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Supplementary material

Chaparral growth ring analysis as an indicator of stand biomass development

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Additional explanation of field methods

Field plots were selected using the following criteria: 1) vegetation composed entirely of chaparral (no portion of the area classified as coastal sage scrub or coast live oak) and 2) reasonably accessible (within 100 m of a road or trail). Plot boundaries were surveyed in the field using a Trimble GeoXM handheld Global Positioning System (GPS) unit with a post-processed accuracy of 1 to 3 m. Within each plot we measured with digital calipers the diameter of all stems 0.4 cm or greater in diameter at 10 cm above the ground, and recorded the species and whether stems were live, dead, or charred.

The biomass of each plot at the year of field sampling was calculated using species-specific regression equations relating stem basal area to dry biomass. We calculated coefficients for the relationship of dry above-ground biomass (*AGB*) as a power function of basal area (*BA*) with a bias correction applied (Baskerville 1972; Sprugel 1983):

$$\boldsymbol{AGB = B_0 (BA)^{B_1} \mathrm{e}^{0.5\,s}} \quad (1)$$

where s is the residual mean square, B_0 is the proportionality coefficient, and B_1 is the scaling exponent.

We generated species-specific equations for *Adenostoma fasciculatum, Ceanothus crassifolius, Ceanothus oliganthus, Eriodictyon trichocalyx*, and *Quercus berberidifolia*. We combined the measurements from each species sampled in more than one year to create a single regression equation for each species. We also used the regression equation for *Salvia mellifera* developed by Riggan and others (1988), and a regression equation calculated using all pooled stem measurements to calculate the biomass of other species that were uncommon in the field plots. Regression models were run separately for live and dead stems. Charred stems were only occasionally found in the plots, and were not the main focus of the study, so charred biomass was roughly estimated in these areas using half the value given by the appropriate equation for dead biomass.

One shrub per species per day was selected to serve as a representative sample to estimate the dry weight of freshly cut biomass. The sampled shrub was brought to the lab where it was separated into small (< 0.5 cm), medium (0.5 cm to 2 cm) and large (>2 cm) diameter fractions. Each size fraction was weighed and subsampled to determine water content. Shrub components were dried to a constant mass in a drying oven at 100˚C. The total shrub water content was determined by applying the water content value measured for each size fraction to the total biomass of each corresponding size fraction. This value was then applied to all shrubs of that species sampled on that day.

A species-specific equation was used to calculate shrub biomass for an average of 88% (and a per-plot range of 43–100%) of the total basal area present in each plot. The stems measured in the study plots were occasionally larger than the stems sampled destructively to calculate regression equations. Across all plots, an average of 2% of stems (and a per-plot range of 0–14%) were so large as to require an extrapolation of the regression equation to estimate biomass.

References

Baskerville GL (1972) Use of logarithmic regression in the estimation of plant biomass. *Canadian Journal of Forest Research* **2**, 49–53. doi:10.1139/x72-009.

Sprugel D (1983) Correcting for bias in log-transformed allometric equations. *Ecology* **64**, 209–210. doi:10.2307/1937343.

Fig. S1. Growth rings in *Ceanothus crassifolius*.

