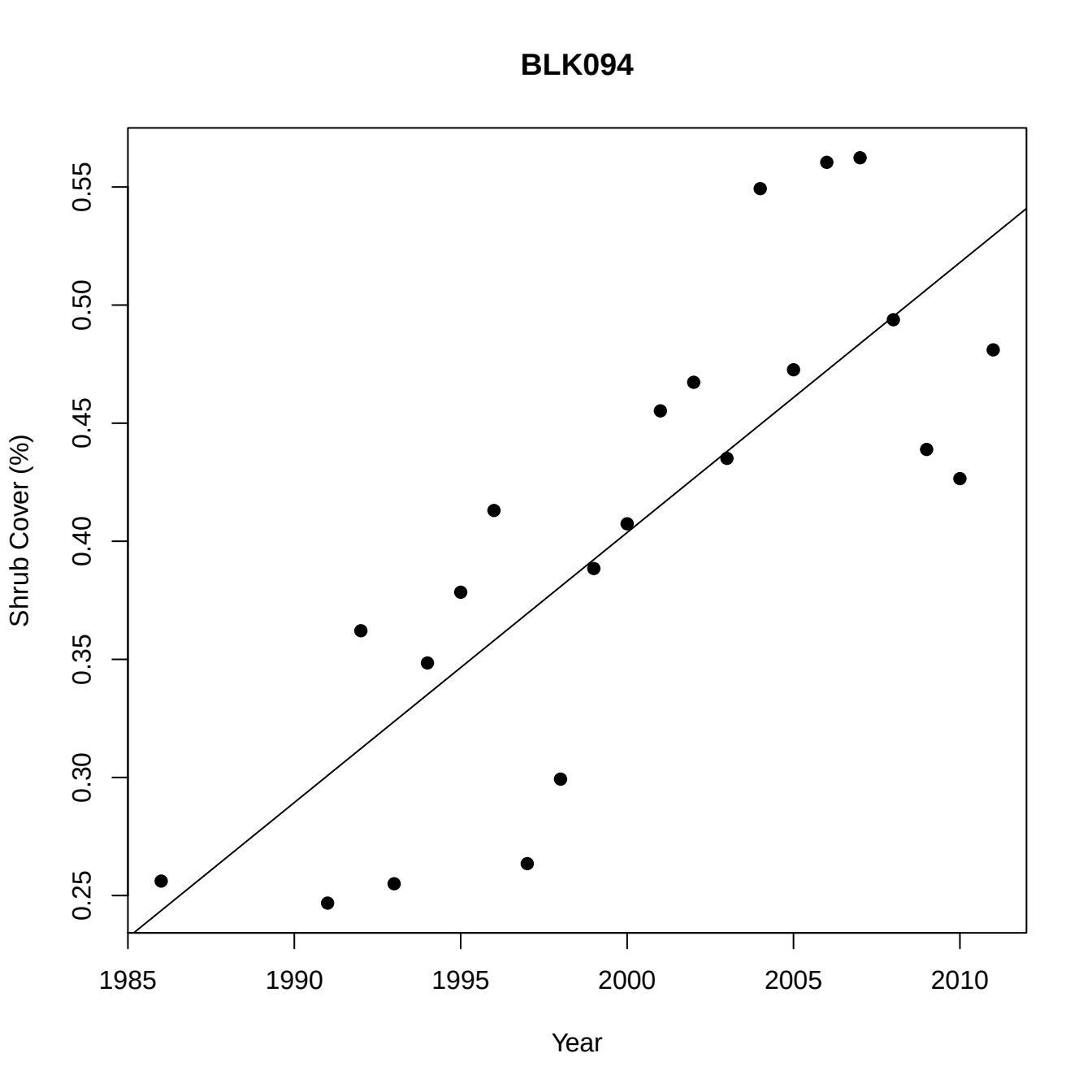

BLK021
Shrub Cover (%)
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
1985
1990
1995
2000
2005
2010
Year

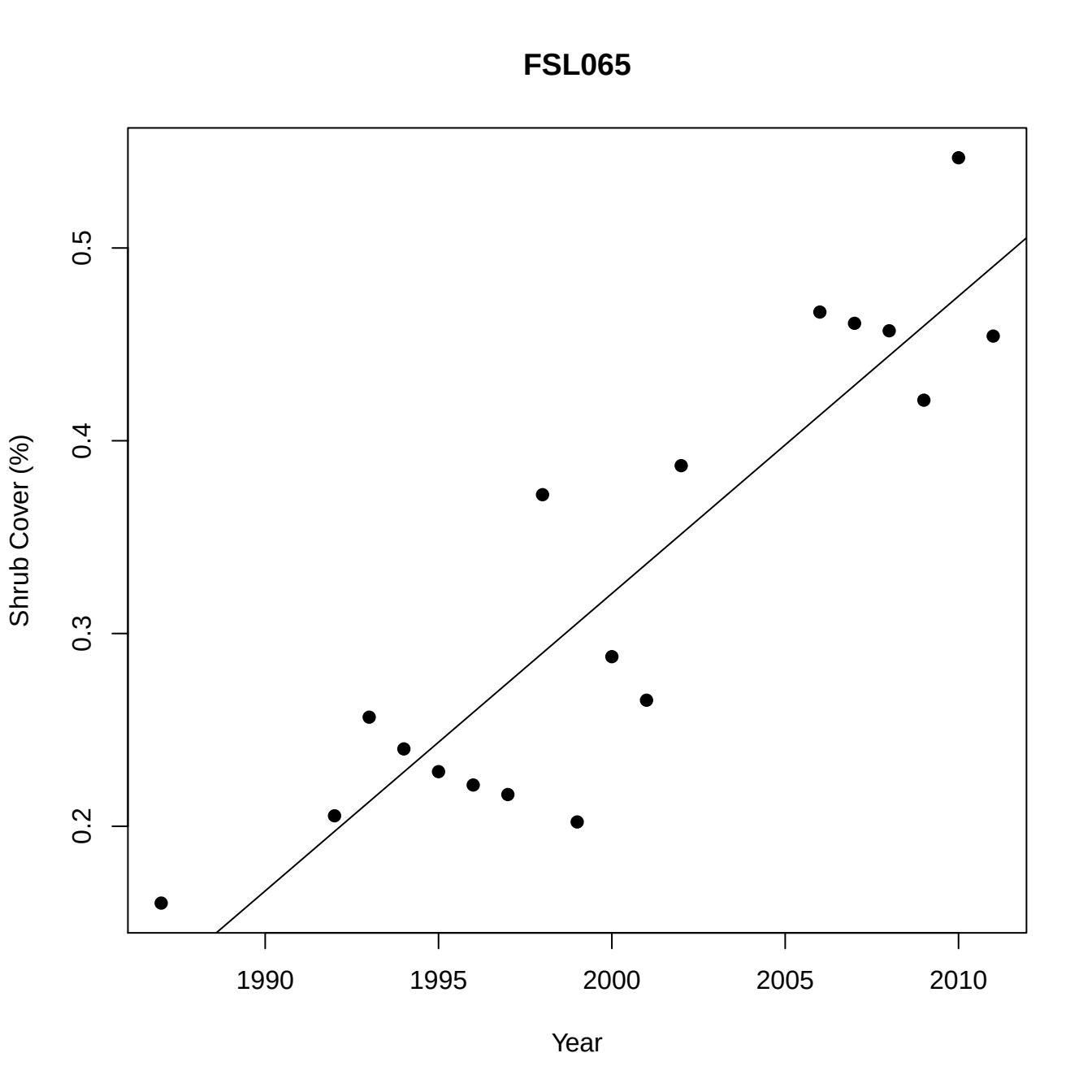

BLK024
Shrub Cover (%)
0.60
0.65
0.70
0.75
0.80
0.85
0.90
1985
1990
1995
2000
2005
2010
Year

