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This publication includes lecture notes of papers presented at the 2013 GREEN EXPO Turf and Landscape Conference. Publication of these lectures provides a readily available source of information covering a wide range of topics and includes technical and popular presentations of importance to the turfgrass industry.

This proceedings also includes research papers that contain original research findings and reviews of selected subjects in turfgrass science. These papers are presented primarily to facilitate the timely dissemination of original turfgrass research for use by the turfgrass industry.

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Dr. Ann Brooks Gould, Editor
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CULTIVATION EFFECTS ON ORGANIC MATTER, SURFACE FIRMNESS, AND TURF QUALITY OF VELVET BENTGRASS

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Interest in using velvet bentgrass (VBG; *Agrostis canina* L.) for golf course putting green turf has been renewed (Brilman and Meyer, 2000). However, compared to other putting green turf, velvet bentgrass is reputed to accumulate excessive thatch due to its dense growth habit. Although thatch accumulation causes many undesirable conditions in putting greens, the most common problem for VBG putting greens is the development of a soft or "puffy" playing surface. Some research exists on effect of cultural management practices such as topdressing and cultivation on thatch accumulation in VBG, but recent studies have been inconclusive (Boesch and Mitkowski, 2007). It would be beneficial to develop cultivation programs that slow thatch accumulation and reduce "puffiness" without excessively decreasing the quality of the turf. The objective of this research was to determine the effects of hollow tine aeration (coring) and vertical cutting (VC) on surface firmness, quality and color of VBG.

MATERIALS AND METHODS

The trial was initiated in fall 2010 on a Greenwich VBG putting green turf that exhibited surface softness in North Brunswick, NJ. The trial was mowed daily with a triplex mower bench set at 0.110 inches. Irrigation was applied only when wilt stress was imminent or to wash in fertilizer applications. Fungicides were applied as needed to avoid disease damage.

Treatment Design

The study used a 2 x 2 x 2 factorial arranged in randomized complete block design with four replications. The factors were vertical cutting, spring hollow tine coring, and fall hollow tine coring. Vertical cutting treatments were applied in the spring (Table 1) using a triplex mower equipped with scarification reels having 0.06-inch wide blades with a 1.57 inch lateral spacing set at a 0.30 inch benchmark depth, and in the summer (Table 1) using a triplex mower equipped with vertical cutting reels having 0.04-inch wide blades with a 0.40 inch lateral spacing set at a 0.15 inch benchmark depth.

All plots were topdressed with medium sand at 1 ft^3 per 1000 ft^2 after spring and summer vertical cutting treatments. Vertical cutting treatments were applied just before the entire study was topdressed with medium sand every 14 days from May to November at 0.7 to 1 ft^3 per 1000 ft^2 and incorporated with brushing. Vertical cutting treatments were not applied when air temperature was forecast to exceed 85°F on the day of treatment.

Coring was applied in fall and spring (Table 1) using a Toro ProCore with 0.5-inch wide tines with a lateral spacing of 1.6 inches and medial (forward) spacing of 2.3 inches. Sand topdressing was applied at a rate of 10 ft^3 per 1000 ft^2 to cored plots and at 1 ft^3 per 1000 ft^2 to non-cored plots after coring events.

Data Collection and Analysis

Data collection included turf quality (9 = highest rating), turf color (9 = highest rating), recovery after cultivation (9 = 100% recovery), volumetric soil water content (Field Scout TDR 300), surface hardness (1.1 lb Clegg Impact Soil Tester dropped from 12 inches), and green speed using the USGA Stimpmeter (1996) to measure the ball roll distance (BRD). Four soil cores per plot were extracted in August 2012 and 2013 (before fall coring) to assess organic matter (OM) content and mat depth. Soil samples were collected using a 1.25-inch diameter sample tube. Organic matter content was deter-

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mined by the loss on ignition (LOI) method (Nelson and Sommers, 1996). Mat depth was the average of 12 measurements per plot (3 per soil sample).

Data were subjected to analysis of variance using the General Linear Model procedure for a randomized complete block design using SAS 9.2.1 (SAS Institute Inc., Cary, NC). Main effect and interaction means were separated by Fisher's protected LSD at the 0.05 probability level. A frequency distribution of BRDs was constructed for each treatment combination to determine treatment effects. Each treatment was compared with the no vertical cutting and no coring treatment (control), which had no disruption of the playing surface. Equality tests between sample variances of BRD distributions for each treatment combination and the control were assessed using folded-form *F* statistic ($P > 0.05$). Sample means with equal variances were compared using a pooled *t*-test ($\alpha = 0.05$) and sample means with unequal variances were compared using the Satterthwaite approximation (Dowdy et al., 2004).

RESULTS AND DISCUSSION

Organic Matter and Mat Depth

Factorial analysis indicated that vertical cutting decreased mat depth in both 2012 and 2013, but did not impact surface OM accumulation and OM concentration. Mat depth was decreased by 4 and 3% in 2012 and 2013, respectively. Surface OM accumulation and OM concentration were both slightly lower in plots receiving vertical cutting, but were not statistically different from no vertical cutting.

Both fall coring and spring coring treatments impacted mat depth, surface OM accumulation, and OM concentration in 2012 and 2013 (Table 2). The main effect of fall coring decreased mat depth by 5 and 7% and spring coring decreased OM depth by 6 and 7% in 2012 and 2013, respectively. In 2012, the main effects of fall coring and spring coring decreased OM concentration to 4.16 and 4.15%, respectively, compared to 4.39% in none cored plots. By the end of 2013, the main effect of fall and spring coring was to decrease OM content to 3.98 and 3.99%, respectively, while the none cored plots maintained an OM content of 4.39%. Both coring treatments also decreased surface OM accumulation in 2012 and 2013; by August 2013, surface OM was decreased 10% by both fall and spring coring.