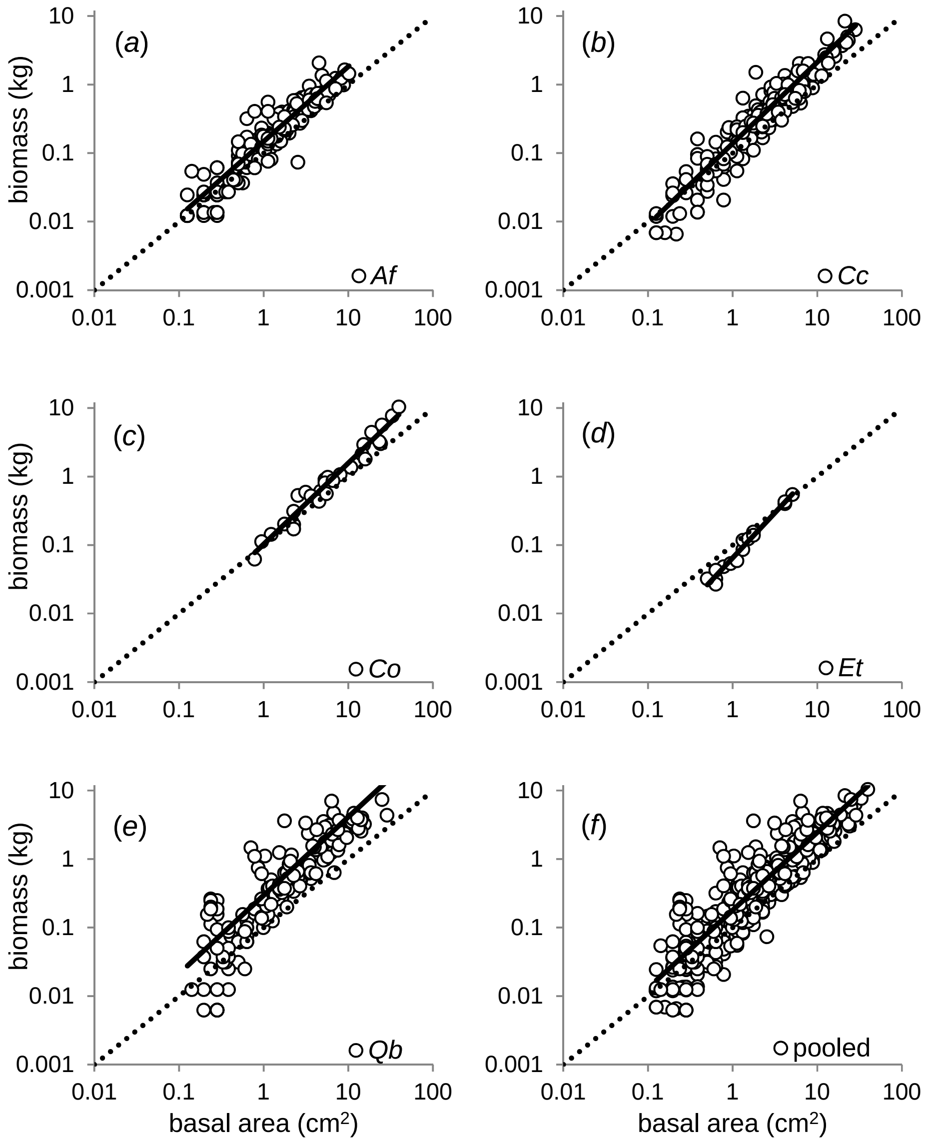

Fig. S2. Scatter plots and least squares regression lines for biomass as a function of basal area for (*a*) *Adenostoma fasciculatum,* (*b*) *Ceanothus crassifolius,* (*c*) *Ceanothus oliganthus,* (*d*) *Eriodictyon trichocalyx,* (*e*) *Quercus berberidifolia,* and (*f*) all pooled measurements, which was used for the small number of species which lacked a species-specific regression equation. The dotted line is the 10:1 line.