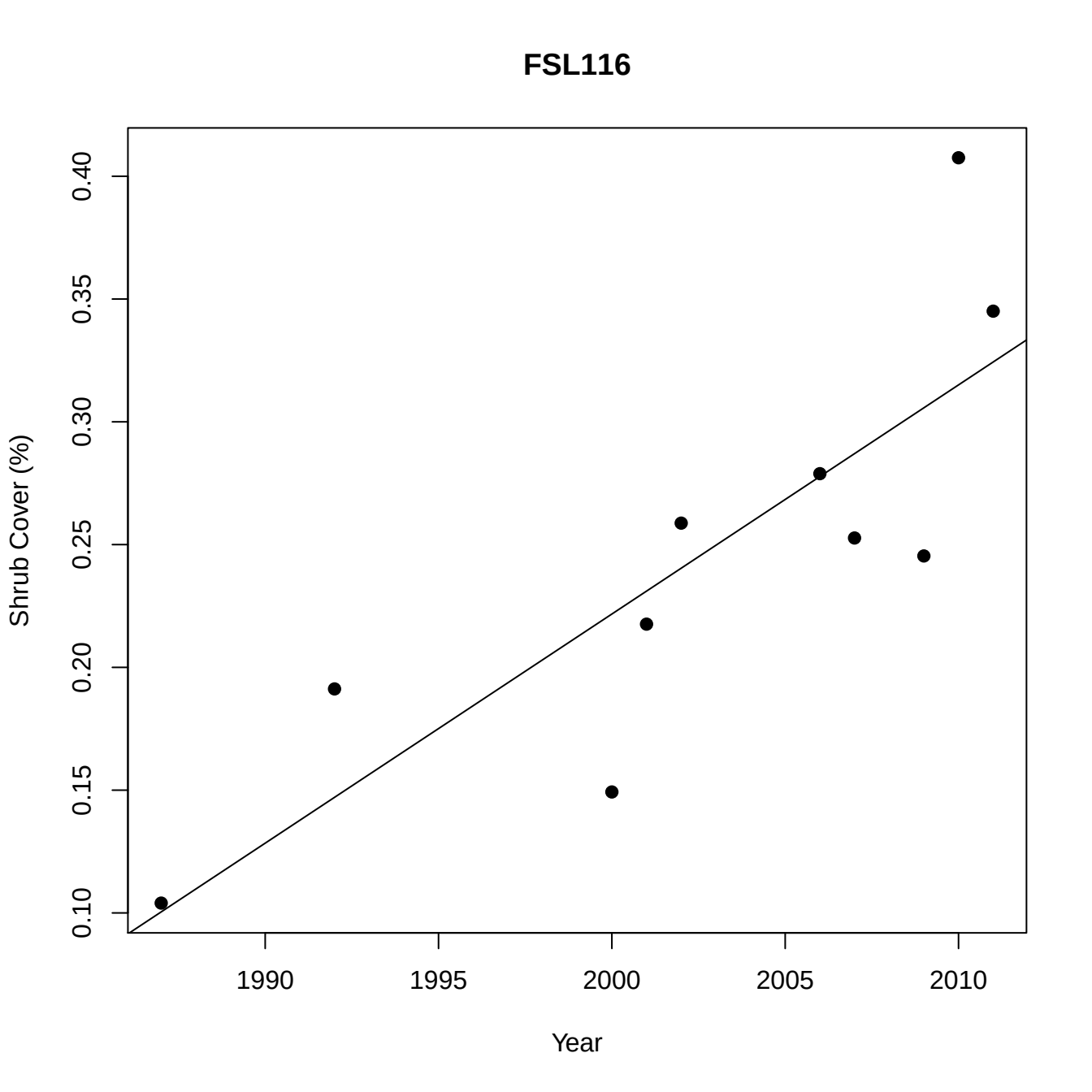

BLK033
Shrub Cover (%)
0.4
0.5
0.6
0.7
0.8
1985
1990
1995
2000
2005
2010
Year

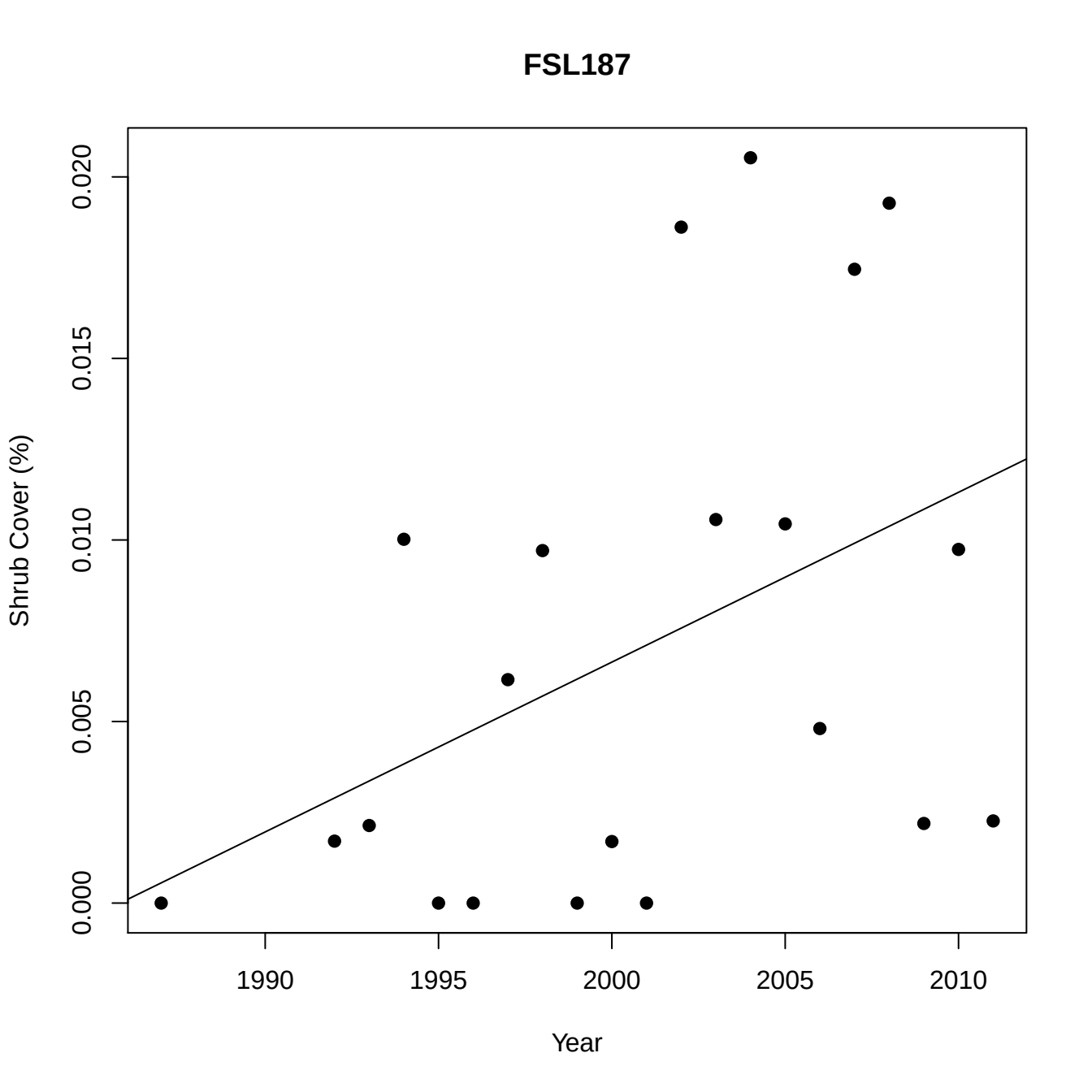

BLK044
Shrub Cover (%)
0.5
0.6
0.7
0.8
1995
2000
2005
2010
Year

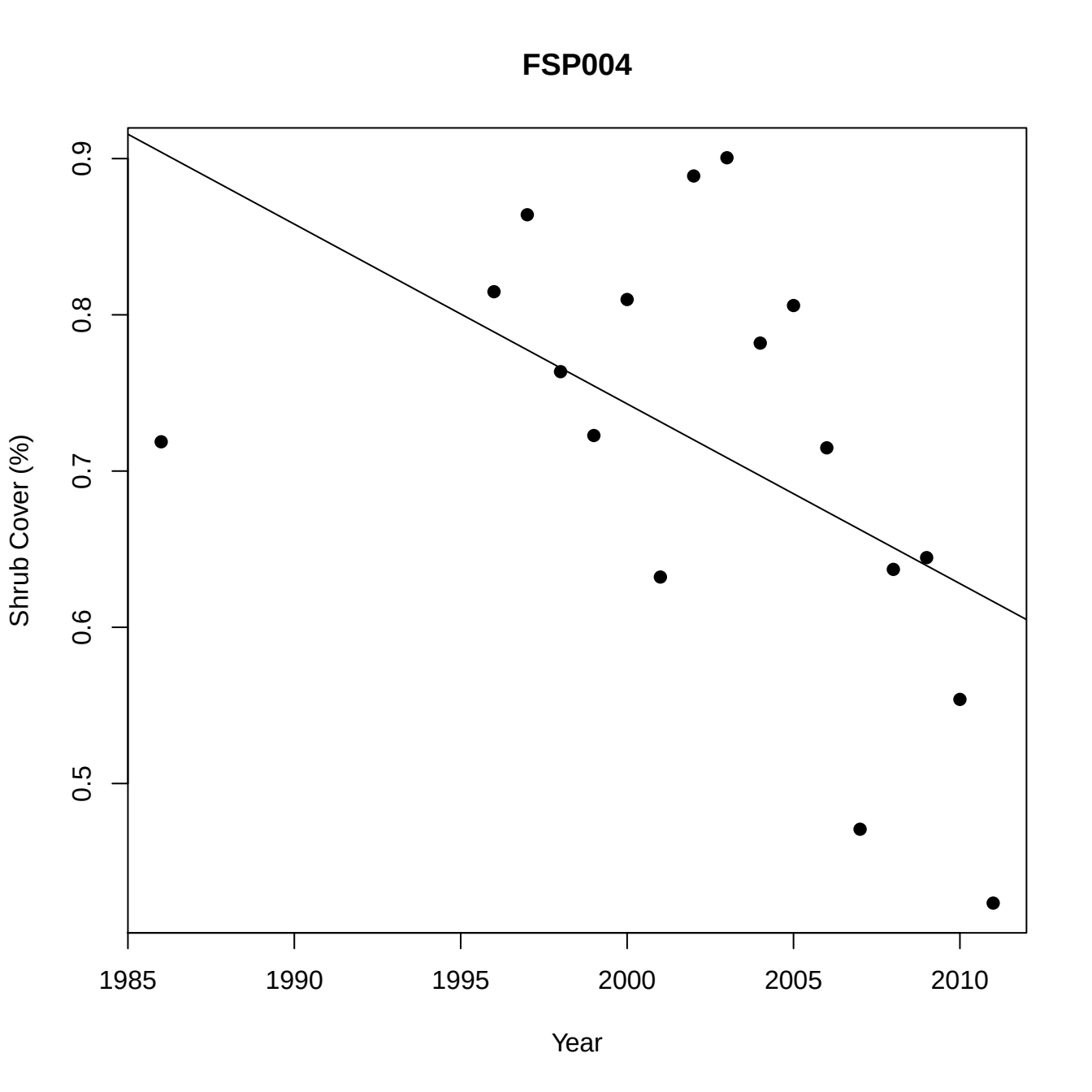

BLK075
Shrub Cover (%)
0.2
0.4
0.6
0.8
1985
1990
1995
2000
2005
2010
Year

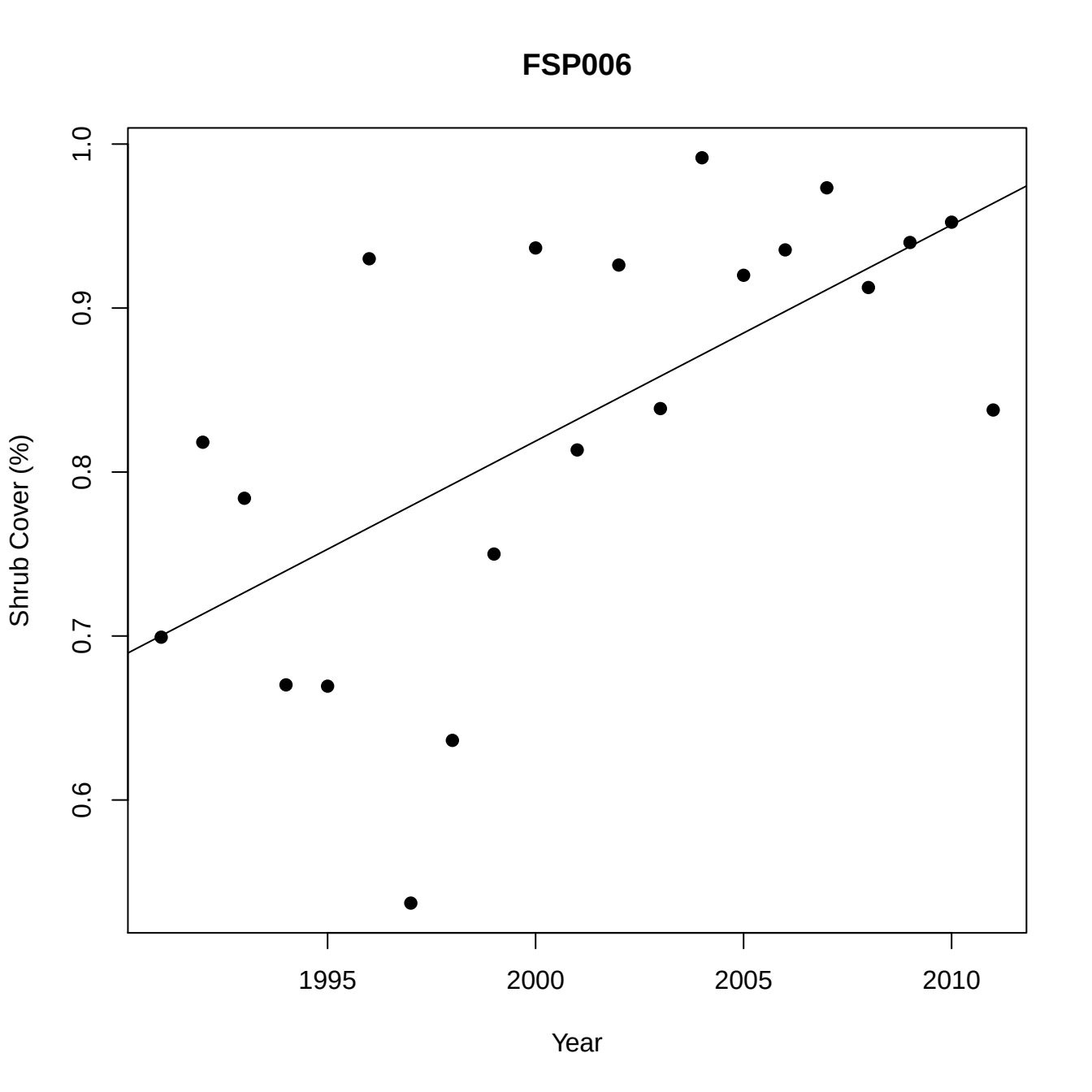

BLK094
Shrub Cover (%)
0.25
0.30
0.35
0.40
0.45
0.50
0.55
1985
1990
1995
2000
2005
2010
Year

