Disturbance has lasting effects on functional traits and diversity of grassland plant communities

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Background. Localized disturbances within grasslands alter biological properties and may shift species composition. For example, rare species in established communities may become dominant in successional communities if they exhibit traits well-suited to disturbance conditions. Although the idea that plant species exhibit different trait 'strategies' is well established, it is unclear how ecological selection for specific traits may change as a function of disturbance. Further, there is little data available testing whether disturbances select for single trait-characters within communities (homogenization), or allow multiple trait-types to persist (diversification). We investigated how (a) traits and (b) functional diversity of post-disturbance gap communities compared to those in adjacent undisturbed grasslands, and (c) if altered functional diversity resulted in the homogenization or diversification of functional traits.

Methods. Here we emulate the impacts of an extreme disturbance in a native grassland site. We measured plant community composition of twelve paired 50 x 50 cm plots (24 total) in Alberta, Canada. Each pair consisted of one undisturbed plot and one which had all plants terminated two years prior. We used species abundances and a local trait database to calculate community weighted means for maximum height, specific leaf area, specific root length, leaf nitrogen percent, and root nitrogen percent. To test the impacts of disturbance on community functional traits, we calculated functional diversity measures and compared them between disturbed and undisturbed communities.

Results. Within two years, species richness and evenness in disturbed communities had recovered and was equivalent to undisturbed communities. However, disturbed and undisturbed communities had distinct community compositions, resulting in lower functional divergence in disturbed plots. Further, disturbance was linked to increases in community-weighted mean trait values for resource-acquisitive traits, such as specific leaf area, and leaf and root nitrogen.

Discussion. Disturbance had lasting effects on the functional traits and diversity of communities, despite traditional biodiversity measures such as richness and evenness recovering within two years. The trait space of gap communities shifted compared to undisturbed communities such that gap communities were dominated by traits enhancing resource uptake and growth rates. Overall, these results show that short-term disturbance fundamentally changes the functional character of early-successional communities, even if they superficially appear recovered.

1 **Disturbance has lasting effects on functional traits and diversity of grassland plant communities**

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22 **Abstract**

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24 species composition. For example, rare species in established communities may become

25   dominant in successional communities if they exhibit traits well-suited to disturbance conditions.

26   Although the idea that plant species exhibit different trait 'strategies' is well established, it is

27   unclear how ecological selection for specific traits may change as a function of disturbance.

28   Further, there is little data available testing whether disturbances select for single trait-characters

29   within communities (homogenization), or allow multiple trait-types to persist (diversification).

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31   compared to those in adjacent undisturbed grasslands, and (c) if altered functional diversity

32   resulted in the homogenization or diversification of functional traits.

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34   measured plant community composition of twelve paired 50 x 50 cm plots (24 total) in Alberta,

35   Canada. Each pair consisted of one undisturbed plot and one which had all plants terminated two

36   years prior. We used species abundances and a local trait database to calculate community

37   weighted means for maximum height, specific leaf area, specific root length, leaf nitrogen

38   percent, and root nitrogen percent. To test the impacts of disturbance on community functional

39   traits, we calculated functional diversity measures and compared them between disturbed and

40   undisturbed communities.

41   **Results.** Within two years, species richness and evenness in disturbed communities had

42   recovered and was equivalent to undisturbed communities. However, disturbed and undisturbed

43   communities had distinct community compositions, resulting in lower functional divergence in

44   disturbed plots. Further, disturbance was linked to increases in community-weighted mean trait

45   values for resource-acquisitive traits, such as specific leaf area, and leaf and root nitrogen.

46   **Discussion.** Disturbance had lasting effects on the functional traits and diversity of communities,

47   despite traditional biodiversity measures such as richness and evenness recovering within two

48   years. The trait space of gap communities shifted compared to undisturbed communities such

49   that gap communities were dominated by traits enhancing resource uptake and growth rates.

50   Overall, these results show that short-term disturbance fundamentally changes the functional

51   character of early-successional communities, even if they superficially appear recovered.