Of all the individual treatments, the combination of vertical cutting with fall and spring coring resulted in the greatest reduction in mat depth, surface OM accumulation, and OM concentration (Table 2). Compared to the control (no vertical cutting and no coring), the vertical cutting with fall and spring coring treatments decreased mat depth from 2.7 to 2.3 inches, OM concentration from 4.54 to 3.74%, and surface OM accumulation from 0.29 to 0.24 lb per ft^2 by August 2013 (Table 2).

Surface Firmness

Factorial analysis of Clegg impact values indicates that all three cultivation factors impacted surface firmness in all three years. In 2011 and 2012, vertical cutting increased surface firmness periodically (6 out of 22 dates); on all other dates vertical cutting was not different from none vertical cut plots (Figure 1). By 2013, vertical cutting treatments consistently increased surface firmness (9 out of 13 dates; Figure 1). These results suggest that several years of vertical cutting may be needed to consistently increase surface firmness of thatchy surfaces.

Fall coring had little effect on surface firmness in 2011, only increasing Clegg impact values on one date (22 August; Figure 2). Initially in 2012, surface firmness in fall cored plots was no different or decreased compared to no fall coring (Figure 2). By mid-July 2012, fall cored plots had increased surface firmness compared to no fall coring. This trend continued until the fall 2012 coring treatment, which significantly decreased surface firmness immediately after coring plots. By the beginning of 2013, fall cored plots had greater surface firmness values than plots not cored in the fall. Similar to 2012, fall coring increased surface firmness throughout the summer (except on 12 July) until fall coring treatments were applied. Following fall coring treatments on 28 August 2013, surface firmness was decreased compared to no fall coring treatments until 4 October 2013 (5 weeks). By 22 October 2013, there was no difference in surface firmness between fall coring and no fall coring treatments.

Similar to fall coring, spring coring had little effect on surface firmness in 2012, only impacting surface firmness on two dates (22 June and 5 July; Figure 3). On these two dates, surface firmness was decreased by spring coring compared to no spring coring. Spring coring had a greater impact on surface firmness in 2012. Following spring coring in 2012, surface firmness was decreased until 15 June 2013 (6 weeks; Figure 3). On all subsequent dates in 2012, surface firmness was increased by spring coring. Before spring coring in 2013, spring cored plots had a greater surface firmness than plots receiving no spring coring. Similar to 2012, spring coring treatments reduced surface firmness for approximately 8 weeks (18 April to 14 June 2013) and then increased surface firmness for the remainder of the season (Figure 3).

Turf Quality and Color

Visual ratings indicated that the main effect of vertical cutting typically produced a significant reduction in turf quality after treatment (Figure 4). There were only a few dates where turf quality was improved. The effect of vertical cutting on turf color (Figure 5) was more obvious than the effect on turf quality. Vertical cutting typically reduced turf color but improved color was observed, most frequently during the late spring and early summer of 2013. Vertical cutting applied late in the summer appeared to result in the greatest reduction in turf color (Figure 5). It is important to note that turf quality and color were typically at an acceptable level during the summer despite these reductions caused by vertical cutting.

There was a subtle negative effect of fall coring on turf quality that lingered into spring and early summer of all years (Figure 6). Turf quality was generally not affected by fall coring during the midsummer period. As expected, turf quality was greatly reduced after coring in early September, which required a couple of weeks for quality to return to an acceptable level. Similar to quality, turf color in the early spring was slightly lower in plots that received fall coring. During the summer, turf color of fall cored plots was largely unaffected until 2013 when color was frequently better in fall cored plots (Figure 7). Other than during spring green-up, color was typically acceptable regardless of the level of fall coring.

As expected, turf quality during the spring was dramatically reduced by spring coring (Figure 8). Once spring coring holes had healed, turf quality was either not affected or slightly lower in spring cored plots. Better turf quality in spring cored plots was rarely observed. Turf color was reduced in the spring after coring and generally was not affected by spring coring during the remainder of the season except during 2013 (Figure 9). Spring cored plots frequently had better turf color from midsummer through fall in 2013.

Ball Roll Distance

As expected, vertical cutting treatments increased BRD on 31 of the 78 measurement dates in 2011, 2012, and 2013 (data not shown). Spring coring and fall coring had less of an impact on BRD, only influencing BRD on 7 and 8 of the 78 measurement dates, respectively. Initially, spring core cultivation decreased BRD (2 dates in 2011); however as the study progressed, BRD was periodically increased by spring coring (5 dates in 2012 and 2013; data not shown). Fall coring occasionally decreased BRD in 2012 and 2013. It is unclear why BRD was decreased by fall coring on these dates since all coring holes had healed by this time. Table 3 shows the frequency distribution, means, and standard deviations for all treatment combinations. All treatment combinations produced BRD > 9.5 ft on at least 80% of measurement dates (Table 3), which is expected on high quality putting surfaces. Pooled *t*-tests indicated that none of the vertical cutting and/or coring treatment combinations decreased BRD compared to no vertical cutting and no coring. All vertical cutting treatment combinations produced slightly higher mean BRD; however those were not statistically different from the control (Table 3).

CONCLUSIONS

All three OM management techniques (vertical cutting, fall coring, and spring coring) reduced mat depth compared to the control. These results suggest that vertical cutting alone may not be effective for managing OM, especially when changes in OM are needed at depth in the profile. The surface effects of vertical cutting were effective at increasing surface firmness (Clegg impact values). Only the fall and spring coring treatments were capable of reducing both surface OM accumulation and OM concentration. Both spring and fall coring were also effective in increasing surface firmness long term; shorter term, reductions in surface firmness should be expected immediately after core cultivation. If surface firmness early in the growing season is a major concern, then core cultivation should be performed in the fall. Fall coring allows more time for the putting surface to firm during periods of limited play (late fall and winter). Although all three cultivation factors produced subtle reductions in turf quality and color during the growing/playing season, these decreases had little to no effect on the playability (ball roll) of the turf.

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Table 1. Application dates for vertical cutting (scarification and verti-cutting) and core cultivation (spring and fall) treatments from fall 2010 through fall 2013 on Greenwich velvet bentgrass turf in North Brunswick, NJ.