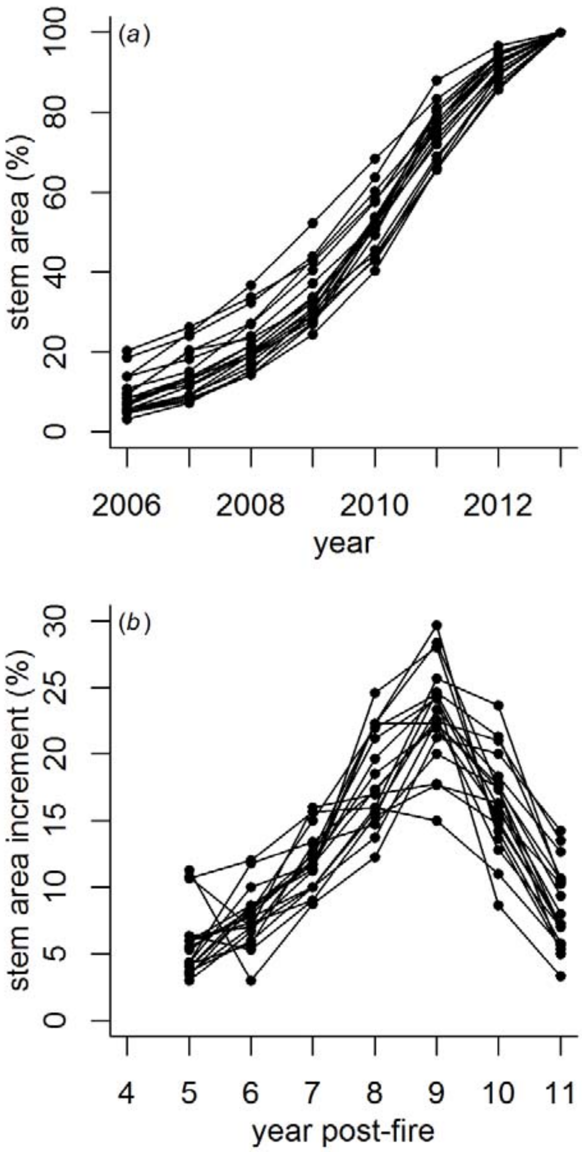

Fig. S3. (*a*) Per-plot annual percentage of total stem area, at age 11 years, for the 19 plots in which sufficient growth ring samples were collected. The calendar year represents the growth that has occurred by the fall of that year. (*b*) annual stem area increment plotted as year since last fire (occurred in 2002).

Table S1. Regression coefficients of stem biomass (kg) as a function of basal area (cm^2) for live stems

The pooled coefficients were calculated by combining measurements across all species

Live biomass						
species	max diameter (cm)	min diameter (cm)	$B_0*e^{0.5s}$	B_1	R^2	stems / shrubs
A. fasciculatum	3.6	0.4	0.148	1.093	0.89	197/13
C. crassifolius	6.0	0.4	0.138	1.188	0.91	182/62
C. oliganthus	7.1	1.0	0.103	1.185	0.96	30/16
E. trichocalyx	2.6	0.8	0.065	1.319	0.98	15/11
Q. berberidifolia	6.1	0.4	0.296	1.144	0.79	167/6
pooled	7.1	0.4	0.179	1.136	0.84	591/108

Dead biomass						
species	max diameter (cm)	min diameter (cm)	$B_0*e^{0.5s}$	B_1	R^2	stems / shrubs
A. fasciculatum	1.05	0.5	0.053	0.500	0.29	8/3
C. crassifolius	1.95	0.5	0.079	1.184	0.89	13/6
Q. berberidifolia	1.90	0.4	0.226	1.037	0.52	33/4
pooled	1.95	0.4	0.163	1.093	0.55	54/13

Table S2. Plot characteristics, including aspect, slope, coordinates, estimate of percent cover, stems per m^2, and shrubs per m^2

Plots listed in italics had insufficient stem cross section samples and were not included in biomass per year estimations

plot ID	aspect	Slope (degrees)	Latitude (N)	Longitude (W)	shrub percent cover estimate	stems per m^2	shrubs per m^2
plot 1	East	31	34.20178	-117.75822	65	2.4	1.1
plot 2	South	25	34.20128	-117.75697	75	9.4	3.6
plot 3	East	27	34.20068	-117.75827	60	12.6	3.8
plot 4	North	31	34.20061	-117.75786	95	3.4	2.8
plot 5	Southwest	28	34.20017	-117.75840	40	5.2	0.8
plot 6	West	28	34.20002	-117.75836	70	15.4	2.1
plot 7	Northeast	29	34.20106	-117.75802	70	10.8	4.1
plot 8	Southwest	26	34.19997	-117.75823	75	6.2	1.8
plot 9	South	28	34.20022	-117.75766	90	17.6	2.3
plot 10	Southwest	21	34.20008	-117.75721	85	10.0	1.9
plot 11	Northeast	21	34.20055	-117.75769	75	6.6	3.3
plot 12	East	29	34.20056	-117.75721	75	4.9	1.8
plot 13	Southwest	27	34.19717	-117.76055	60	9.6	1.3
plot 14	Northeast	29	34.19695	-117.76037	95	6.0	1.3
plot 15	East	20	34.19680	-117.76100	40	7.4	1.4
plot 16	East	22	34.19666	-117.76096	70	3.9	1.1
plot 17	South	19	34.19615	-117.75987	95	12.8	3.3
plot 18	Northeast	13	34.19681	-117.76041	92	20.2	2.6
plot 19	Northeast	33	34.19666	-117.75932	98	5.0	3.6
plot 20	Northeast	21	34.19660	-117.75943	99	6.9	2.3
plot 21	Southwest	21	34.19589	-117.75957	70	9.5	4.5
plot 22	Southwest	30	34.19526	-117.75926	90	6.6	2.8
plot 23	South	23	34.19614	-117.75864	95	6.3	3.6
plot 24	West	34	34.19700	-117.75869	99	6.6	2.9