52   **Introduction**

53   Habitat heterogeneity in grasslands is maintained in part by small-scale mortality

54   inducing disturbances, such as fossorial mammal activity (Davidson & Lightfoot, 2008;

55   Davidson, Detling, & Brown, 2012), drought (Godfree et al., 2011), overgrazing (di Virgilio and

56   Morales, 2016), pathogens (Mursinoff & Tack, 2017), and even herbicide drift (Fried, Villers, &

57   Porcher, 2018). In extreme instances, disturbance can result in the total mortality of mature

58   vegetation (e.g. Cahill 2003). Though each of these disturbances have unique characteristics,

59   they all result in the localized death of established vegetation, creating vegetation "gaps"

60   (Suding, 2001). Gaps result in changes to competitive hierarchies and abiotic soil conditions and

61   competitive hierarchies (Suding & Goldberg, 2001; Suding, 2001), leading to changes in species

62   diversity and community composition.

63   Examining traits can shed light on the specific impacts of disturbance on plant

64   communities. Traits are measurable individual morphological, physiological, or phenological

65   characteristics that provide insight into life history strategies and influence plant ranges and

66   species interactions (Viole et al., 2007; Cadotte, Carscadden, & Mirotchnick, 2011). "Functional

67   traits" specifically impact growth, reproduction and survival (Viole et al., 2007). At small scales,

68   trait differences can influence local diversity patterns by determining competitive outcomes (Liu

69   et al., 2015). Traits can also provide insight as to species resource acquisition strategies by

70   indicating species location on the fast-slow plant economics spectrum, where "fast" strategies

71   prioritize resource acquisition and growth while "slow" strategies favour stress tolerance and

72   longevity (Reich et al., 2014). Measuring functional traits after a disturbance (such as those

73   which create gaps) can reveal how a community has changed in functional strategies and can be

74   used to examine the resulting community's functional diversity. Cadotte (2007) describes gap

75   species as prioritizing rapid resource uptake, whereas non-gap species take a slower, tolerance-

76   based approach. For example, specific leaf area (SLA) values are likely to be larger in post-

77   disturbance successional communities as high SLA is correlated to fast growth and low

78   competitive ability (Kunstler et al., 2016). Additionally, Loughnan and Gilbert (2017) found that

79   SLA may be involved with shifts in competitive ability as greater SLA is associated with more

80   sunlight acquisition and thus increased energy acquisition. Thus, changes in communities after

81   mortality are likely due to differences in the trait profiles of successional species.

82   It is important to note that these changes in species composition and community-level

83   traits changes may not be reflected in the total number of species in the community (i.e. species

84   richness). Disturbance may change the nature of community assembly in successional

85   communities by altering the process by which species from the regional pool are able to colonize

86   local communities (HilleRisLambers et al., 2012, Escobedo et al., 2021). Disturbance changes

87   the environmental filters which constrain species dispersal and recruitment to communities

88   (Myers et al., 2015; Brown & Cahill, 2020); in this case we would expect the resulting

89   community to contain species that possess functional traits better suited to the new set of

90   environmental filters, changing the community-level traits and functional diversity of the

91   disturbed community. Thus, if taxonomic measures like species richness or evenness remain

92   unchanged after disturbance, they may mask functional differences and result in a mirage of

93   stability when, in fact, the community has undergone great change. This emphasizes the

94 importance of studying functional traits and quantifying functional diversity to understand

95 community drivers.

96   Functional diversity is a subset of biological diversity which measures the traits present

97 in an ecosystem (Tillman, 2001). It is distinct from taxonomic diversity as it reflects the breadth

98 of the functional space occupied by species in a community (Rosenfeld, 2002; Villéger et al.,

99 2008), whereas taxonomic diversity indicates the number of species in a given community

100 separate from any measure of community function (Laliberté & Legendre, 2010). Some

101 functional diversity measures are not greatly influenced by taxonomic measures such as species

102 richness (Laliberté & Legendre, 2010) and can offer a more nuanced approach to understanding

103 community characteristics. Disturbance affects functional diversity (Parreira de Castro, Dolédec,

104 & Callisto, 2018) and can potentially result in functional homogenization, or selection for similar

105 trait-characters in species colonizing in disturbed communities (Olden et al., 2004). However,

106 resource fluxes associated with disturbance (Davis, Grime, & Thompson, 2000) may lead to trait

107 diversification within colonizing species to allow for more efficient utilization of the increased

108 resources available in disturbed communities (Chapman, Childers, & Vallino, 2016; Jentsch &

109 White, 2019). As functional diversity is associated with the provisioning of ecosystem services

110 (Díaz et al., 2007; Roscher et al., 2012; Pakeman, 2014), the homogenizing or diversifying

111 effects of disturbance on functional diversity must be better understood.