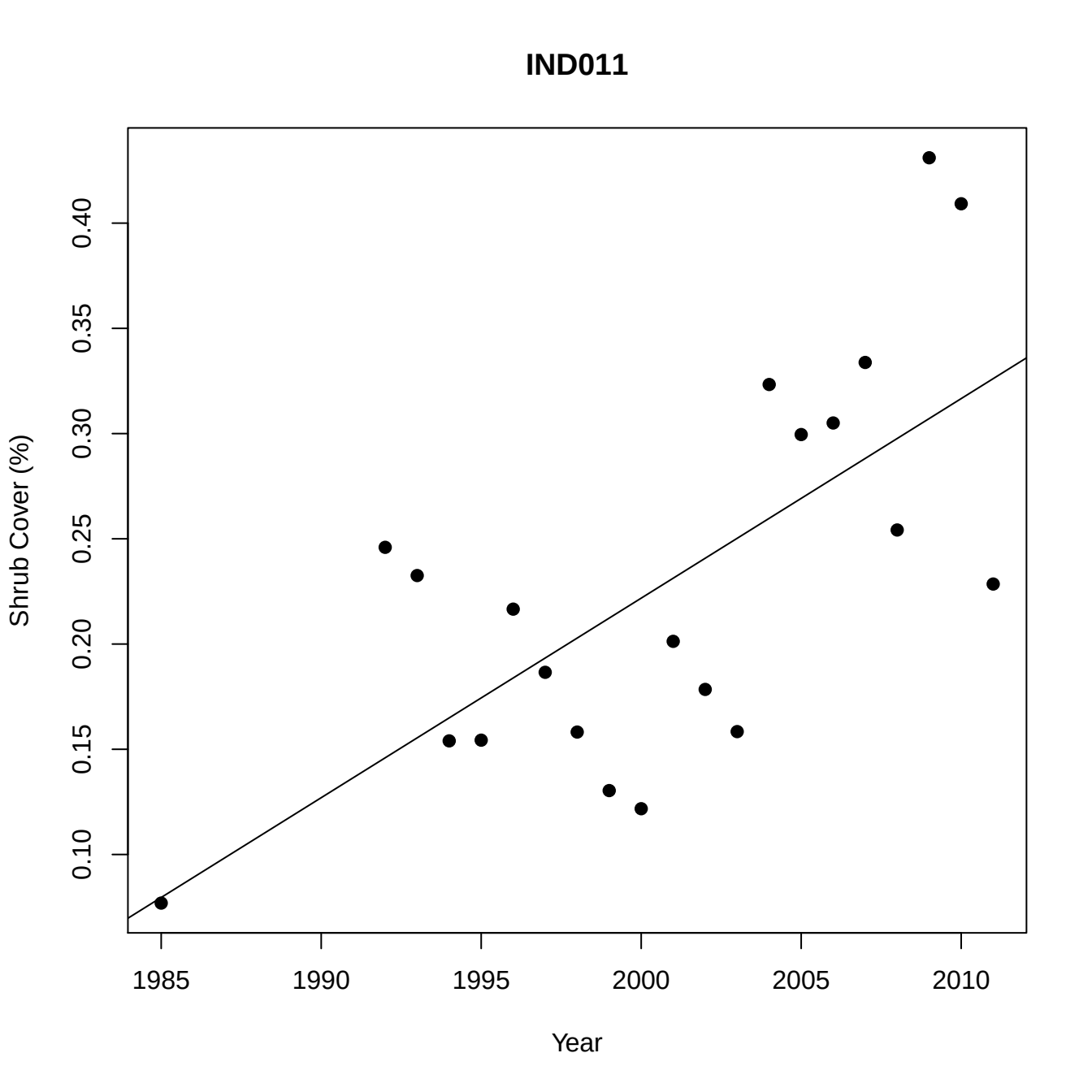

FSL065
Shrub Cover (%)
0.2
0.3
0.4
0.5
1990
1995
2000
2005
2010
Year

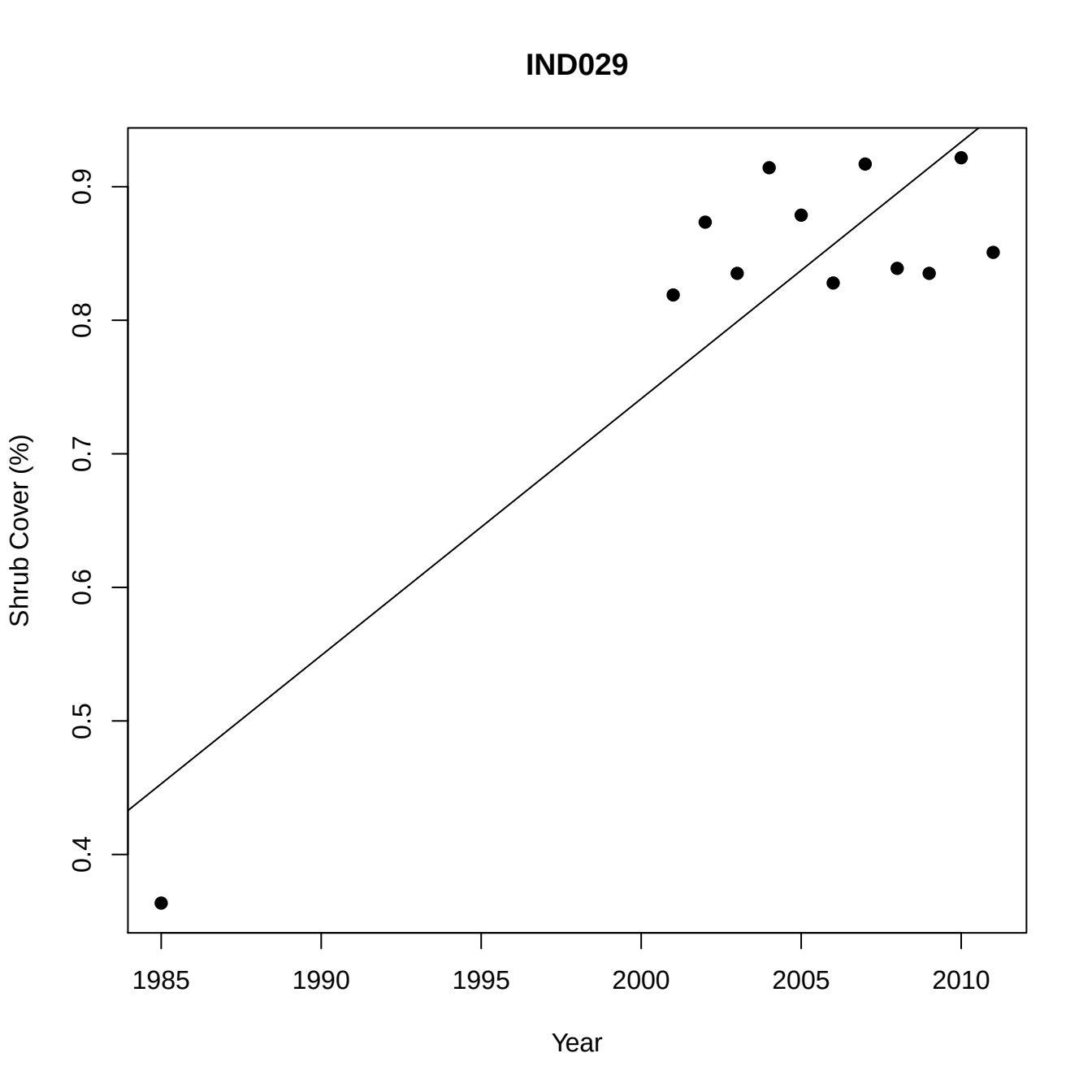

FSL116
Shrub Cover (%)
0.10
0.15
0.20
0.25
0.30
0.35
0.40
1990
1995
2000
2005
2010
Year

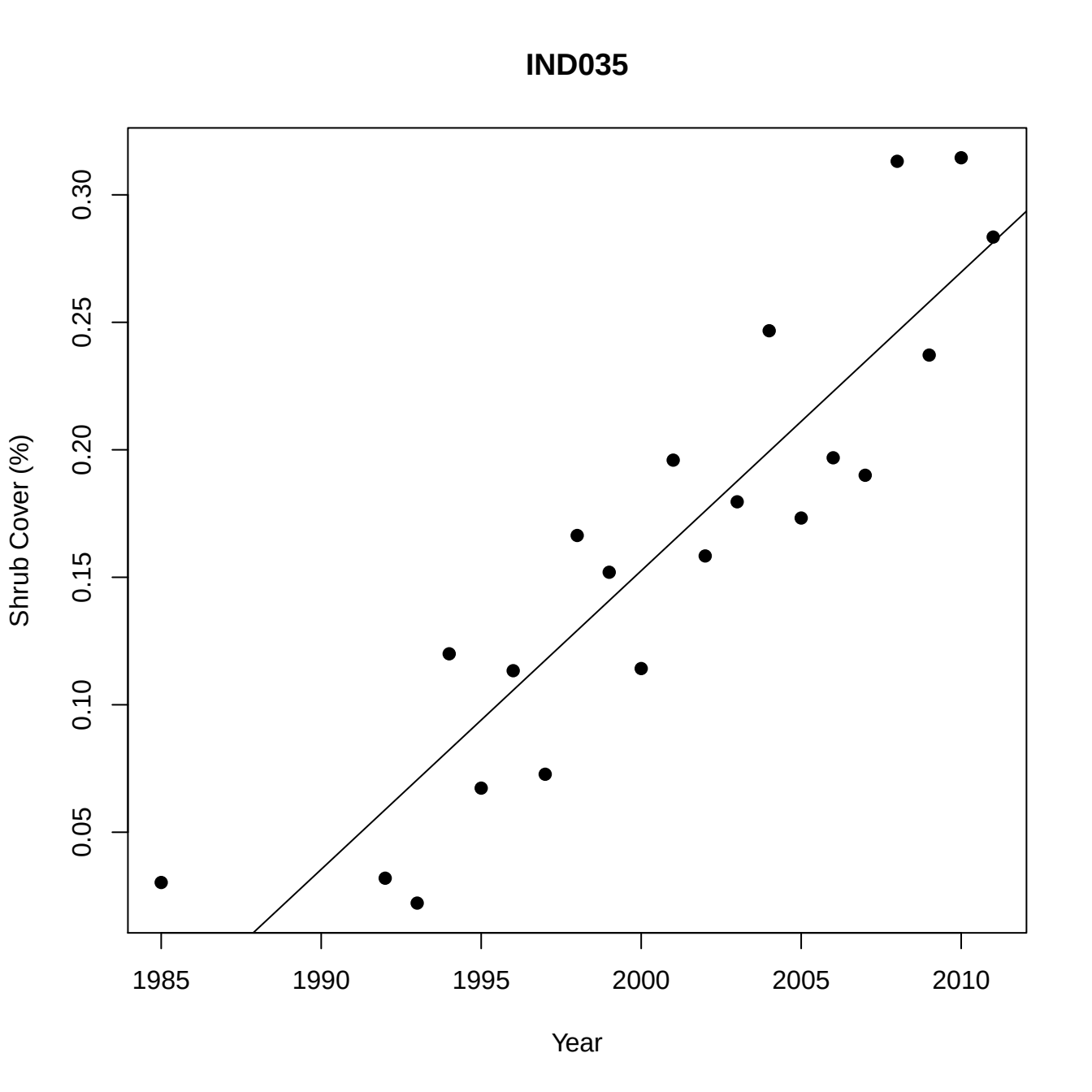

FSL187
Shrub Cover (%)
0.000
0.005
0.010
0.015
0.020
1990
1995
2000
2005
2010
Year