Treatment	2010	2011	2012	2013
Scarification	N.A.[1]	14, 21 April	27 April	18 April
Verti-cutting	N.A.	13, 31-May; 20, 30 June; 12, 30 Aug.	19, 31 May; 8 June, 16, 31 Aug.; 24 Sept.	17 June; 4, 16 Aug.
Spring coring	N.A.	21 April	6 May	18 April
Late summer coring	1 Sept.	12 Sept.	9 Sept.	28 Aug.

[1] Not applicable

Table 2. Mat depth, organic matter (OM) content, and organic matter concentration for verti-cutting and coring treatment combinations applied to Greenwich velvet bentgrass turf mowed at 0.11 inch in North Brunswick, NJ.

Treatment		Mat depth		OM concentration		Surface OM Accumulation	
Verti-cut	Coring	2012	2013	2012	2013	2012	2013
		----------inches----------		-------------%-------------		------------lb ft^2------------	
none	none	2.43	2.70	4.57	4.54	0.295	0.294
scarify	none	2.28	2.59	4.08	4.62	0.279	0.298
none	fall	2.23	2.54	4.38	4.25	0.283	0.275
scarify	fall	2.14	2.43	4.23	4.12	0.273	0.266
none	spring	2.21	2.51	4.22	4.27	0.273	0.277
scarify	spring	2.10	2.45	4.37	4.15	0.283	0.269
none	fall + spring	2.11	2.34	4.03	3.81	0.261	0.246
scarify	fall + spring	2.09	2.27	4.00	3.74	0.258	0.242
	LSD at 0.5% =	0.11	0.13	0.24	0.31	0.016	0.020

Table 3. Frequency distribution (n = 75) of ball roll distances (BRD) and a comparison of mean BRD for all combinations of verti-cutting and coring levels on Greenwich velvet bentgrass turf in North Brunswick, NJ, during 2011, 2012, and 2013.

Treatment		BRD range (ft)										
Verti-cut	Coring	< 8.5	8.5 to 9.5	9.5 to 10.5	10.5 to 11.5	11.5 to 12.5	12.5 to 13.5	> 13.5	Mean[1]	SD	Equality of variance[2]	*t*-test[3]
		%							ft		$P > F$	$P > t$
none	none	0	16	33	33	16	1	0	10.5	1.04	–	–
scarify	none	0	15	31	32	20	3	0	10.7	1.05	0.883	0.299
none	fall	3	17	33	37	9	0	0	10.3	0.95	0.446	0.198
scarify	fall	0	16	25	33	21	4	0	10.7	1.02	0.908	0.338
none	spring	1	16	32	37	12	1	0	10.5	0.96	0.501	0.993
scarify	spring	0	15	25	31	24	4	1	10.8	1.09	0.693	0.115
none	fall + spring	0	17	31	37	13	1	0	10.5	0.99	0.714	0.966
scarify	fall + spring	0	16	21	37	23	3	0	10.8	1.03	0.976	0.145

[1] Mean BRD of 8, 43, and 24 observations made in 2011, 2012, and 2013, respectively, for each treatment combination

[2] Equality test between sample variances of BRD distributions for each treatment combination and no verti-cutting and no coring assessed using the ratio of the folded-form *F* statistic. Sample variances are equal when $P > 0.05$

[3] BRD distribution for each treatment combination were compared with no verti-cutting and no coring to determine if BRD differences were observed during 2011, 2012, and 2013. A pooled *t*-test ($\alpha = 0.05$) was used to detect differences when sample variances were equal ($P > 0.05$); when unequal ($P < 0.05$), comparisons were made using the Satterthwaite approximation