112   If species in post-disturbance gap areas are more likely to possess traits which support

113 faster resource acquisition (e.g. Cadotte, 2007; Kunstler et al., 2016), then shifts in trait

114 distributions after disturbance may alter functional diversity by changing the success of different

115 trait suites to favor "fast" traits prioritizing resource acquisition.at the local scale. However, it is

116 unclear which traits differ between plants in disturbed and undisturbed areas, and how these

117   different strategies are reflected in functional diversity. To resolve these outstanding questions,

118   we ask:

1. How do functional traits of a grassland community change after disturbance?

2. How does functional diversity change after disturbance?

3. If functional distributions do change, will it result in the homogenization or diversification of community-level traits?

123   If disturbance causes shifts in habitat filters, then we expect to observe shifts in the functional

124   trait space of the resulting community. If disturbance constrains the competitive strategies that

125   succeed in successional communities (for instance, favouring plants with resource-acquisitive

126   traits), we would expect changes in trait values (i.e. community-weighted means) and potentially

127   the homogenization of community-level traits. Alternatively, if species turnover after disturbance

128   drives shifts in community traits, we then expect to observe both taxonomic and functional trait

129   shifts, which could in turn diversify community-level traits.

130   **Methods**

131   **Study site**

132   Our study site was located in the Roy Berg Kinsella Research Ranch in Kinsella, AB,

133   Canada (53°5′ N, 111°33′ W). Data collection took place in a native grassland dominated by

134   *Hesperostipa curtiseta* (Hitchc.) Barkworth, *Festuca hallii* (Vasey) Piper and *Poa pratensis* (L.)

135   (Brown and Cahill, 2019). The site is part of the Aspen Parkland ecoregion, a savanna-type

136   habitat characterized by a mosaic of mixed-grass prairie and trembling aspen (*Populus*

137   *tremuloides* Michx.). The field site is periodically grazed by cattle with a heavy grazing event in

138   October 2019 and a light grazing event occurring in May 2020.

139   **Study design**

140   We sampled twenty-four plots (50 cm x 50 cm), arranged in twelve blocks of paired

141   plots, which were originally established in 2016 (Brown & Cahill, 2020). Each block contained

142   an undisturbed plot, where no standing vegetation was terminated, and a disturbed plot, where all

143   standing vegetation was terminated. Disturbed plots were created in May 2016, by having all

144   biomass trimmed to the soil surface and an undiluted glyphosate herbicide (Roundup©, Bayer)

145   liberally applied to the remaining stems to ensure death of the resident vegetation. This treatment

146   was maintained through August 2018 with any regenerating plant materials or newly germinated

147   recruits trimmed and painted with herbicide during the growing seasons. This treatment does not

148   represent any specific natural event, and instead is testing the extreme event of complete removal

149   of the resident vegetation, without a soil disturbance. Additionally, this treatment does not

150   remove the seed bank present at the site (Brown & Cahill, 2020) and thus does not affect new

151   plant recruitment from seed after the treatment window (see Grubb, 1977).

152   Plant community composition was measured in July 2018 by visually estimating percent

153   cover of all species present within each plot. Two years post-treatment, in July 2020, plot pairs

154   were revisited, by which time vegetation had regrown in the disturbed plots. Communities were

155   colonized through enhanced germination of seed from the existing seed bank and seed dispersal

156   from surrounding areas (Brown & Cahill 2020), Community composition was measured using

157   percent cover estimation of each species. Sedges were unable to be identified to species and were

158   recorded as "*Carex* spp.".

159   *Plant traits*

160   Disturbance can alter abiotic conditions (Suding & Goldberg 2001); however, here we

161   focus on its impacts on vegetative traits. Plant trait data came from a database developed

162   principally at this field site (Cahill, 2020), thus representing local trait data. Details of trait

163   measures are found in Cahill (2020), but largely follow the methods outlined in Cornelissen et al.