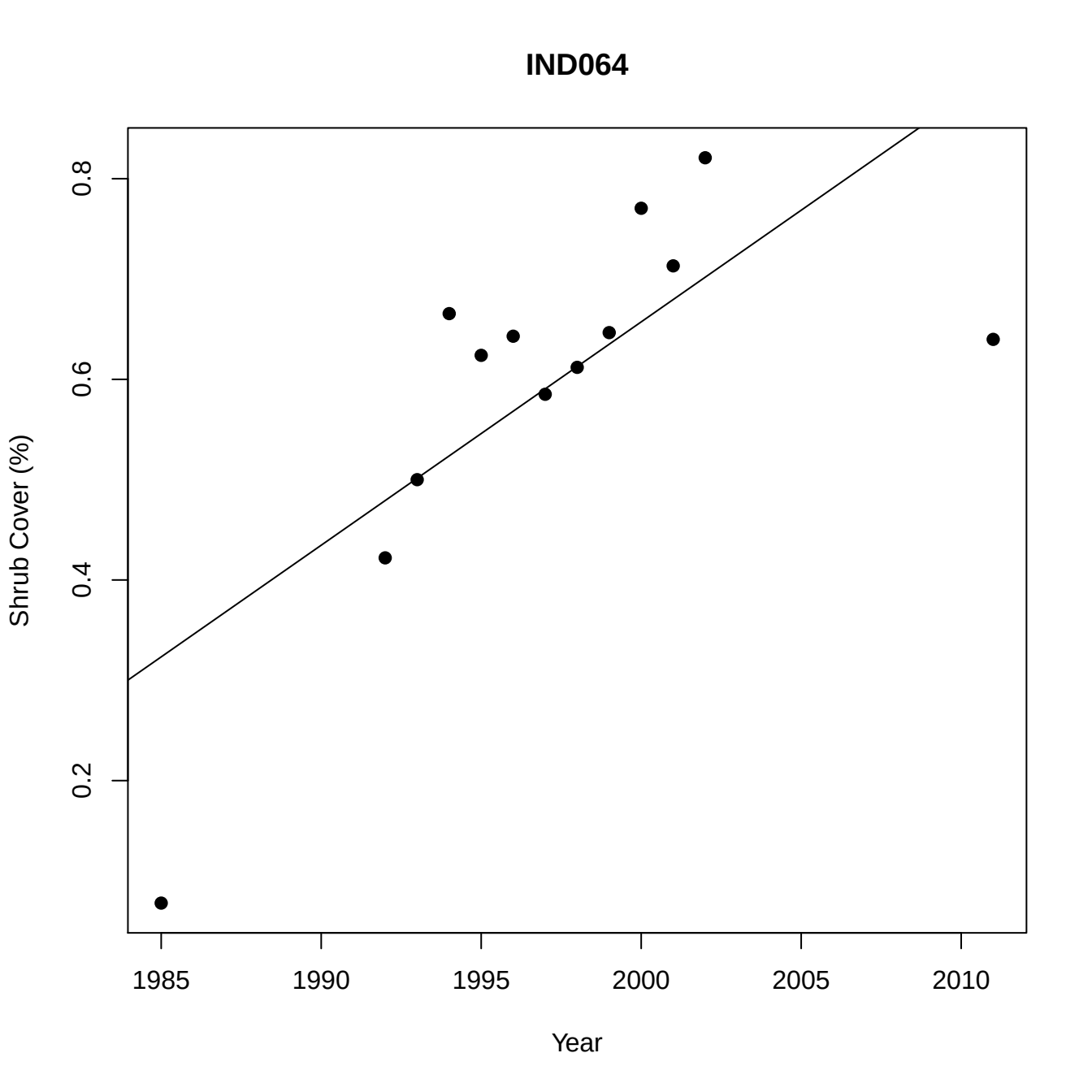

FSP004
Shrub Cover (%)
0.5
0.6
0.7
0.8
0.9
1985
1990
1995
2000
2005
2010
Year

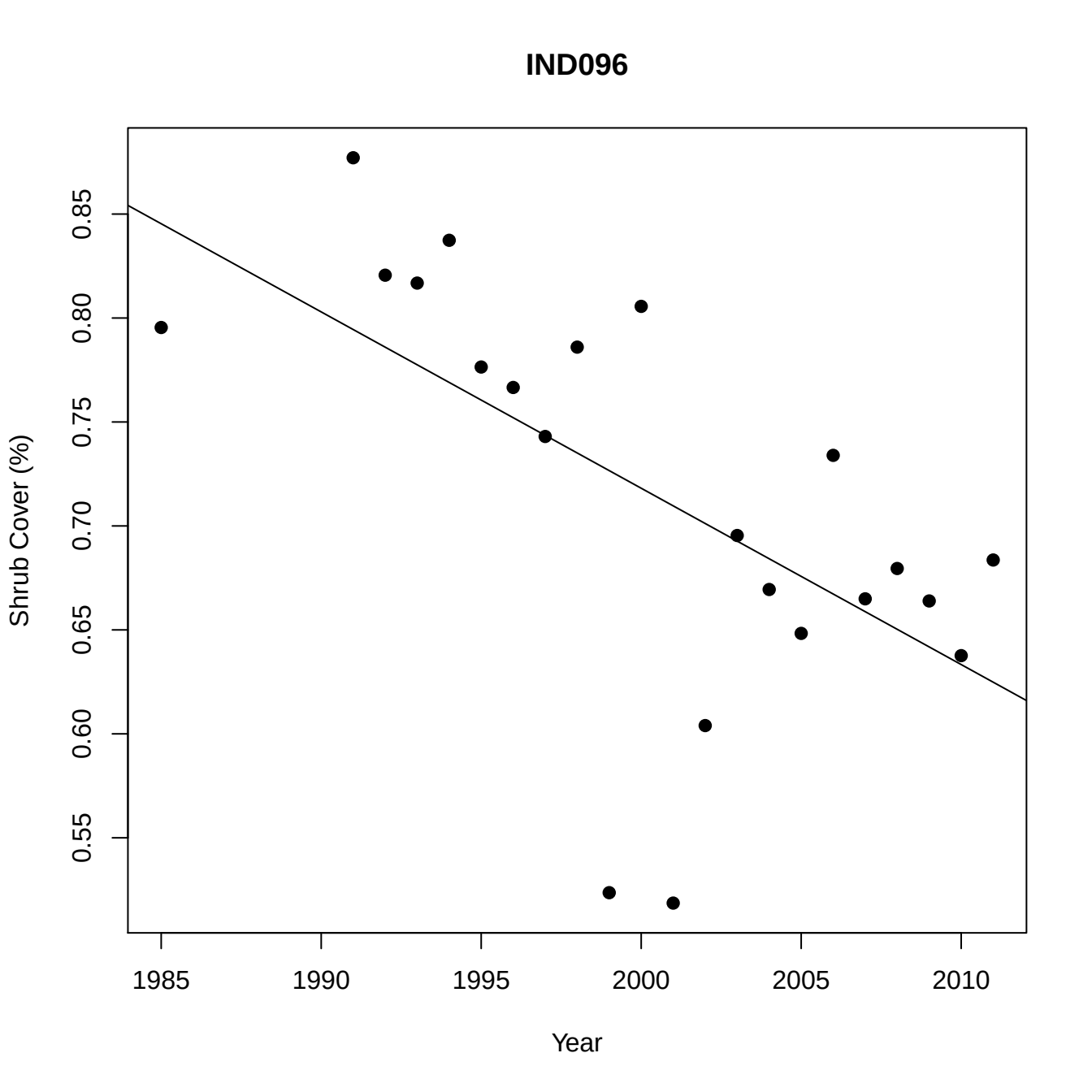

FSP006
Shrub Cover (%)
1.0
0.9
0.8
0.7
0.6
1995
2000
2005
2010
Year

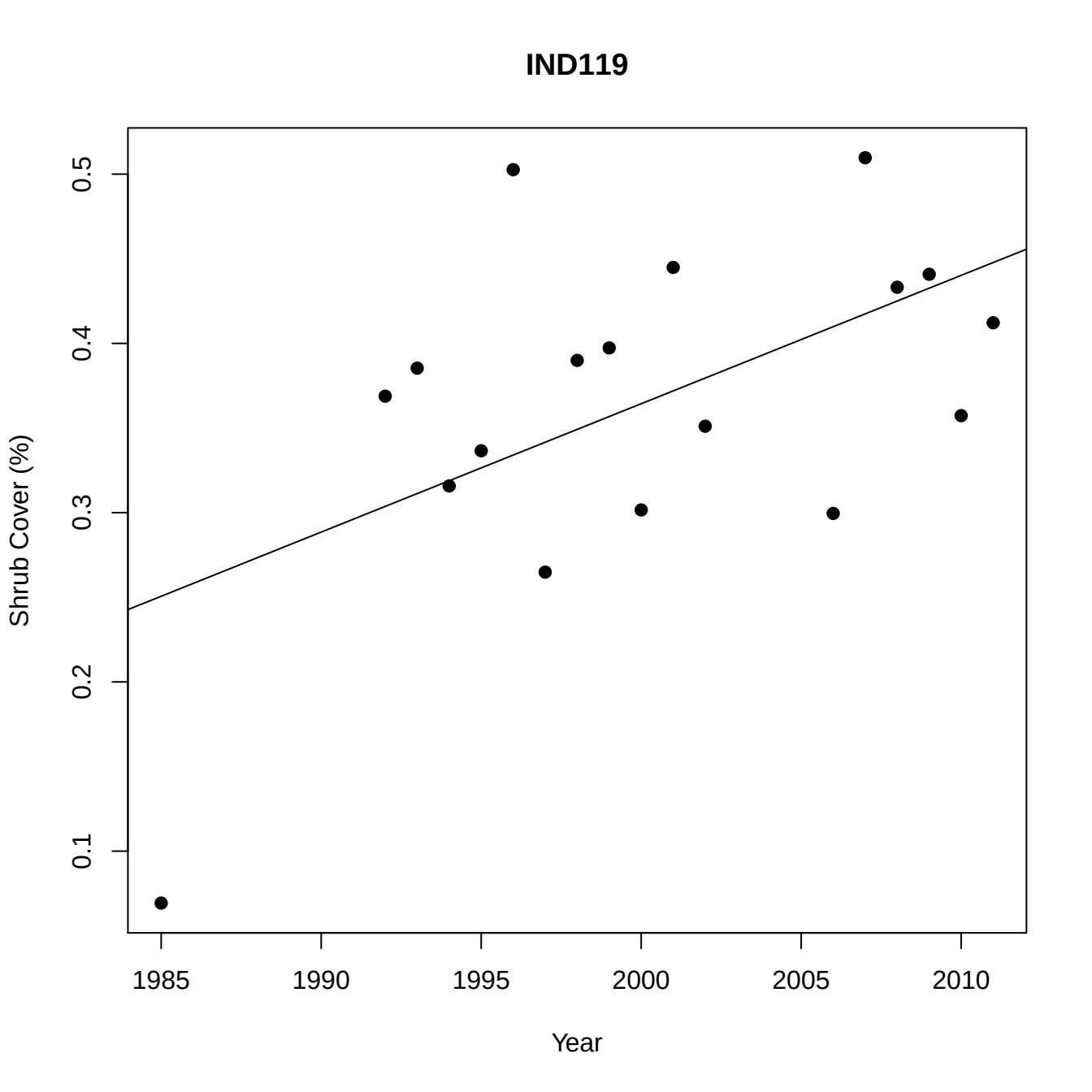

IND011
Shrub Cover (%)
0.10
0.15
0.20
0.25
0.30
0.35
0.40
1985
1990
1995
2000
2005
2010
Year

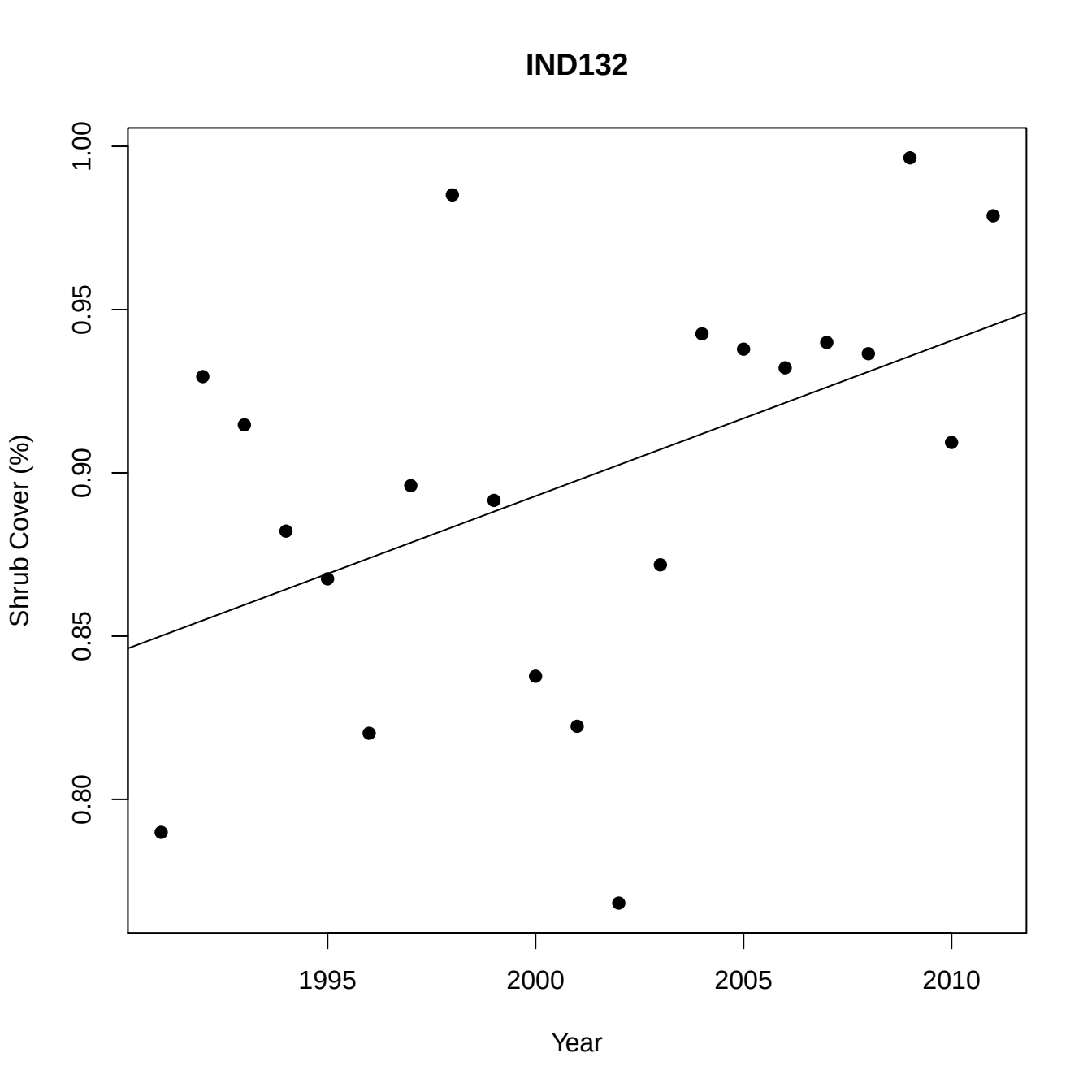

IND029
Shrub Cover (%)
0.4
0.5
0.6
0.7
0.8
0.9
1985
1990
1995
2000
2005
2010
Year

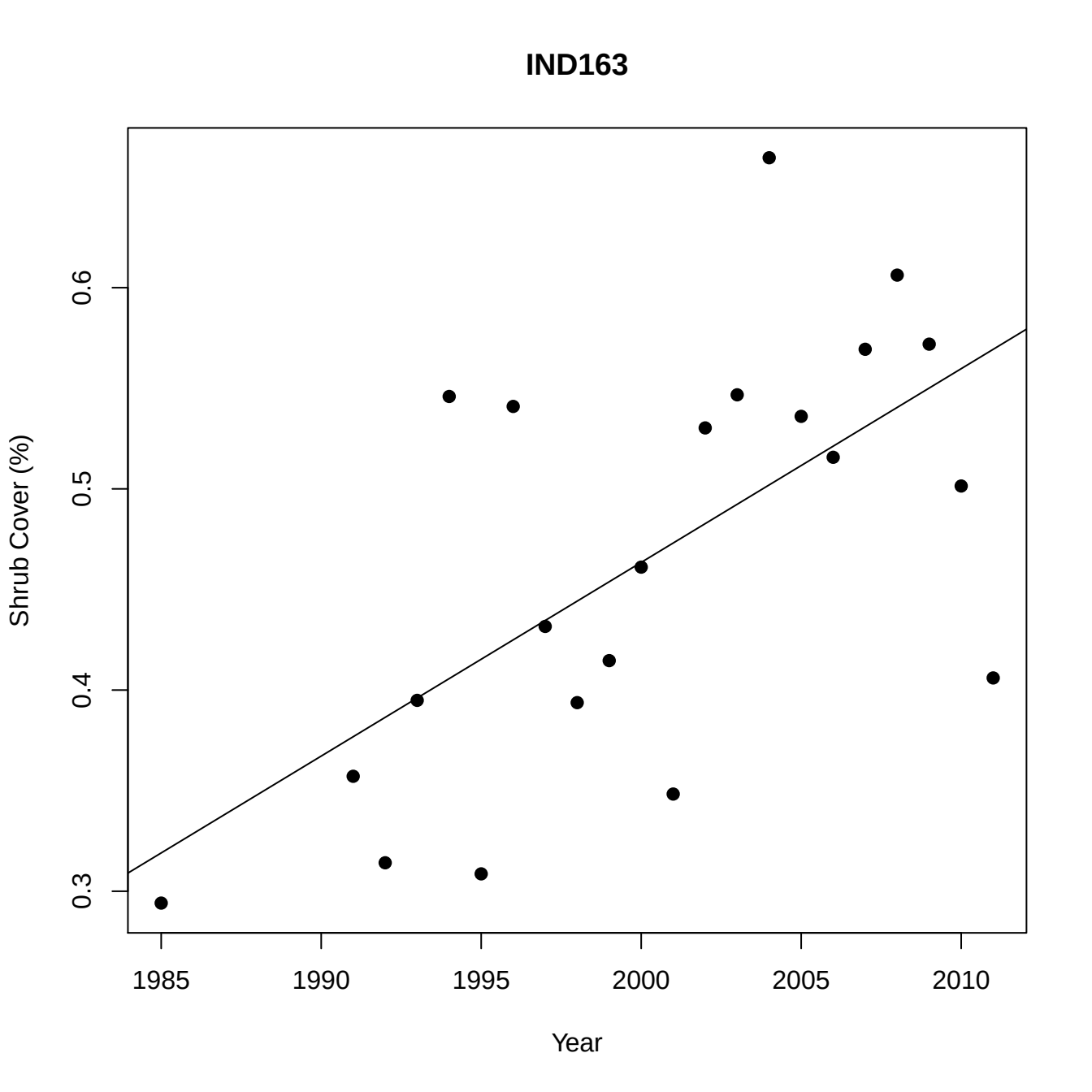

IND035
Shrub Cover (%)
0.05
0.10
0.15
0.20
0.25
0.30
1985
1990
1995
2000
2005
2010
Year