Table S3. Biomass of total live shrub biomass (includes dead stems attached to otherwise live shrubs), entirely dead shrubs, charred stems, and totals per species

The percent of dead stem biomass relative to total biomass is presented for each species total. Plots listed in italics had insufficient stem cross section samples and were not included in biomass per year estimations. Species listed include *Ceanothus crassifolius* (*Cc*), *Adenostoma fasciculatum* (*Af*), *Salvia mellifera* (*Sm*), *Ceanothus oliganthus* (*Co*), *Eriodictyon trichocalyx* (*Et*), *Quercus berberidifolia* (*Qb*), *Eriogonum fasciculatum* (*Ef*), *Cercocarpus betuloides* (*Cb*), *Heteromeles arbutifolia* (*Ha*), *Prunus ilicifolia* (*Pi*)

	Biomass (kg m^{-2})										
plot ID	combined total live shrub	entirely dead shrubs	charred stem estimate	*Cc* total shrub biomass (% dead)	*Af* total shrub biomass (% dead)	*Sm* total shrub biomass (% dead)	*Et* total shrub biomass (% dead)	*Co* total shrub biomass (% dead)	*Qb* total shrub biomass (% dead)	other total shrub biomass (% dead)	other species
plot 1	1.1	–	–	0.9 (<1%)	–	–	–	–	–	0.1 (0%)	*Ef*
plot 2	2.3	0.1	–	1.1 (0%)	–	–	0.7 (4%)	–	–	0.3 (3%)	*Ef*
plot 3	2.0	0.5	0.1	0.7 (<1%)	0.6 (0%)	–	0.1 (3%)	–	–	–	
plot 4	1.1	0.2	0.1	0.3 (0%)	–	–	–	0.2 (0%)	–	0.4 (0%)	*Cb*
plot 5	1.0	–	–	0.6 (<1%)	–	0.4 (0%)	–	–	–	0.1 (0%)	*Ef*
plot 6	2.4	0.4	–	0.2 (0%)	0.3 (2%)	1.5 (0%)	–	–	–	–	
plot 7	1.6	0.1	–	1.1 (<1%)	0.4 (<1%)	–	–	–	–	–	
plot 8	2.5	0.2	–	1.7 (<1%)	–	0.6 (5%)	–	–	–	–	
plot 9	2.4	0.3	0.1	1.0 (0%)	–	0.1 (0%)	–	–	–	0.9 (9%)	*Ef*
plot 10	1.8	–	0.3	0.1 (3%)	1.1 (<1%)	0.5 (0%)	–	–	–	–	
plot 11	2.4	0.1	0.5	1.8 (0%)	0.3 (0%)	–	0.2 (9%)	–	–	–	
plot 12	1.7	0.3	–	0.6 (0%)	–	0.2 (0%)	–	–	–	0.5 (0%)	*Ef*
plot 13	1.7	–	0.4	0.8 (0%)	0.6 (2%)	0.2 (0%)	–	–	–	–	
plot 14	3.4	–	0.1	1.8 (0%)	–	–	–	–	–	1.5 (0%)	*Ha*
plot 15	2.3	0.1	0.4	2.2 (0%)	–	–	–	–	–	–	
plot 16	1.2	0.1	0.6	0.6 (<1%)	0.5 (1%)	–	–	–	–	–	
plot 17	3.9	0.3	0.9	2.1 (1%)	1.5 (4%)	–	–	–	–	–	
plot 18	2.9	0.2	–	2.7 (4%)	–	–	–	–	–	–	
plot 19	4.7	0.6	1.0	–	–	–	–	3 (0%)	1.1 (0%)	–	
plot 20	6.7	–	2.1	0.1 (0%)	–	–	–	2.6 (2%)	4 (10%)	–	
plot 21	2.5	0.2	–	2.3 (<1%)	–	–	0.1 (2%)	–	–	–	
plot 22	2.9	–	–	1.2 (0%)	–	0.5 (0%)	1.2 (3%)	–	–	–	
plot 23	4.4	0.6	–	–	–	–	–	3.8 (3%)	–	–	
plot 24	4.4	–	0.6	1.1 (<1%)	–	–	–	–	–	3.3 (<1%)	*Pi, Cb*
mean	2.6	0.2	0.3								
s.d.	1.4	0.2	0.5								