164   (2003) and Pérez-Harguindeguy et al. (2013). Here we focused on five traits which encompass

165   aspects of plant structure and above- and belowground resource acquisition: maximum height,

166   specific leaf area (SLA), specific root length (SRL), leaf nitrogen percentage (N %), and root N

167   %. See Cahill (2020) for trait definitions. These traits were chosen to provide a holistic scope of

168   above and below ground functional strategies with reference to trait groups described by Cadotte

169   (2017). Site-specific trait data was available in the database for all species except for *Cirsium*

170   *vulgare* (Savi) Tenore, *Collomia linearis* Nuttall, *Gentianella amarella* (Linnaeus) Börner,

171   *Sonchus arvensis* Linnaeus, and two unidentified forbs. Trait data was obtained for species that

172   represent at least 93% of total composition, which exceeds the 80% threshold standard for trait

173   studies (Pakeman & Quested 2007).

174   *Trait profiles and functional diversity*

175   To characterize communities by their traits, we first calculated community weighted

176   means (CWMs) for five traits: SLA, maximum height, leaf N %, root N %, and SRL. CWMs are

177   the average value of a given trait in a community weighted by the abundance of all species

178   possessing said trait (Lavorel et al., 2008), and are useful for understanding community

179   properties and dynamics, as well as quantifying community change (Garnier et al., 2004, 2007;

180   Louault et al., 2005). CWMs were calculated at the species-level. While disturbance is likely to

181   result in intraspecific variability in functional traits, here we focus on species-level values as a

182   first-level test to detect if disturbance does result in persistent change to community functional

183   traits. We encourage future studies to collect trait data from individual plants across species to

184   quantify how intraspecific trait variation changes with disturbance regimes. Outlier trait values

185   (values more than three standard deviations away from the species' mean) were removed prior to

186   calculating CWM. We then quantified the functional diversity of communities using functional

187   richness (FRic), functional evenness (FEve), functional divergence (FDiv), and Rao's quadratic

188   entropy (Q) (Villéger, Mason, & Mouillot, 2008; Mouchet et al., 2010; Table 1). These metrics

189   allow us to characterize the volume (via FRic), evenness (via FEve), and spread (via FDiv and

190   Q) of the communities' functional traits in multidimensional space. By using these multivariate

191   descriptors of communities, we are able to compare communities' character before and after

192   disturbance, as well as to determine if community traits become more or less homogenous as a

193   result of disturbance. We used package vegan (Oksanen et al., 2017) in program R (v 4.0.0; R

194   Core Team, 2020) to compute species richness and evenness, using methods from Oksanen

195   (2020). We used package FD (Laliberté, Legendre, & Shipley, 2014) to compute CWMs. We

196   also computed FRic, FDiv, FEve, and Rao's Q using package FD.

197   **Statistical analysis**

198   To determine if community traits differed between control and disturbed treatments after

199   recovery, we used five separate linear mixed models (LMMs). The CWM's for SLA, height, leaf

200   N %, root N %, and SRL were used as response variables, plot type (disturbed or undisturbed)

201   was a fixed effect and block (i.e., disturbed and undisturbed plot location) was a random effect.

202   "Block" was included as a random effect in models to account for spatial autocorrelation in

203   community data as disturbed and undisturbed plots were adjacent. All LMMs were run using an

204   underlying normal distribution with the lme4 (Bates et al., 2015) and lmerTest (Kuznetsova,

205   Brockhoff, & Christensen, 2017) packages. We also used four separate LMMs to quantify how

206   functional diversity measures, namely FRic, FDiv, FEve, and Rao's Q, differed between

207   disturbance types. FRic, FDiv, FEve, and Roa's Q were used as response variables, block was

208   included as a random effect and plot type (disturbed or undisturbed) was a fixed effect in all

209 models. Functional richness was log-transformed to fit assumptions of normality. To determine

210 whether disturbed and undisturbed communities had different community compositions, we

211 conducted a permutational multivariate analysis of variance (PERMANOVA), with plot as a

212 strata, using packages vegan and RVAideMemoire (Hervé, 2021).