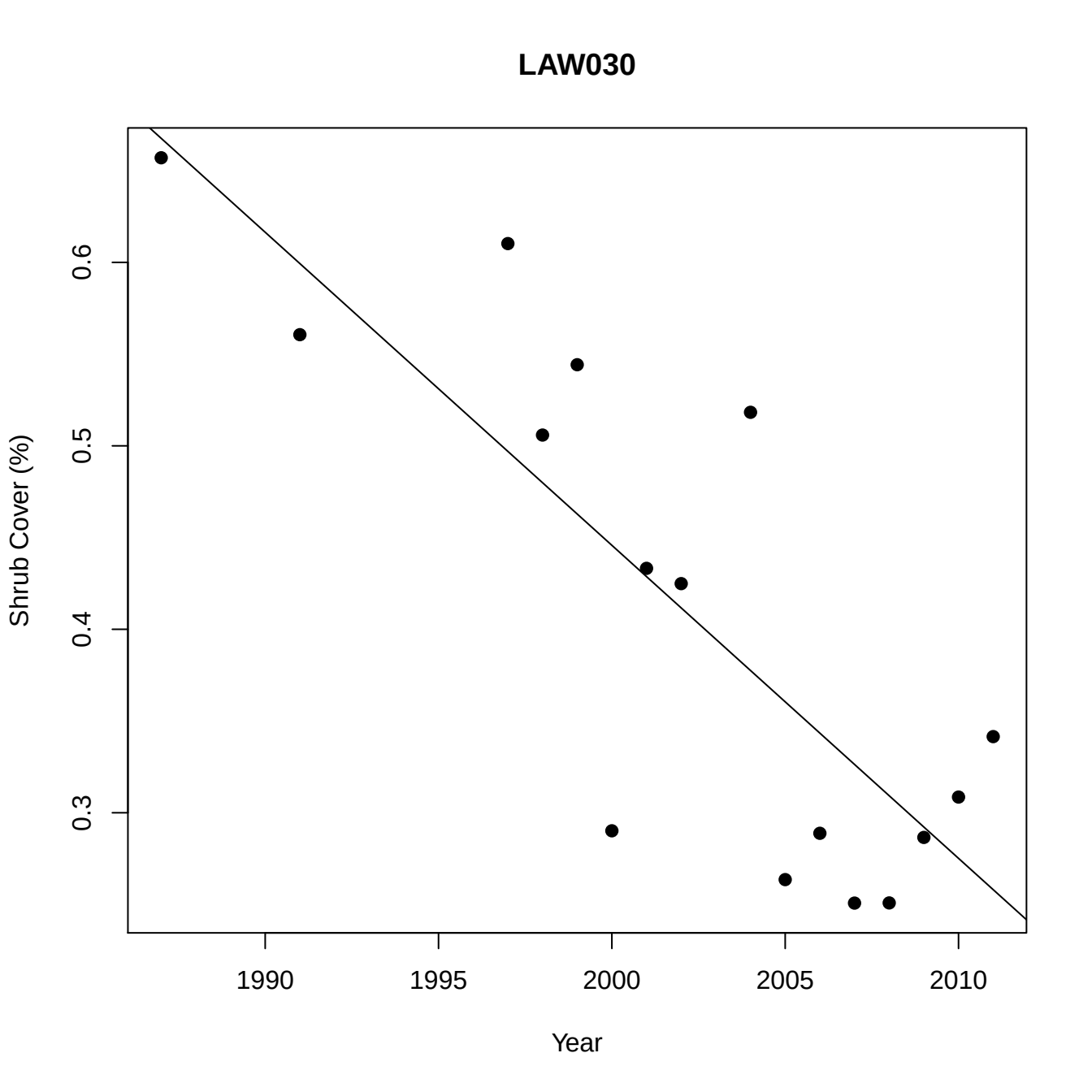

IND064
Shrub Cover (%)
0.2
0.4
0.6
0.8
1985
1990
1995
2000
2005
2010
Year

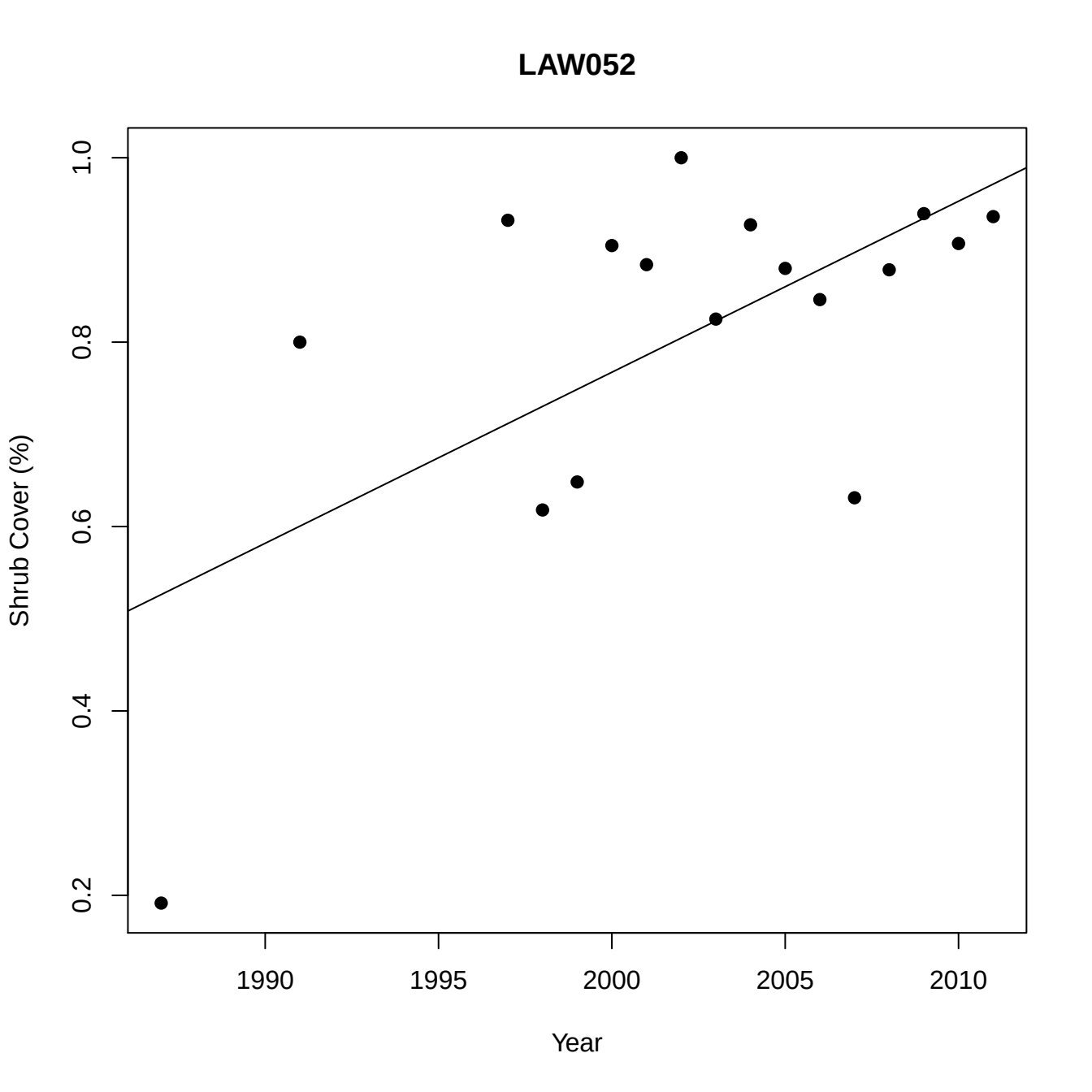

IND096
Shrub Cover (%)
0.55
0.60
0.65
0.70
0.75
0.80
0.85
1985
1990
1995
2000
2005
2010
Year