Table S4. Diameter of each stem cross section as measured from each calendar year

All cross sections were from the species *Ceanothus crassifolius*, with the exception of those from plot 20, which were from the species *Ceanothus oliganthus*

	diameter (cm)							
plot ID	2006	2007	2008	2009	2010	2011	2012	2013
plot 1	0.39	0.63	0.83	1.47	2.89	5.01	6.11	6.52
plot 1	0.53	0.66	1.14	1.86	3.01	4.35	5.11	5.41
plot 1	0.27	0.40	0.83	1.49	2.47	3.80	4.32	4.57
plot 1	0.46	0.74	1.39	2.19	3.73	4.77	5.90	6.46
plot 1	0.35	0.45	0.72	1.04	1.52	2.05	2.46	2.69
plot 2	0.38	0.49	0.65	1.03	1.47	2.01	2.44	2.57
plot 2	0.39	0.47	0.54	0.74	1.10	1.70	2.24	2.58
plot 2	0.31	0.45	0.56	0.83	1.17	1.64	2.01	2.26
plot 2	0.43	0.57	0.88	1.50	1.98	2.48	3.07	3.51
plot 3	0.17	0.50	0.95	1.75	2.95	4.41	5.87	6.78
plot 3	0.46	0.86	1.40	2.00	3.06	4.35	4.98	5.25
plot 3	0.21	0.37	0.55	0.82	1.13	1.62	2.06	2.28
plot 5	0.03	0.08	0.19	0.43	0.98	1.82	2.43	2.58
plot 5	0.37	0.53	0.91	1.51	2.26	3.29	3.89	4.07
plot 5	0.20	0.31	0.63	1.27	2.53	3.76	4.41	4.66
plot 6	0.09	0.37	0.54	0.94	1.66	2.98	4.31	5.31
plot 6	0.21	0.43	0.79	1.27	2.28	4.08	5.57	5.84
plot 6	0.21	0.28	0.50	0.85	1.33	1.87	2.43	2.61
plot 8	0.81	1.14	2.34	3.12	4.29	5.98	6.78	7.41
plot 8	0.59	0.69	0.83	1.12	1.56	2.09	2.40	2.54
plot 8	0.11	0.22	0.46	0.79	1.12	1.65	2.14	2.37
plot 8	1.32	1.97	3.31	5.11	6.85	8.92	9.90	10.2
plot 8	0.13	0.38	1.10	1.92	3.27	4.79	5.51	5.90
plot 9	0.37	1.19	1.43	2.06	2.75	3.91	5.23	5.88
plot 9	0.28	0.58	0.62	0.78	1.06	1.53	1.90	2.11
plot 9	0.37	0.61	0.73	1.01	1.44	2.08	2.72	3.42
plot 9	0.08	0.20	0.24	0.32	0.46	0.74	0.99	1.18
plot 11	0.04	0.20	0.58	1.25	2.39	4.39	6.21	7.03
plot 11	0.02	0.16	0.43	1.17	2.10	2.99	3.92	4.17
plot 11	1.08	2.18	5.23	8.21	12.42	17.56	20.32	22.05
plot 11	0.33	0.54	1.12	1.96	3.22	4.44	4.87	5.11