213 **Results**

214   Between 2018 and 2020, total species richness in undisturbed plots decreased from 55 to

215 52 while average species richness in disturbed plots increased from 0 in 2018 to 53 in 2020

216 (Table S1). Six species were found only in disturbed communities (*Androsace septentrionalis*,

217 *Cirsium arvense*, *Mulgedium pulchellum*, *Thalictrum venulosum*, an unidentified *Brassicaceae*

218 plant, and an unidentified herbaceous dicot; Table S1). *Androsace septentrionalis*, *Cirsium*

219 *arvense*, and *Mulgedium pulchellum* are commonly found in disturbed areas (Tannas, 2004). In

220 particular, *Cirsium arvense* is associated high rates of reproduction and dispersal. 15 species

221 were found only in undisturbed communities (Table S1). These species, except *Fallopia*

222 *convolvulus*, are all native to Alberta (Desmet & Brouilet, 2013).

223   Despite persistent effects on local diversity, and although disturbed plots began with zero

224 species present in 2018, within two years there was no significant difference between plot-level

225 (alpha) richness and evenness between disturbed and undisturbed plots (richness = 17, evenness

226 = 0.82; Fig.1). However, underlying this similarity are differences in species composition (R^2 =

227 0.24, F = 7.06, p = 0.001; Fig. 2), with one third of plant species unique to either treatment type

228 (Fig. 1, Table S1). Gap communities were segregated from undisturbed communities in

229 multivariate space, with the exception of one disturbed/undisturbed pair (pair #12) (Fig. 2).

230   Community weighted means of SLA, leaf N %, and root N % differed between disturbed

231 and undisturbed plots, with disturbed plots typically having trait values more consistent with the

232 'fast' end of the leaf economics spectrum. Specifically, disturbed plots had significantly larger

233 CWM for SLA, leaf %N, root %N, and there was a trend towards larger root SRL (Fig.3; Table

234 2). There was no difference in CWM of maximum height, indicating a more rapid recovery to

235 overall physiognomy relative to other functional characteristics of the communities.

236 Gap communities were functionally distinct from undisturbed communities after two

237 years of recovery. Undisturbed communities showed higher FDiv values (FDiv = 0.08± 0.02, p =

238 0.0020; Fig.4). FEve (FEve = 0.07± 0.02, p = 0.0129; Fig.4), FRic (difference = 1.07± 1.16, p =

239 0.376; Fig.4), and Rao's Q (difference = 0.004± 0.002, p = 0.0733; Fig.4) were not significantly

240 different among the two treatments (Table 3).

241 **Discussion**

242 Although local communities recovered in species richness after only two years, there

243 were a number of legacies of disturbance found in functional traits. There are persistent effects of

244 disturbance on local diversity, suggesting successional communities are shaped by a combination

245 of local dispersal and niche conditions. However, given competition can be reduced by

246 disturbance (Wilson & Tilman, 1993), dispersal most likely limits recruitment in gap

247 communities. At the same time, at the plot level we find there is great stability in species

248 richness and evenness, suggesting the local structure of communities in this system is highly

249 stable but the species who fill each "role" are variable. Thus, the functional differences we

250 observe are not due to fundamental changes in the dominance structure (i.e. evenness) of

251 successional communities, but rather due to species filtering.

252 **Traits after disturbance**

253 Consistent with *a priori* expectations, we show disturbance leads to functional shifts

254 favouring species with higher SLA, leaf N %, and root N %, which are important for the rapid

255 acquisition of resources. SLA and leaf nitrogen content are widely viewed as indicative of a fast-

256 growing, rapid nutrient acquisition strategy (Wright et al., 2004; Liu et al., 2017). Greater leaf

257 nitrogen content works in concert with high SLA to increase energy exploitation through

258 improved photosynthetic capacity, as high leaf N content is necessary for photosynthetic protein

259 functioning (Wright et al., 2004). High root N is also indicative of quick resource acquisition as

260 it is related to high root respiration, high foraging ability, and low root longevity (Craine et al.,

261 2002; Reich, 2014; Roumet et al., 2016; McCormack et al., 2017). SRL, while higher in gap

262 communities, was not significantly different between plot types. Typically SRL indicates

263 potential resource uptake per root mass investment (Reich, 2014), and high SRL is associated

264 with quick growth, high foraging capacity, and lower root longevity (Comas & Eissenstat, 2004;

265 Roumet et al., 2016); as such, that gap communities did not show significantly higher SRL is

266 contrary to our expectations. Overall, the higher levels of SLA, leaf N %, and root N % among

267 the disturbed plots signal post-disturbance conditions permit the success of quick-growing plants

268 that can quickly access resources. Thus, it is likely that the spatial variability of disturbances in

269 this system are an important means to create functional variation across the landscape.