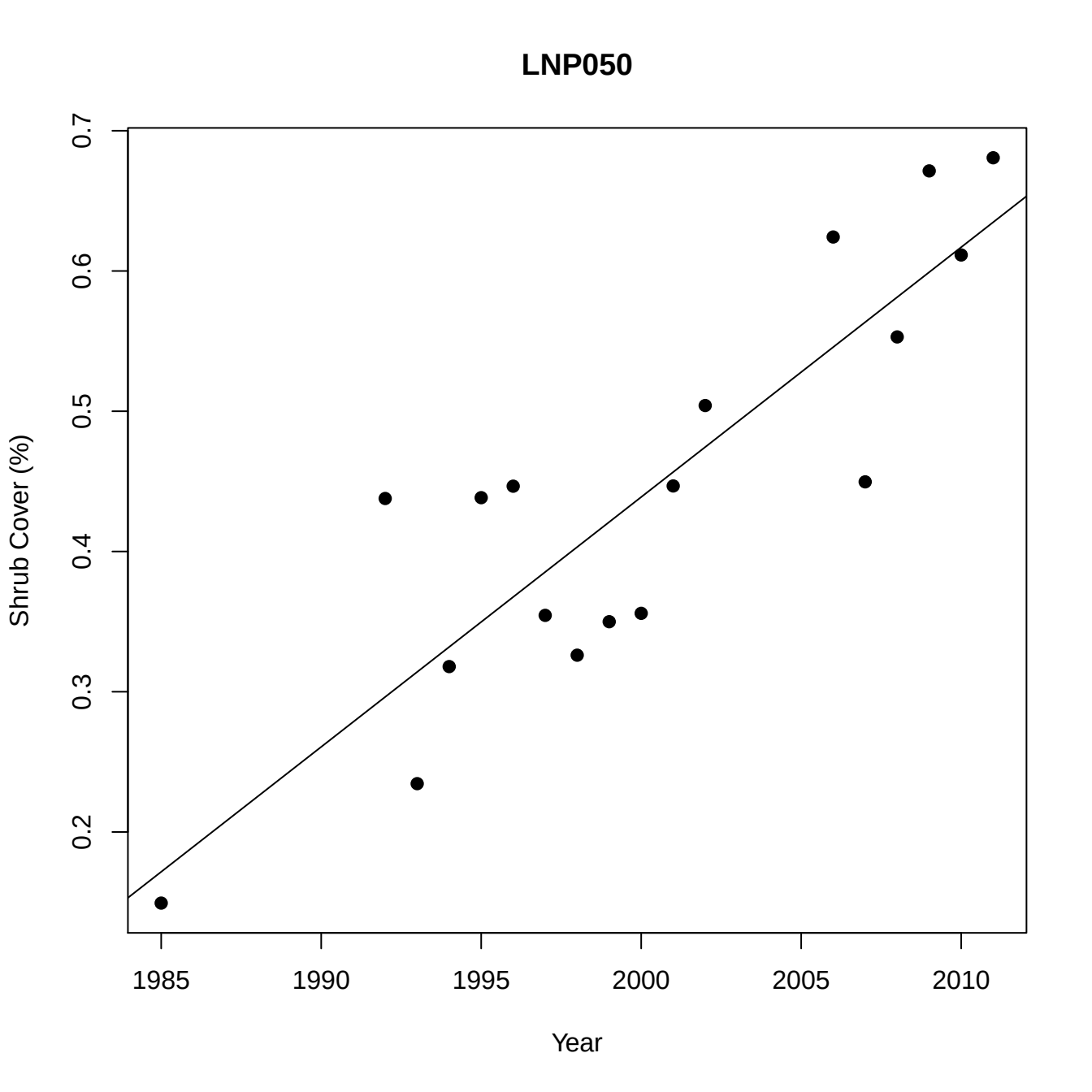

IND119
Shrub Cover (%)
0.1
0.2
0.3
0.4
0.5
1985
1990
1995
2000
2005
2010
Year

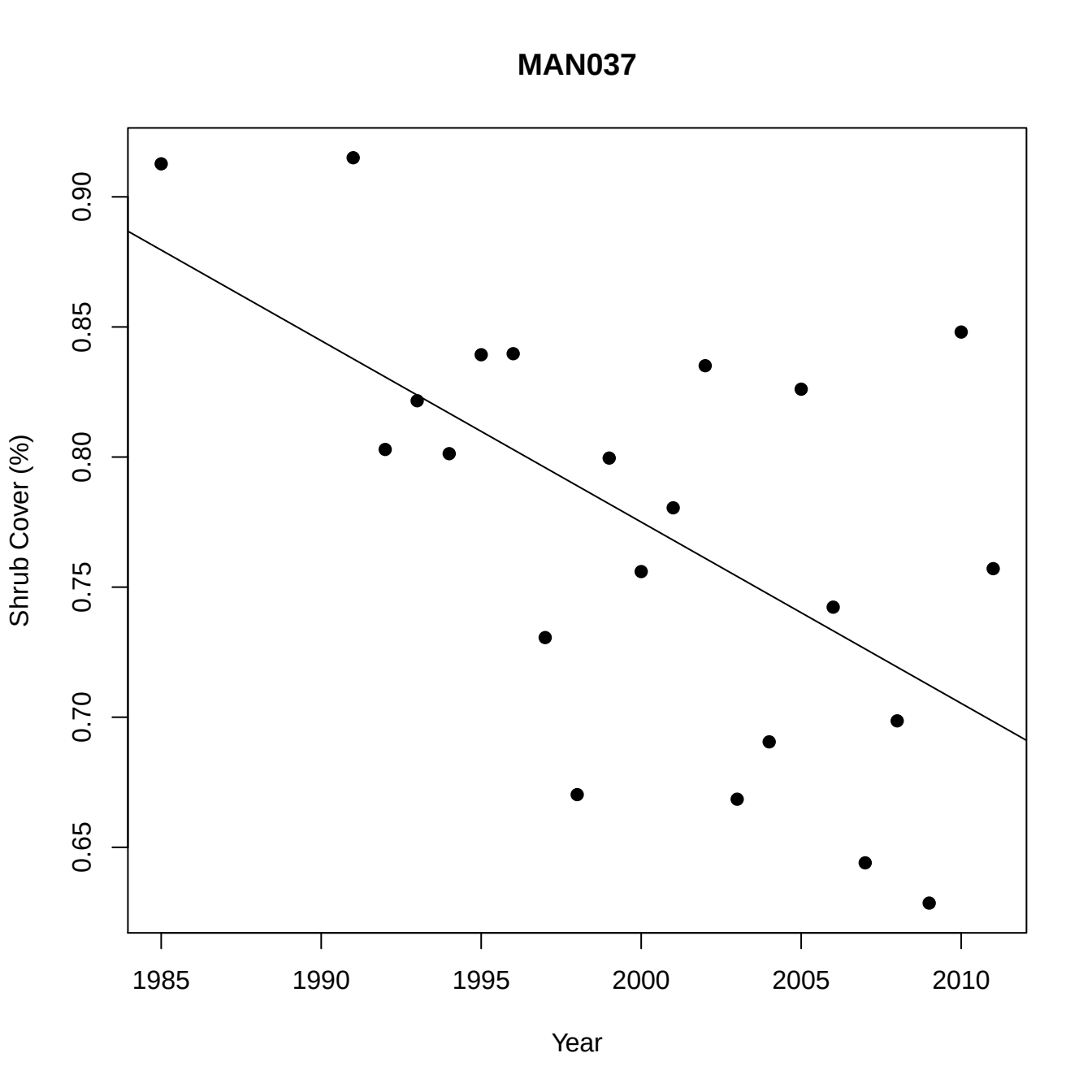

IND132
Shrub Cover (%)
1.00
0.95
0.90
0.85
0.80
1995
2000
2005
2010
Year

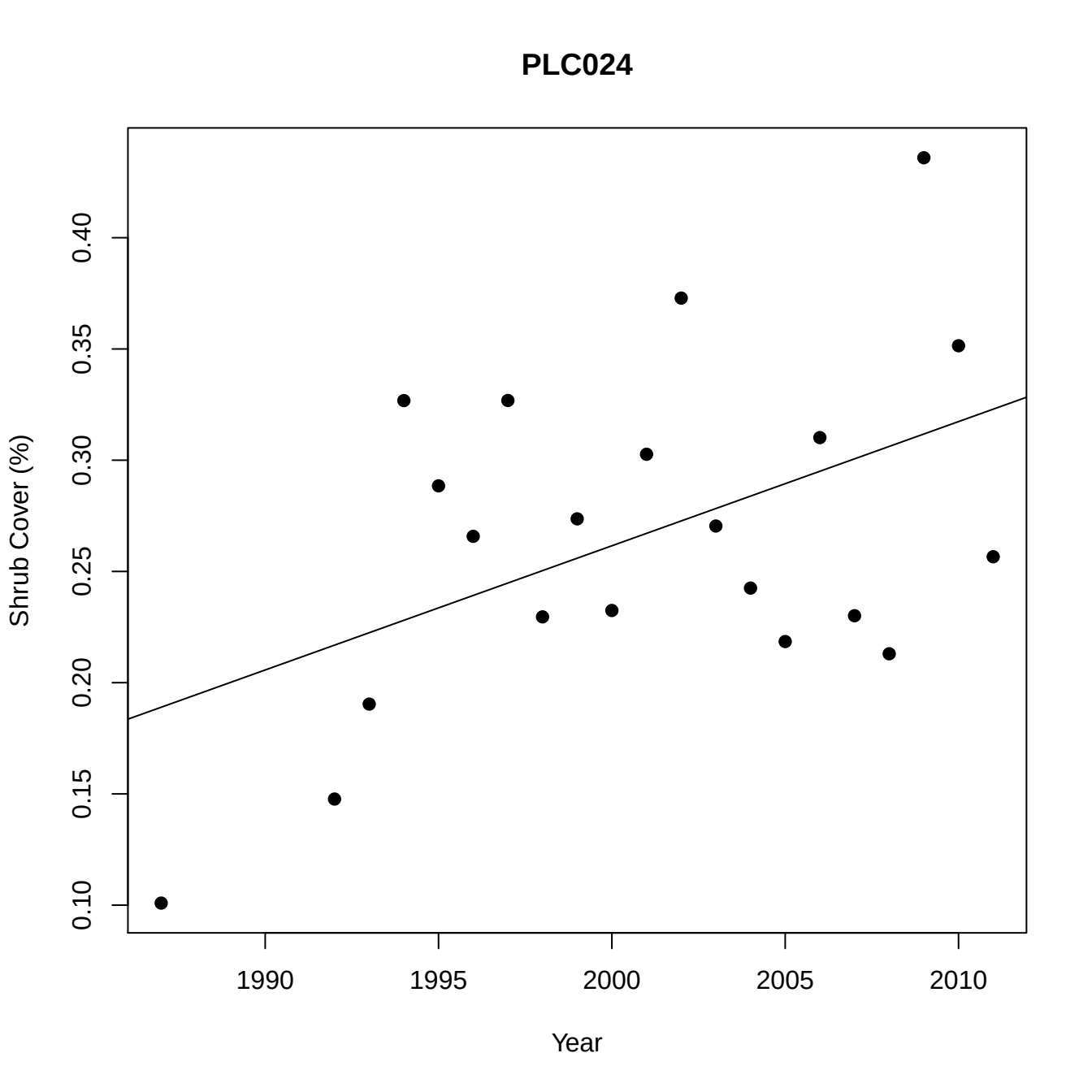

IND163
Shrub Cover (%)
0.3
0.4
0.5
0.6
1985
1990
1995
2000
2005
2010
Year

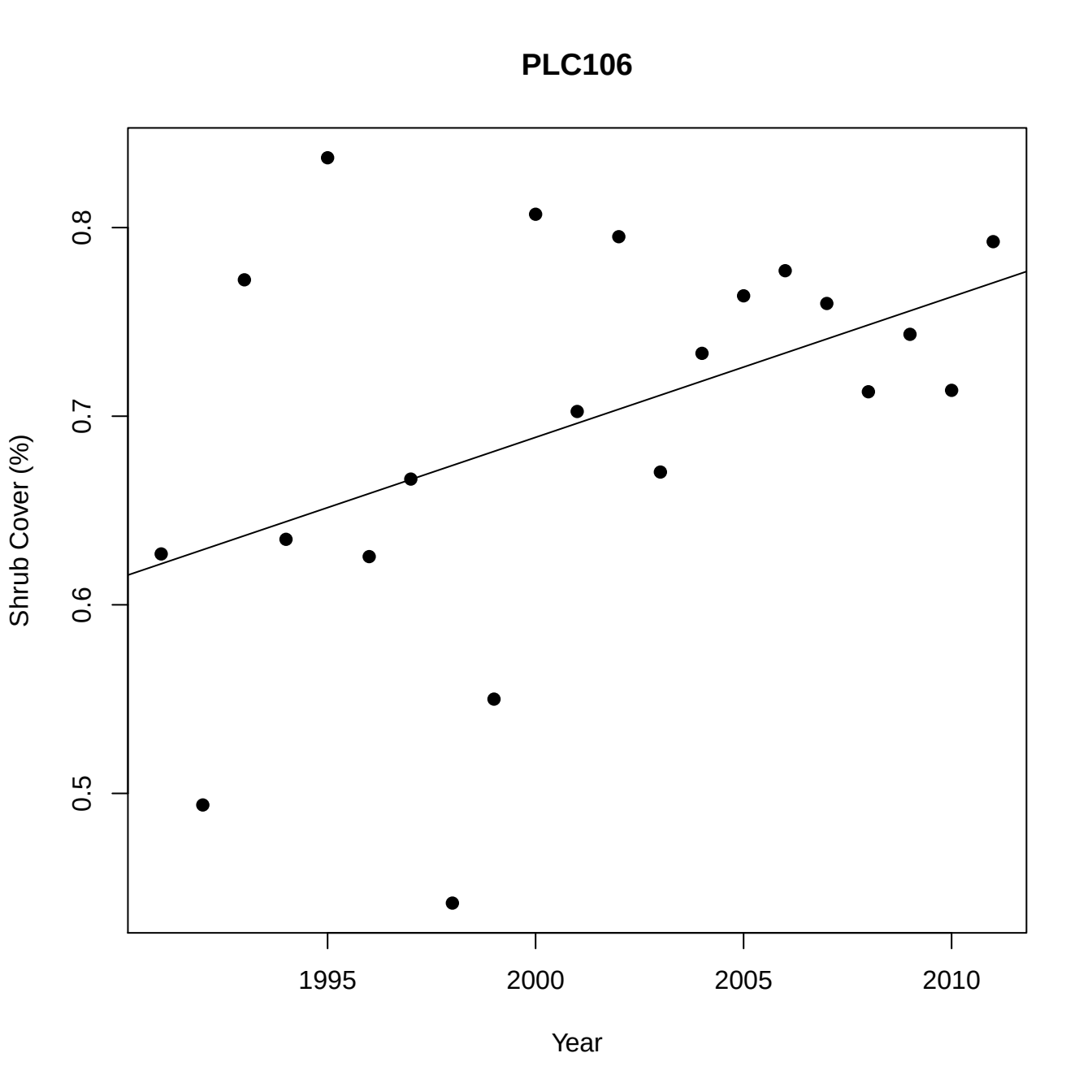

LAW030
Shrub Cover (%)
0.3
0.4
0.5
0.6
1990
1995
2000
2005
2010
Year