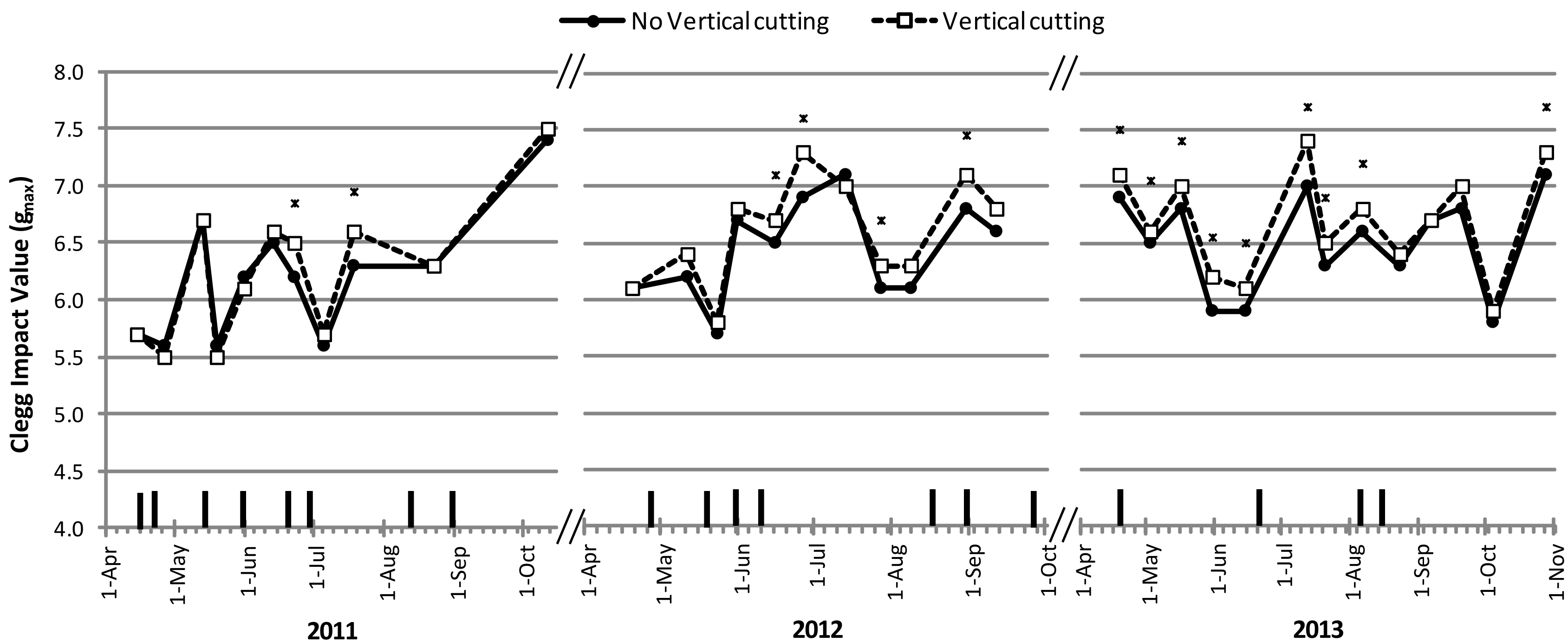

Figure 1. Clegg impact values of Greenwich velvet bentgrass turf as affected by vertical cutting treatments during 2011, 2012, and 2013. (* significant at α = 0.05.)

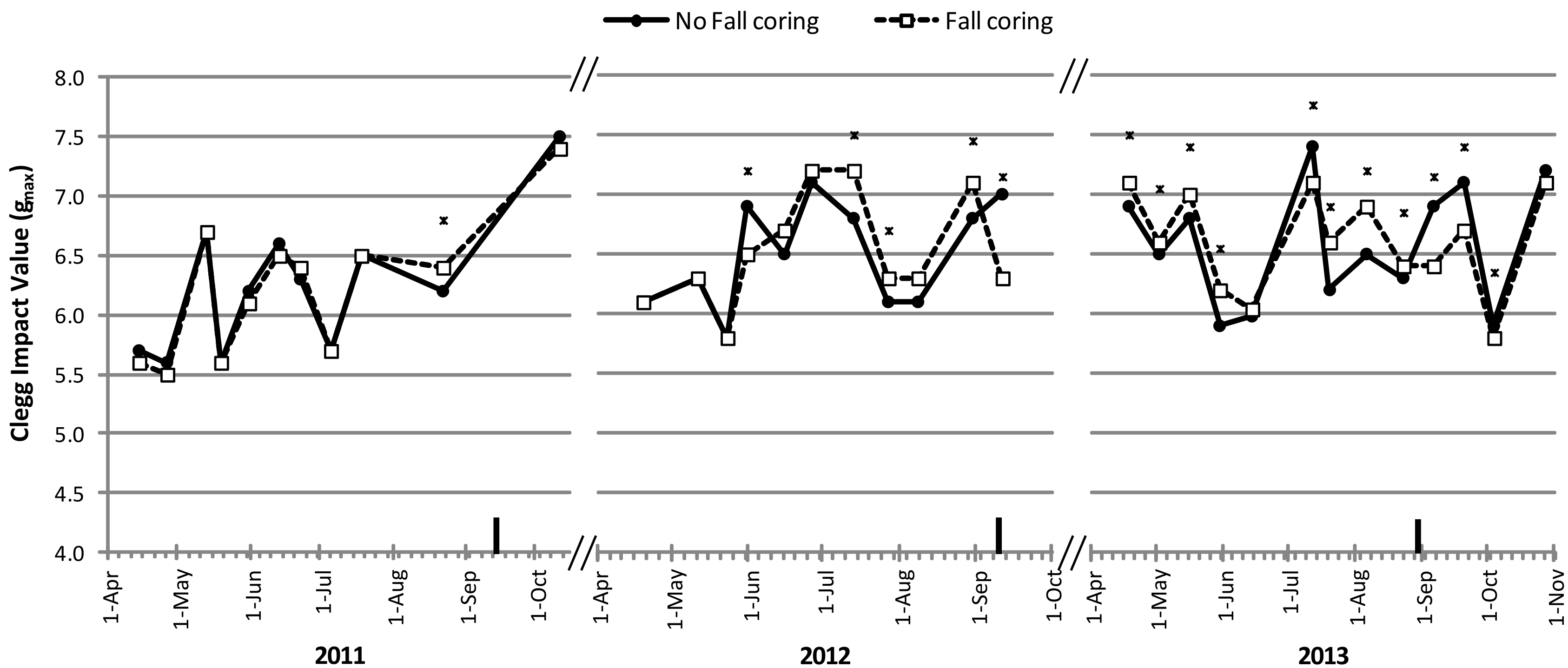

Figure 2. Clegg (0.5 kg) impact values of Greenwich velvet bentgrass turf as affected by fall coring treatments during 2011, 2012, and 2013. (Vertical bars on x-axis represent fall coring events; * significant at α = 0.05.)