(Continued on next page)

	diameter (cm)							
plot ID	2006	2007	2008	2009	2010	2011	2012	2013
plot 12	0.21	0.32	0.52	0.82	1.34	1.99	2.38	2.75
plot 12	0.23	0.41	0.5	0.64	0.92	1.52	2.02	2.24
plot 12	0.07	0.28	0.64	1.02	1.55	2.20	2.81	3.29
plot 13	0.16	0.33	0.40	0.56	0.89	1.43	1.80	2.02
plot 13	0.14	0.28	0.37	0.53	0.76	1.16	1.59	1.81
plot 13	0.16	0.25	0.43	0.69	1.15	1.78	2.35	2.59
plot 14	0.59	1.20	2.07	2.73	4.70	6.78	8.44	9.05
plot 14	0.09	0.17	0.47	0.97	1.77	2.55	3.09	3.26
plot 14	0.14	0.30	0.61	0.94	1.54	2.13	2.61	2.86
plot 15	0.59	1.05	1.60	2.56	3.85	5.79	7.39	8.62
plot 15	0.15	0.22	0.34	0.48	0.78	1.18	1.50	1.65
plot 15	0.06	0.25	0.34	0.51	0.71	1.11	1.55	1.89
plot 15	0.19	0.55	1.23	2.02	2.76	4.23	5.71	6.59
plot 16	0.21	0.55	0.95	1.49	2.4	3.54	4.37	5.03
plot 16	0.31	0.48	0.78	1.25	1.97	2.80	3.29	3.51
plot 16	0.13	0.22	0.31	0.45	0.67	1.02	1.37	1.70
plot 16	1.19	1.66	2.73	4.13	6.35	8.36	9.32	9.59
plot 17	0.45	0.76	0.88	1.36	1.84	2.46	3.00	3.20
plot 17	0.37	1.00	1.40	2.04	2.8	3.67	4.50	4.82
plot 17	0.21	0.41	0.59	0.91	1.28	1.63	1.95	2.16
plot 17	0.28	0.76	1.17	2.16	3.04	3.83	4.29	4.56
plot 18	0.20	0.24	0.37	0.51	0.79	1.09	1.41	1.53
plot 18	0.43	0.50	0.69	0.88	1.26	1.70	2.06	2.23
plot 18	0.78	1.11	1.25	1.52	1.77	2.17	2.49	2.71
plot 20	3.49	4.58	6.22	8.26	11.55	15.03	16.23	16.75
plot 20	1.16	1.57	2.15	2.8	3.88	5.25	5.84	6.09
plot 20	1.32	1.51	2.00	3.04	4.72	7.14	7.91	8.15
plot 21	1.12	1.77	2.51	3.35	3.96	4.51	4.89	5.08
plot 21	0.05	0.27	0.44	0.7	0.96	1.17	1.34	1.44
plot 21	0.23	0.27	0.39	0.56	0.79	1.06	1.24	1.32
plot 22	0.23	0.29	0.6	1.04	2.36	3.64	4.22	4.44
plot 22	0.02	0.53	1.05	2.05	3.89	6.42	8.05	8.68
plot 22	1.04	1.44	2.54	3.96	6.31	8.42	9.42	9.77
plot 22	0.30	0.43	0.68	0.97	1.96	3.23	3.89	4.19
plot 22	0.39	0.61	1.03	2.13	4.06	6.56	7.61	8.11
plot 24	0.91	1.68	3.54	5.7	10.34	15.42	17.7	18.21
plot 24	0.36	0.64	1.53	2.46	4.01	5.75	6.77	7.30
plot 24	0.17	0.33	0.45	0.8	1.52	2.82	3.38	3.58