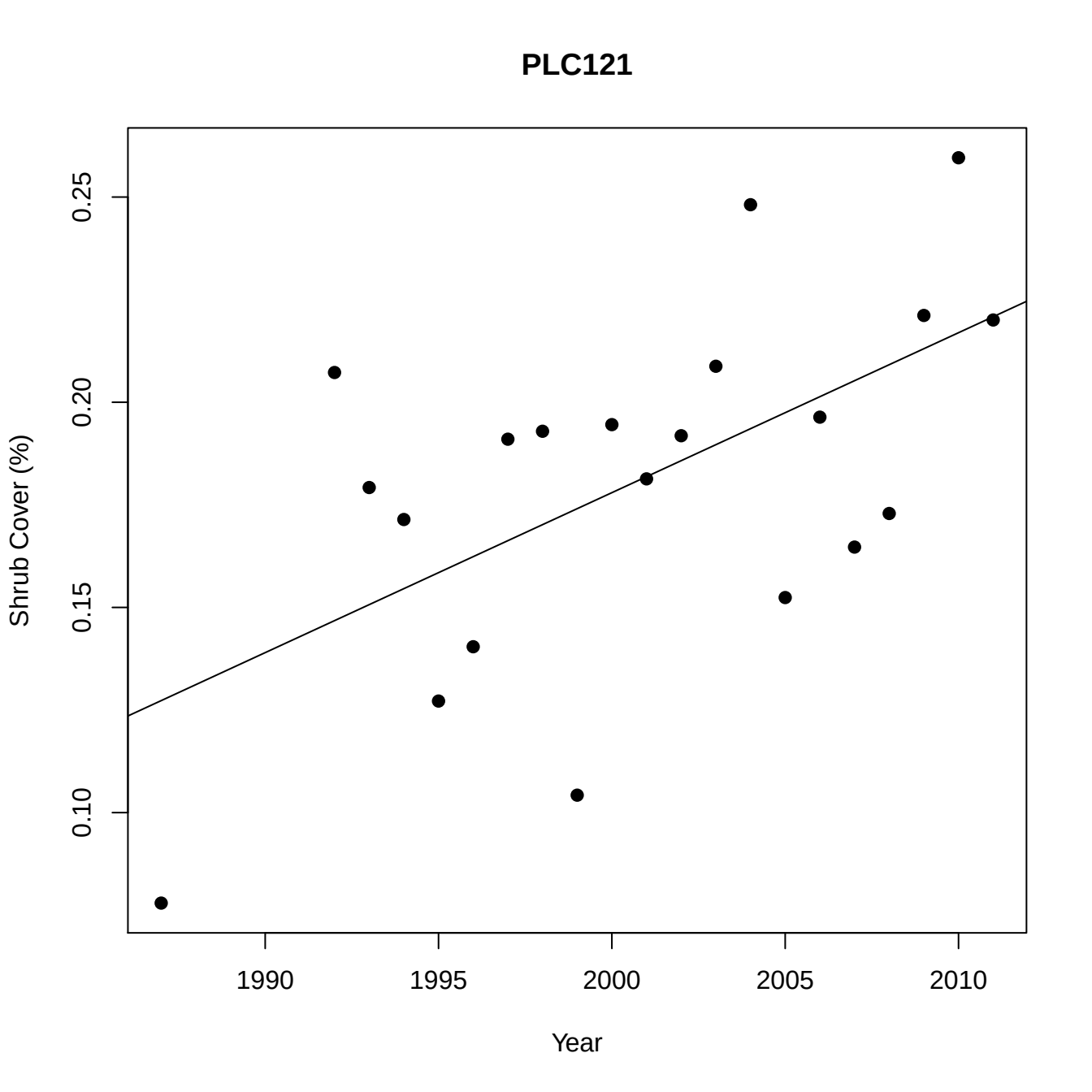

LAW052
Shrub Cover (%)
0.2
0.4
0.6
0.8
1.0
1990
1995
2000
2005
2010
Year

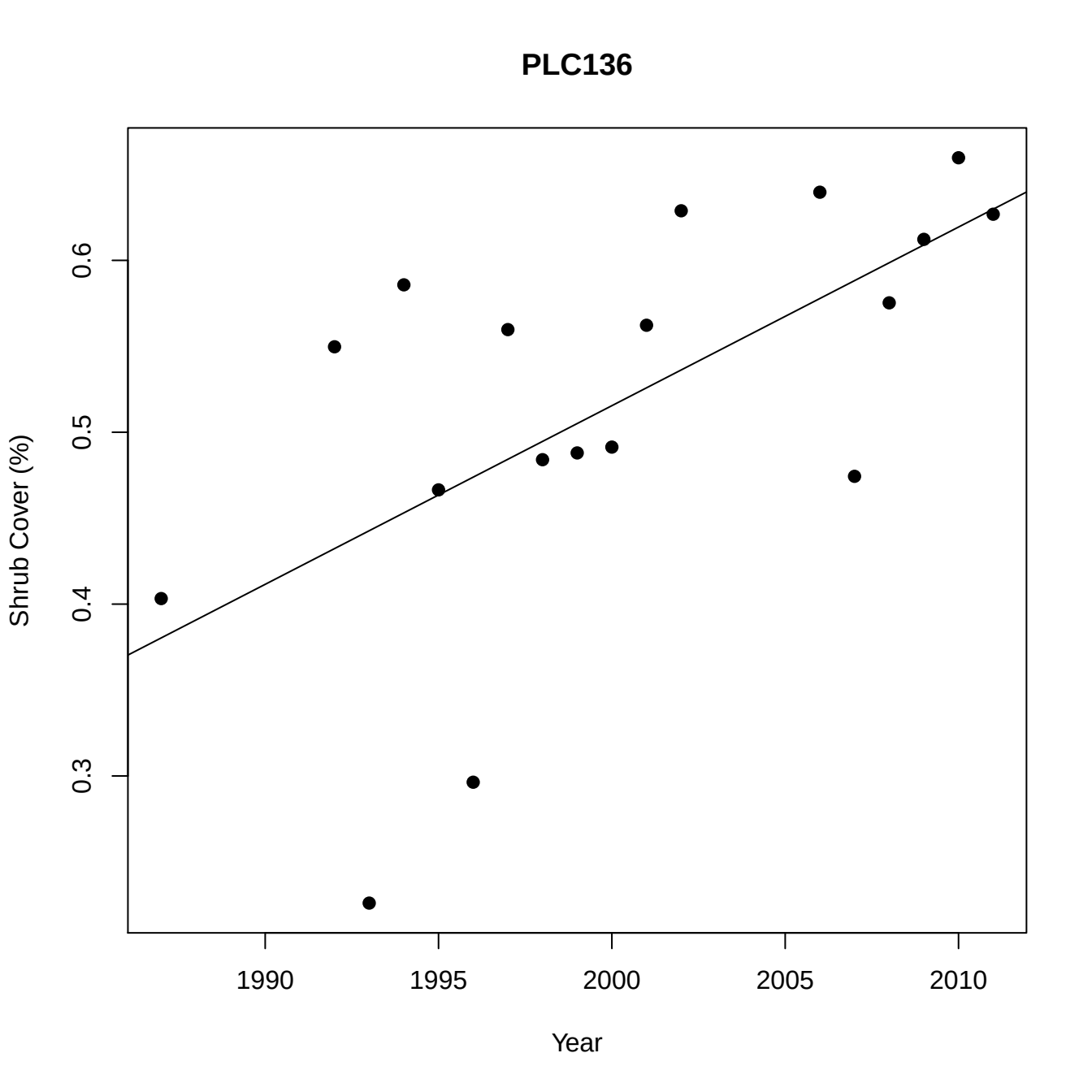

LNP050
Shrub Cover (%)
0.2
0.3
0.4
0.5
0.6
0.7
1985
1990
1995
2000
2005
2010
Year

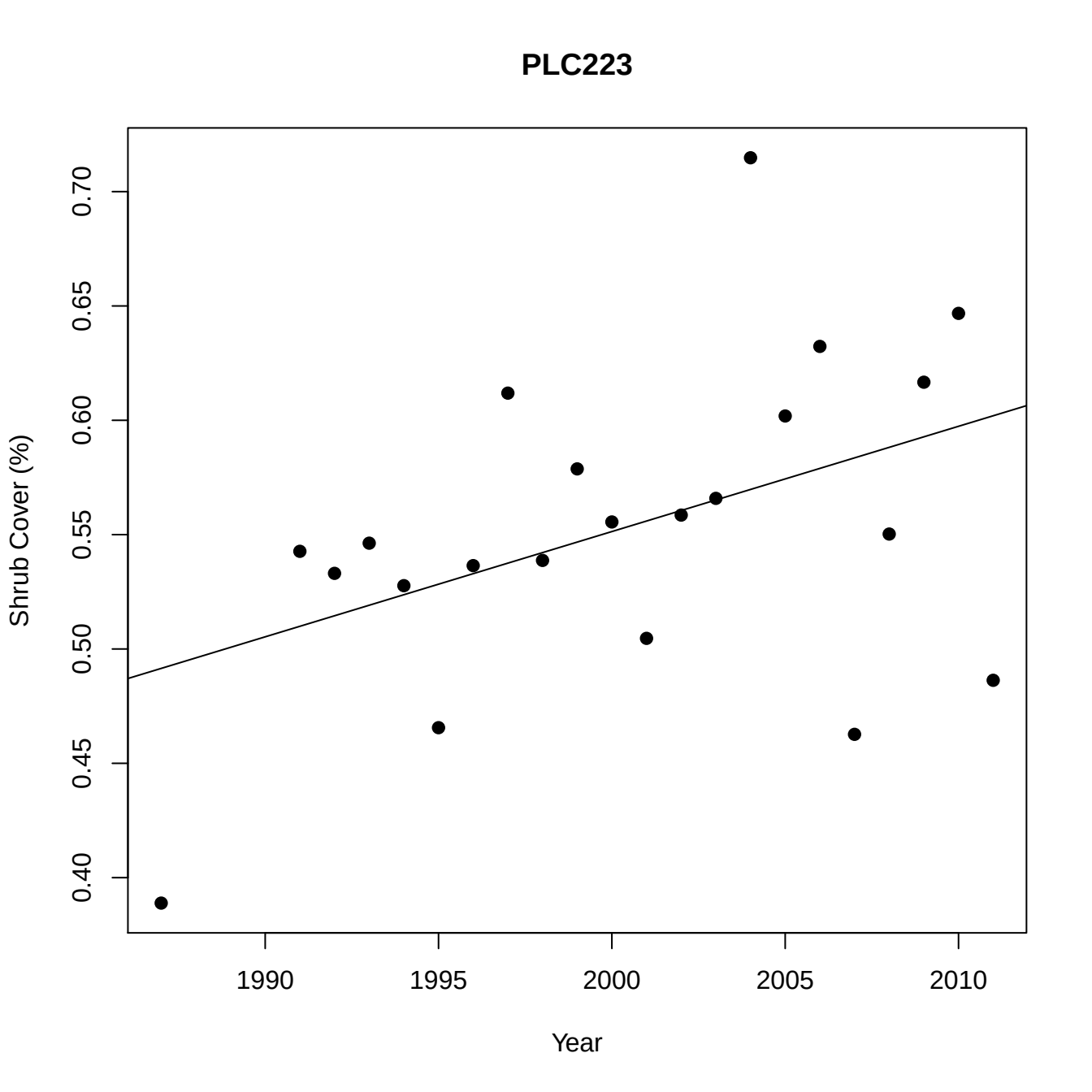

MAN037
Shrub Cover (%)
0.65
0.70
0.75
0.80
0.85
0.90
1985
1990
1995
2000
2005
2010
Year

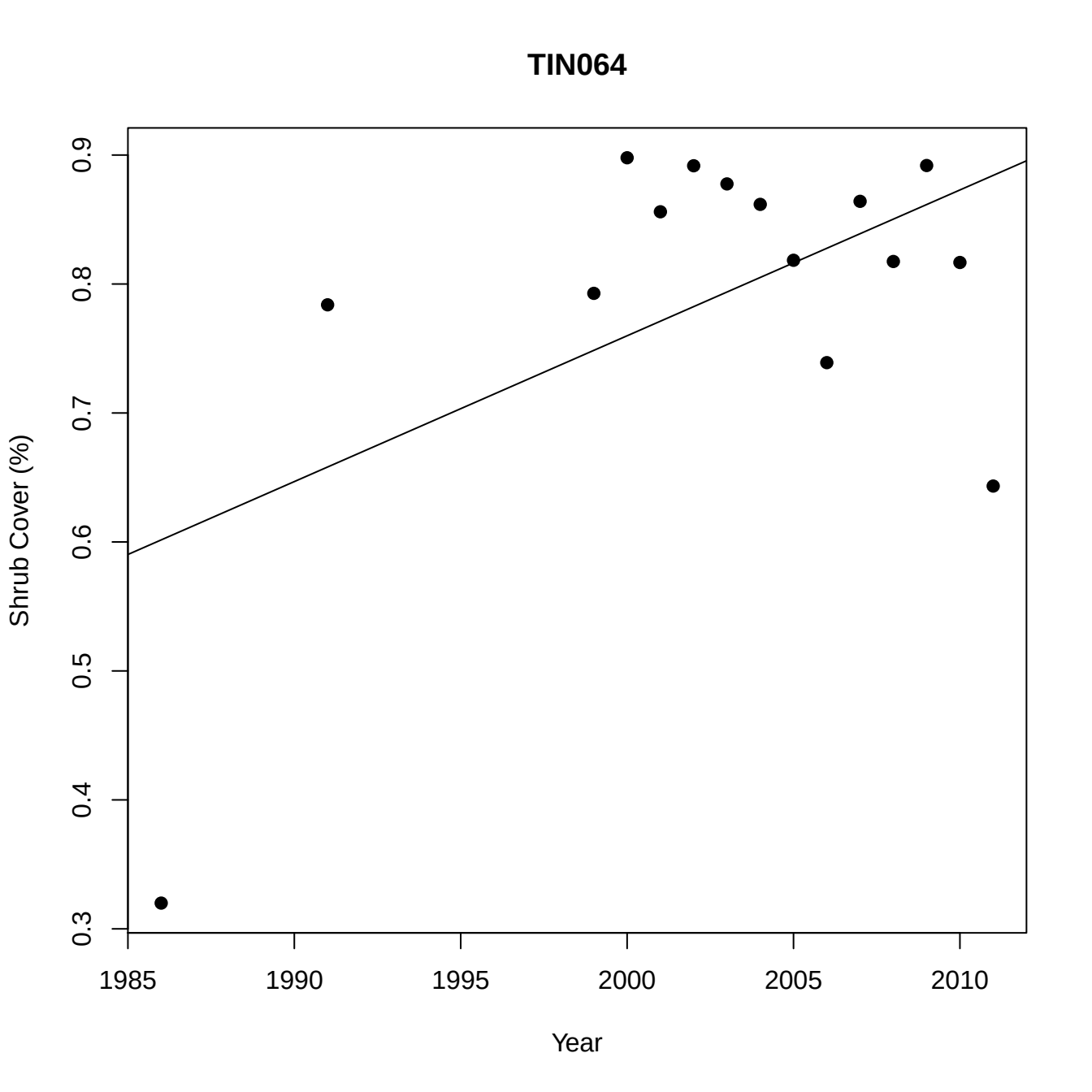

PLC024
Shrub Cover (%)
0.10
0.15
0.20
0.25
0.30
0.35
0.40
1990
1995
2000
2005
2010
Year