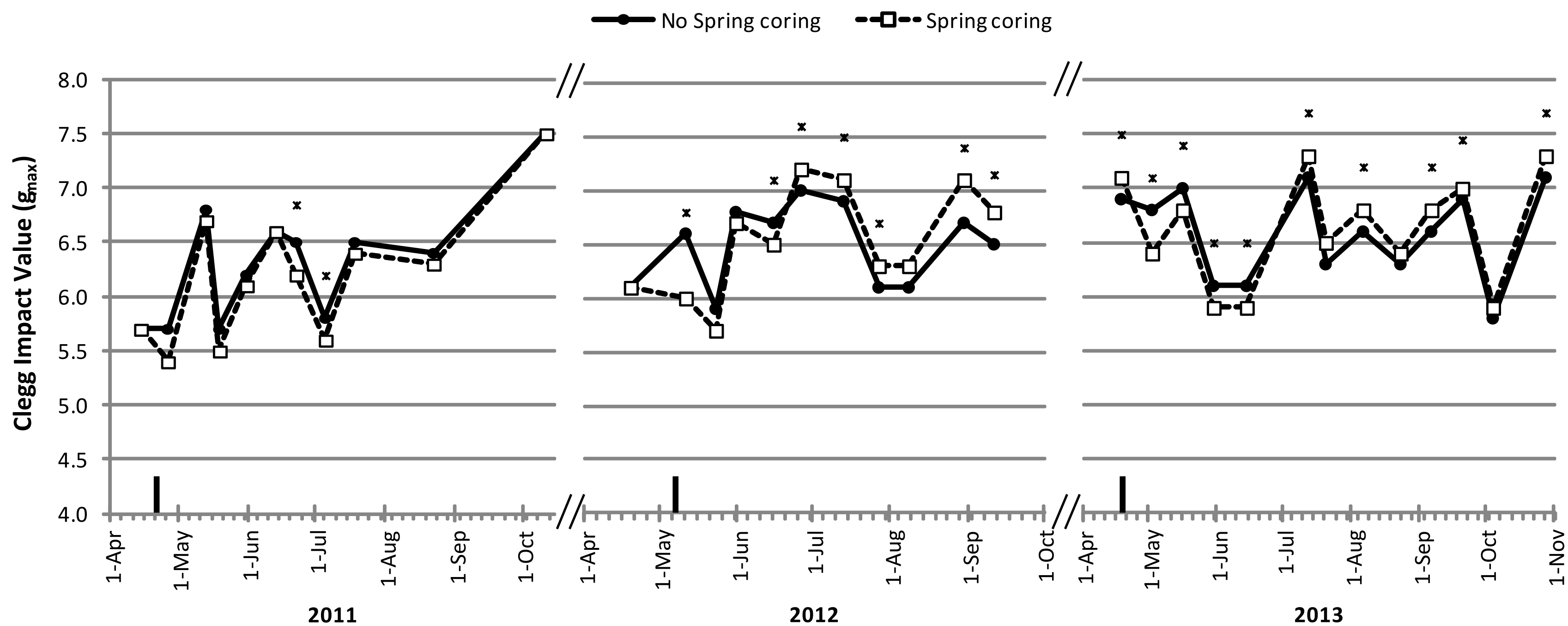

Figure 3. Clegg (0.5 kg) impact values of Greenwich velvet bentgrass turf as affected by spring coring treatments during 2011, 2012, and 2013. (Vertical bars on x-axis represent spring coring events; * significant at α = 0.05.)

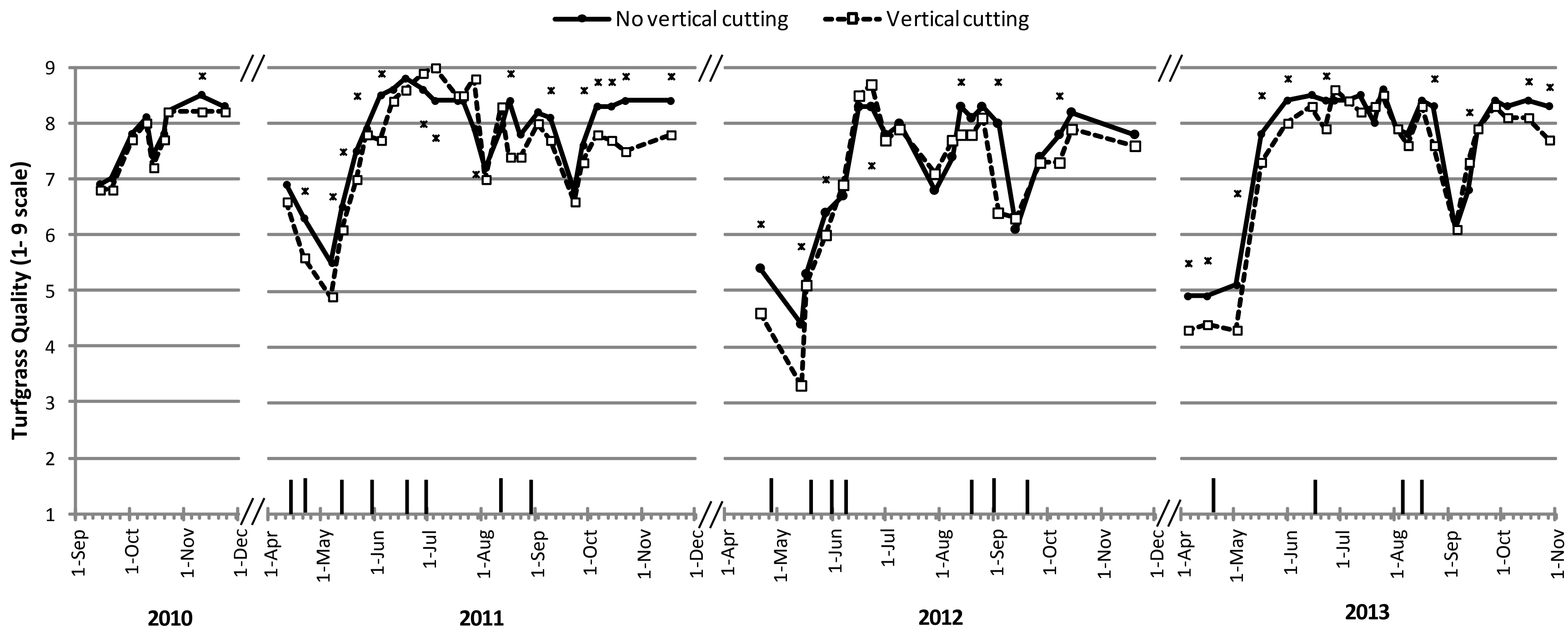

Figure 4. Quality ratings of Greenwich velvet bentgrass turf as affected by vertical cutting during 2011, 2012, and 2013. (Vertical bars on x-axis represent vertical cutting treatments; * significant at $\alpha = 0.05$.)

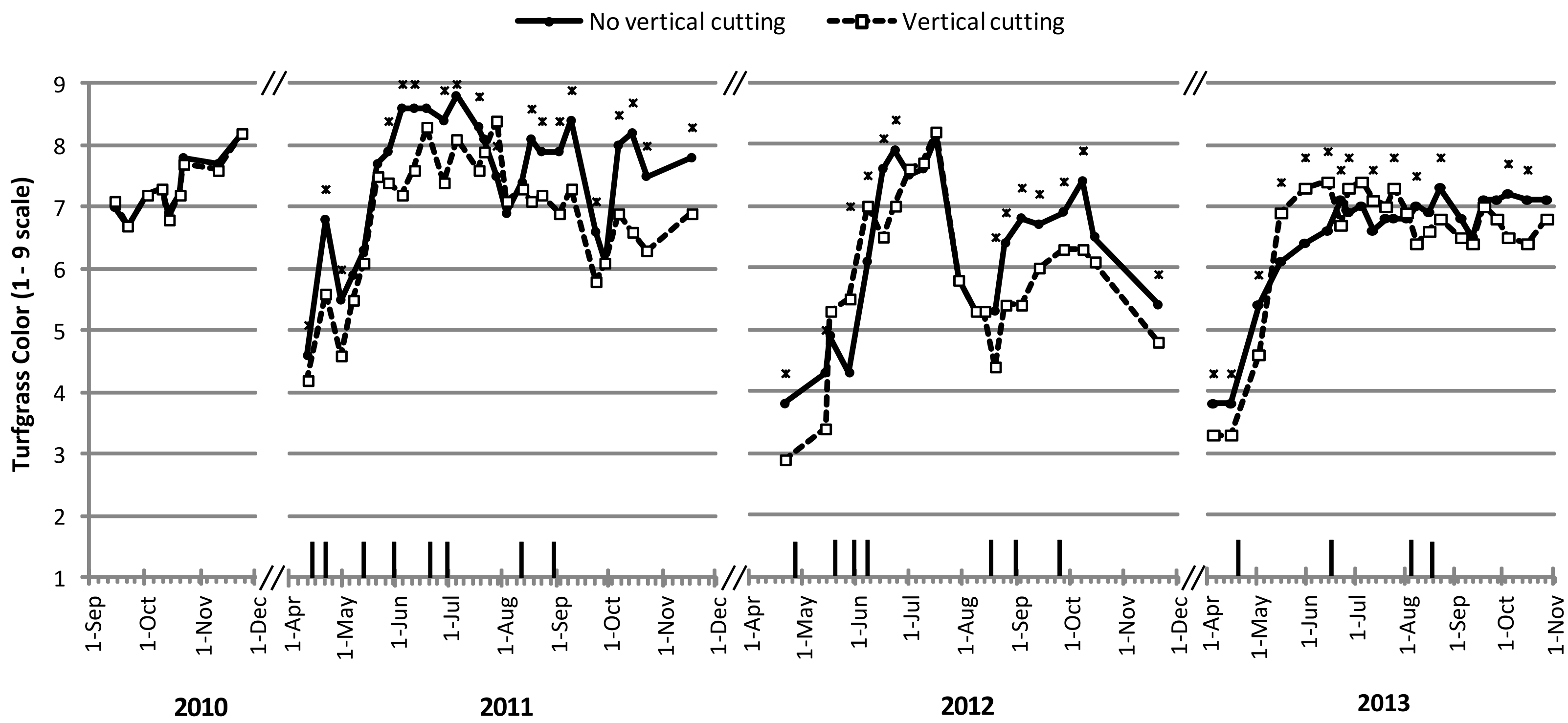

Figure 5. Color ratings of Greenwich velvet bentgrass turf as affected by vertical cutting during 2011, 2012, and 2013. (Vertical bars on x-axis represent vertical cutting treatments; * significant at α = 0.05.)

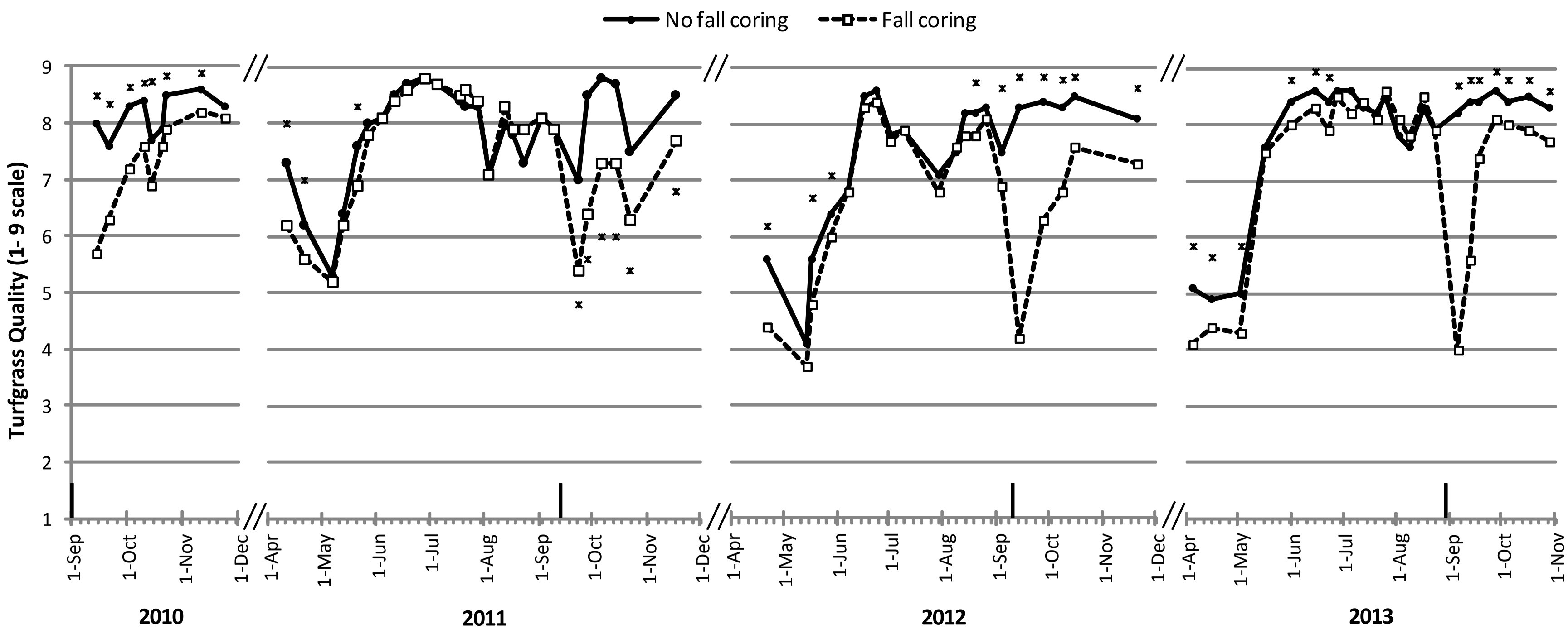

Figure 6. Quality ratings of Greenwich velvet bentgrass turf as affected by fall coring during 2011, 2012, and 2013. (Vertical bars on x-axis represent coring events; * significant at α = 0.05.)