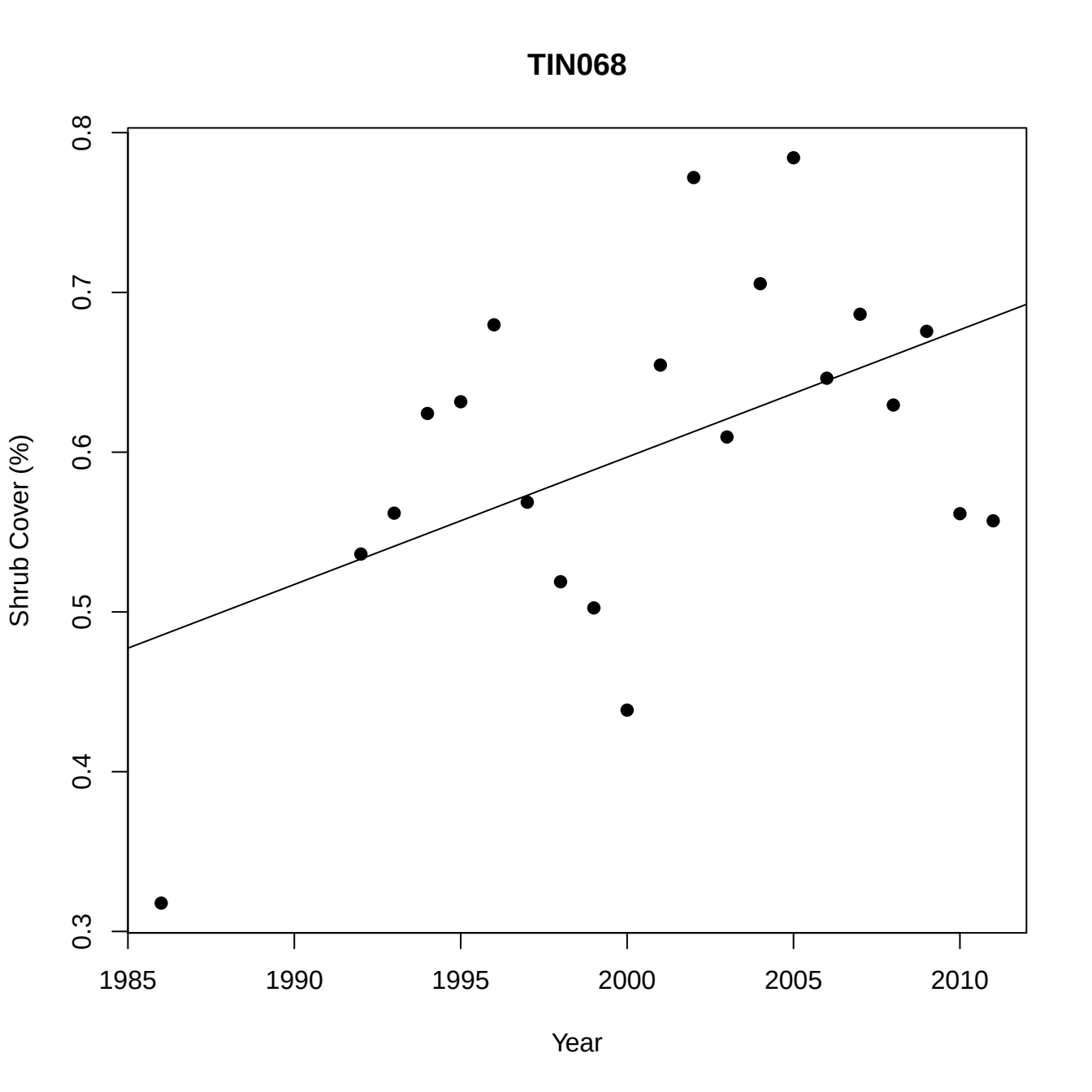

PLC106
Shrub Cover (%)
0.5
0.6
0.7
0.8
1995
2000
2005
2010
Year

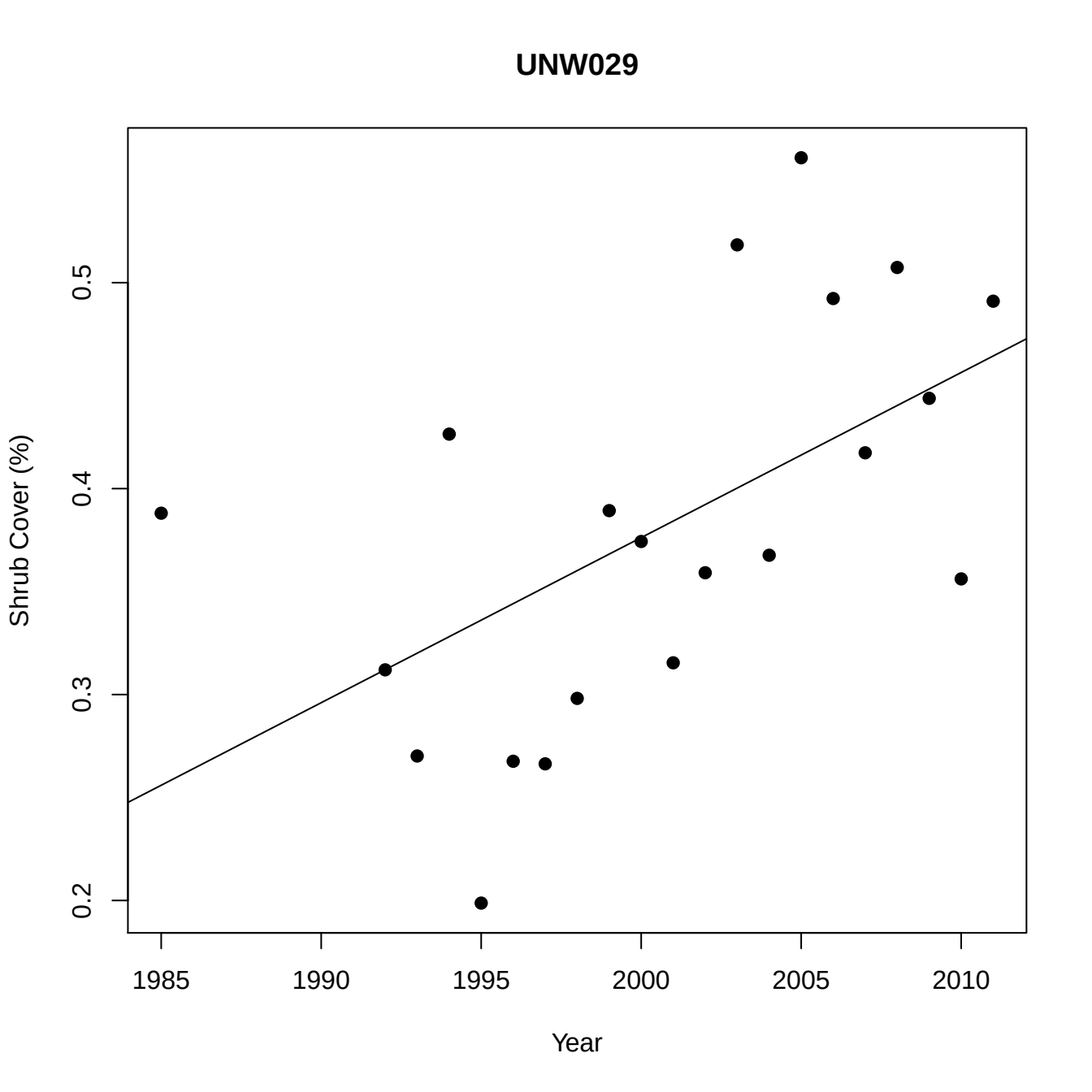

PLC121
Shrub Cover (%)
0.10
0.15
0.20
0.25
1990
1995
2000
2005
2010
Year

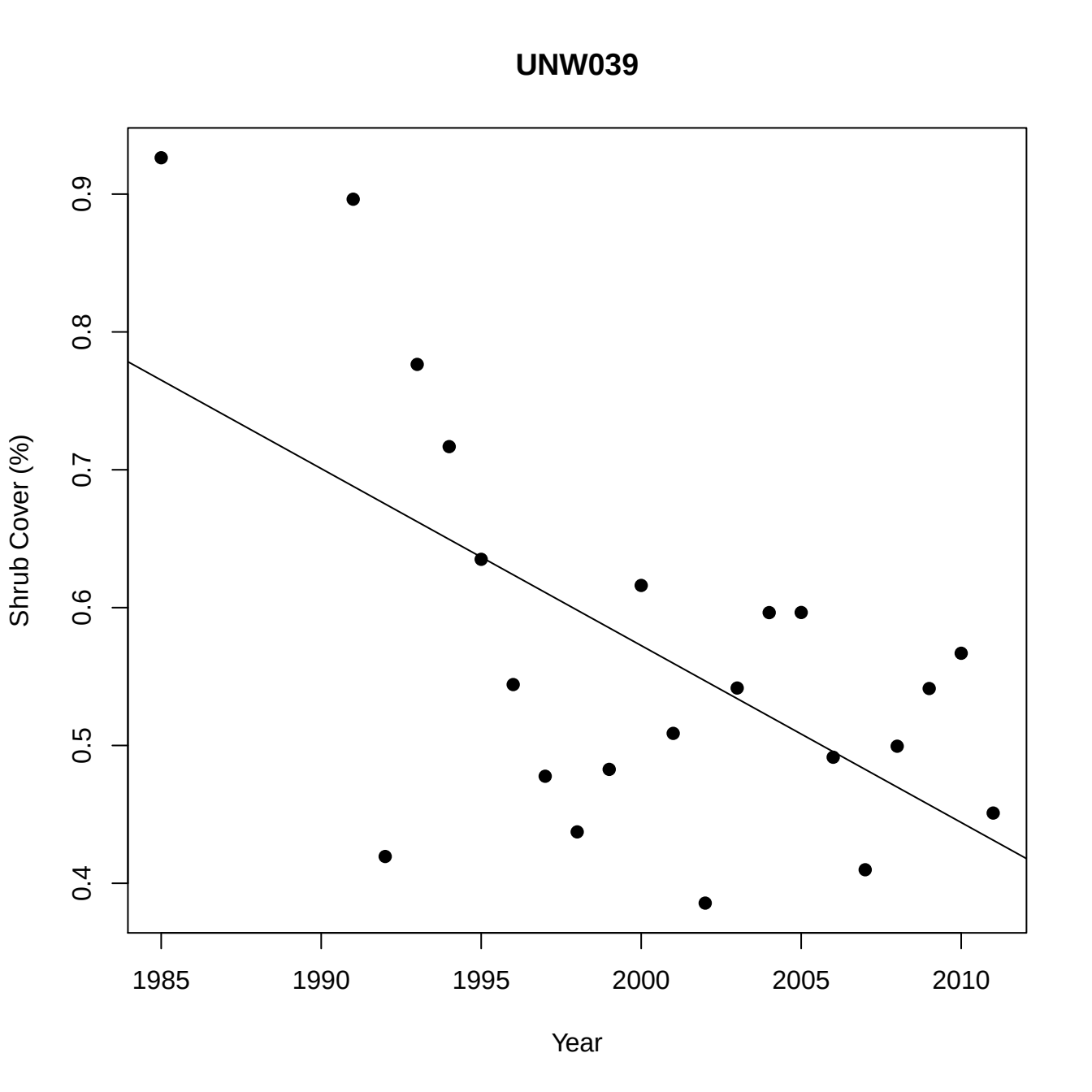

PLC136
Shrub Cover (%)
0.3
0.4
0.5
0.6
1990
1995
2000
2005
2010
Year

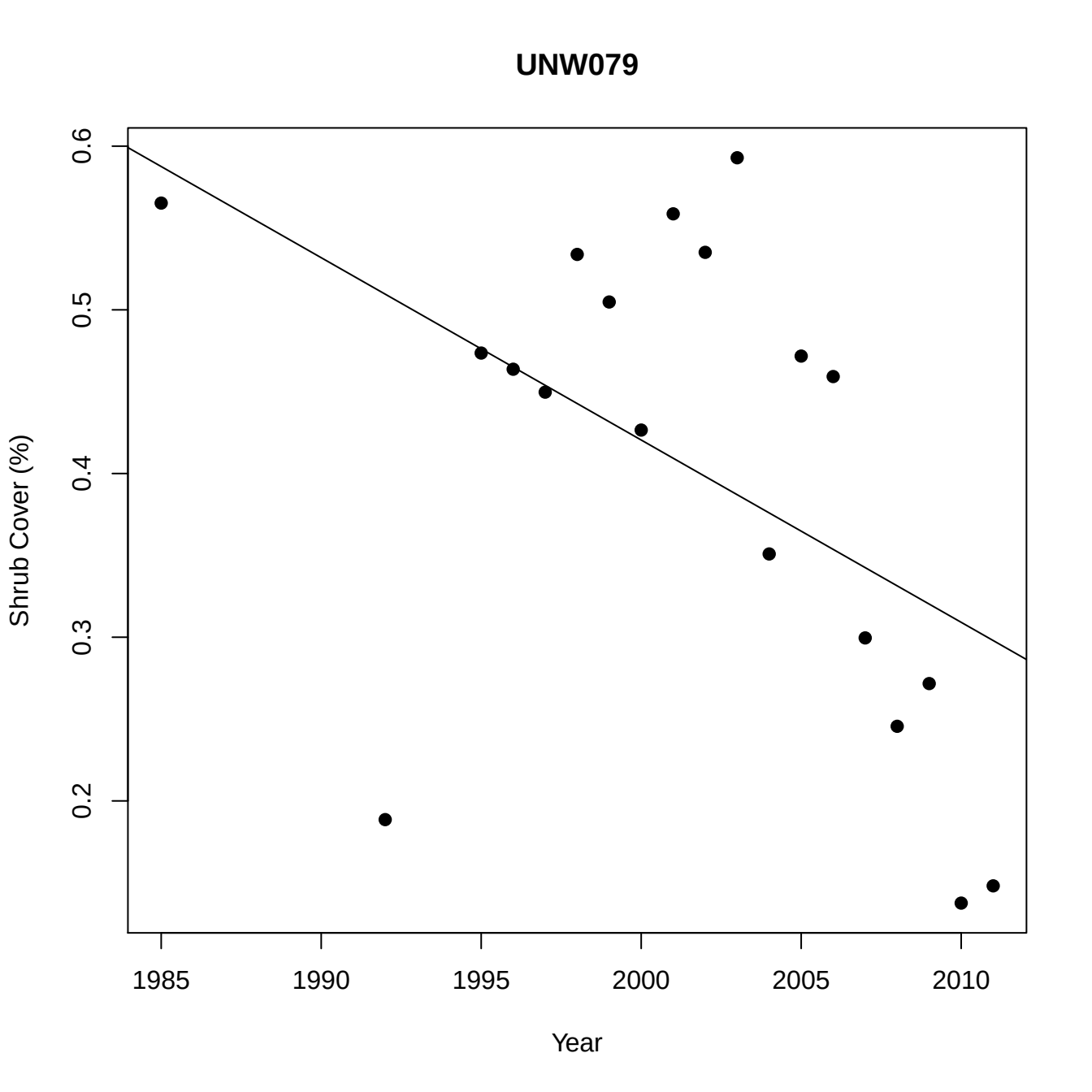

PLC223
Shrub Cover (%)
0.40
0.45
0.50
0.55
0.60
0.65
0.70
1990
1995
2000
2005
2010
Year


TIN064
Shrub Cover (%)
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1985
1990
1995
2000
2005
2010
Year


TIN068
Shrub Cover (%)
0.3
0.4
0.5
0.6
0.7
0.8
1985
1990
1995
2000
2005
2010
Year


UNW029
Shrub Cover (%)
0.2
0.3
0.4
0.5
1985
1990
1995
2000
2005
2010
Year


UNW039
Shrub Cover (%)
0.4
0.5
0.6
0.7
0.8
0.9
1985
1990
1995
2000
2005
2010
Year


UNW079
Shrub Cover (%)
0.2
0.3
0.4
0.5
0.6
1985
1990
1995
2000
2005
2010
Year