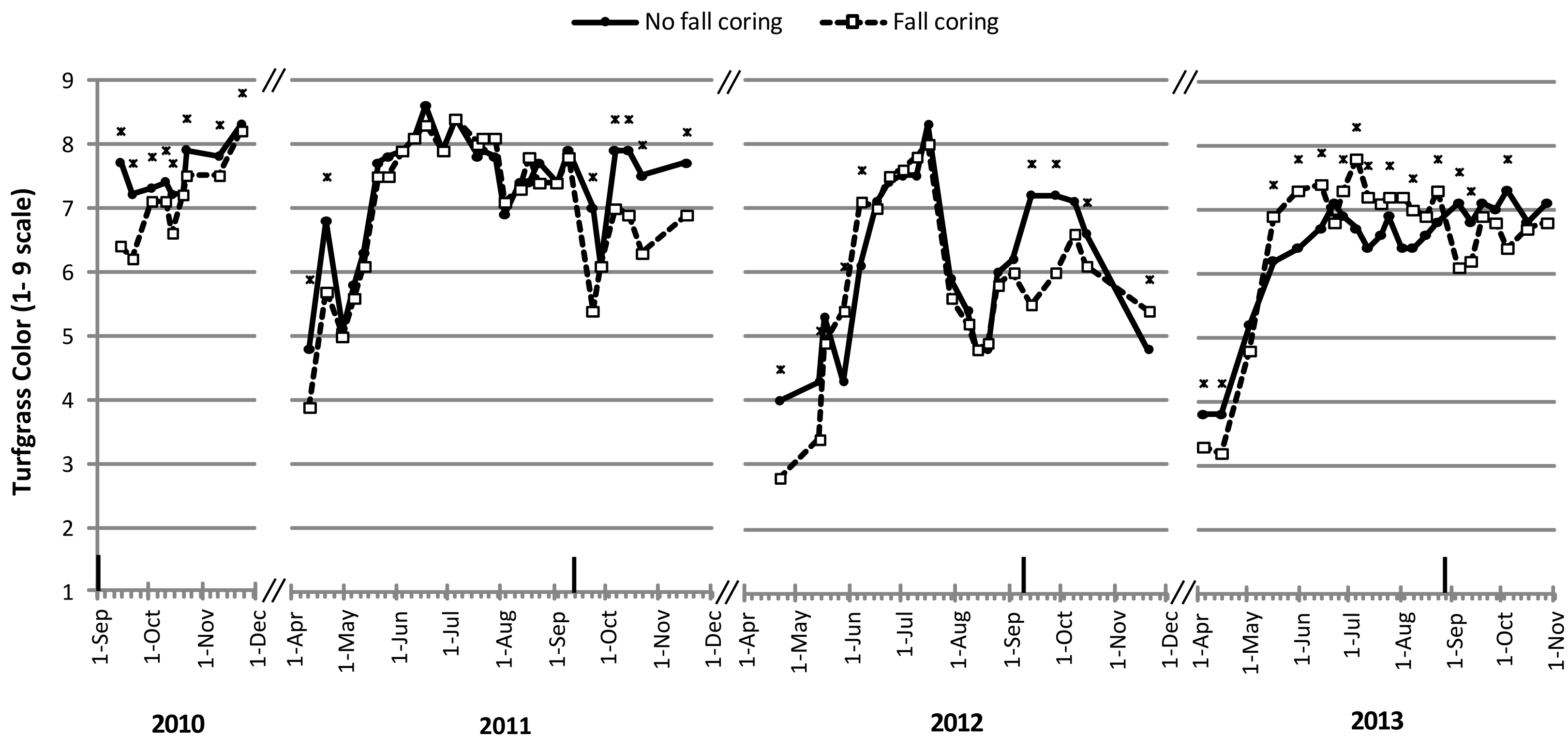

Figure 7. Color ratings of Greenwich velvet bentgrass turf as affected by fall coring during 2011, 2012, and 2013. (Vertical bars on x-axis represent coring events; * significant at α = 0.05.)

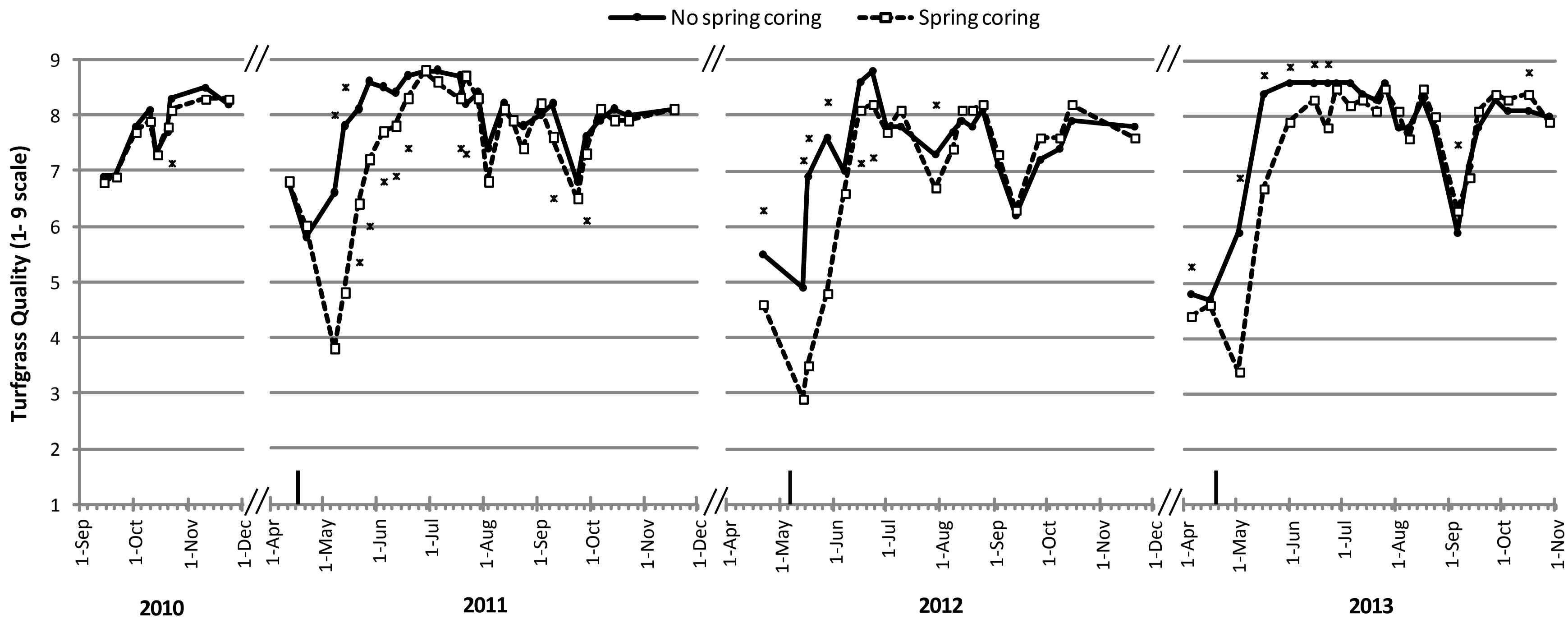

Figure 8. Quality ratings of Greenwich velvet bentgrass turf as affected by spring coring during 2011, 2012, and 2013. (Vertical bars on x-axis represent coring events; * significant at α = 0.05.)

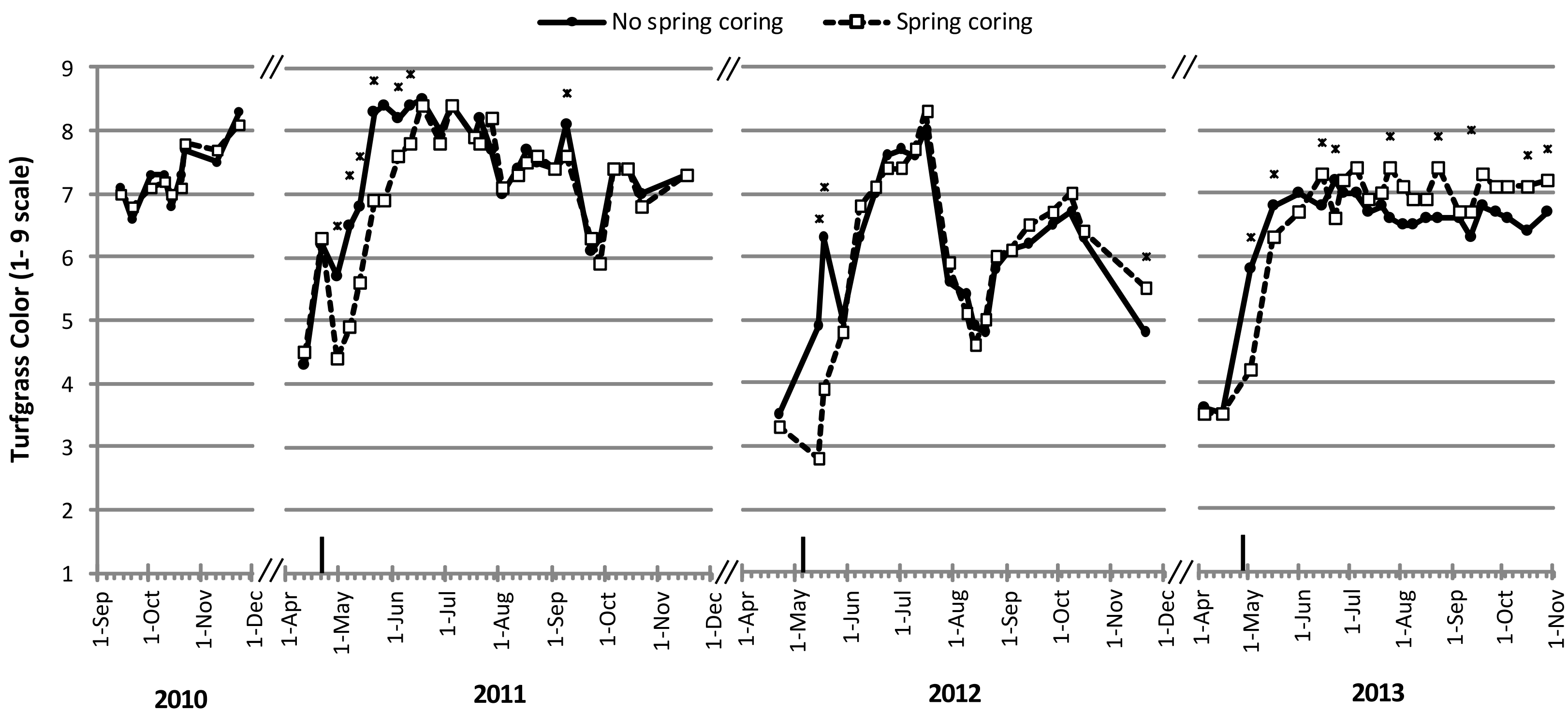

Figure 9. Color ratings of Greenwich velvet bentgrass turf as affected by spring coring during 2011, 2012, and 2013. (Vertical bars on x-axis represent coring events; * significant at $\alpha = 0.05$.)