270 Height variation in grasslands is a significant predictor of species richness and

271 community productivity (Brown & Cahill, 2019), yet we found that maximum height recovers

272 quickly (within two years) after disturbance and is not significantly different among successional

273 and undisturbed communities. This is surprising as greater height is thought to be indicative of

274 greater competitive ability (Givnish, 1995; Cornelissen et al., 2003; Falster and Westoby, 2003).

275 **Functional diversity after disturbance**

276 Disturbance causes a number of changes to functional diversity, with functional diversity

277 typically increasing in gap communities (Purschke et al., 2013; Eler et al., 2018). However, we

278   observed that disturbance either decreased or did not affect functional diversity measures. There

279   was no difference in FRic values between the disturbed and undisturbed plots, indicating both

280   treatments filled the same amount of functional niche space (Schleuter et al., 2010). Similarly,

281   FEve did not differ between treatments, denoting that species abundances and/or the functional

282   distances between species were equally even in disturbed and undisturbed plots. However, FDiv

283   values were significantly higher in undisturbed communities. Lower FDiv values in the disturbed

284   plots signify that the most abundant species in disturbed plots had more homogenous trait ranges.

285   Thus, while disturbance does not affect the breadth or evenness of community functional traits, it

286   does lower FDiv, promoting homogenization of functional diversity.

287   **Conclusions**

288   Overall, we found while traditional metrics of community composition such as species

289   richness and evenness recovered within two years of disturbance, there were persistent impacts

290   of disturbance on community-level traits and functional diversity. SLA, leaf N %, and root N %

291   values were significantly larger in the disturbed condition, supporting the conclusion that species

292   in gap areas are more likely to possess traits that support faster resource acquisition. The

293   prevalence of individuals possessing these "fast" traits was reflected in distinct differences in

294   community membership among undisturbed and gap communities. Disturbance also impacted

295   functional diversity by promoting homogenization of community's functional traits. In all, this

296   work suggests functional trait shifts from small disturbances are a critical mechanism for

297   maintaining spatial heterogeneity in grassland systems, even as species richness and evenness

298   recover.

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304

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Functional diversity metric definitions.

Functional diversity metric definitions	
Functional diversity (FD)	The functional space occupied by species, where axes are functional features (Rosenfeld, 2009; Villeger et al. 2008). The functional differences between a group of species (Tillman, 2001)
Functional richness (FRic)	The breadth of functional space filled by a communities (Villeger et al. 2008)
Functional evenness (FEve)	The evenness of the distribution of abundances and functional features of species (Villeger et al. 2008)
Functional divergence (FDiv)	The average distance of species abundances from the centre of functional space (Mouchet et al. 2010)
Rao's quadratic entropy (Q)	The average functional distance between two randomly selected species in a group (Mouchet et al. 2010).

Results of the linear mixed models (LMM) for traits.

Community weighted means for specific leaf area (SLA), height, shoot percent nitrogen (shoot N %), root percent nitrogen (root N %), and specific root length (SRL) were used as response variables in separate models. Plot pair (i.e., disturbed and undisturbed plot location) was a random effect and plot type (disturbed or undisturbed) was used as the fixed effect. SE stands for standard error and df denotes degrees of freedom. Bold type indicates significant results.

	Disturbed plot mean ± SE	Undisturbed plot mean ± SE	df	*p*-value
Maximum height (cm)	35.78 (± 1.05)	36.30 (± 1.16)	11	0.66
Specific leaf area (cm^2/g)	139.96 (± 2.99)	119.34 (± 2.99)	11	**2.64 x 10^{-5}**
Specific root length (cm/g)	5612.82 (± 448.19)	4550.30 (± 570.50)	11	0.09
Leaf nitrogen (%)	1.92 (± 0.04)	1.74 (± 0.06)	11	**0.01**
Root nitrogen (%)	1.05 (± 0.03)	0.95 (± 0.04)	11	**0.02**

Results of the linear mixed models (LMM) for functional diversity.

Functional richness (FRic), functional divergence (FDiv), functional evenness (FEve), and Rao's Q were used as response variables in separate models. Plot pair (i.e., disturbed and undisturbed plot location) was a random effect and plot type (disturbed or undisturbed) was a fixed effect. SE stands for standard error and df denotes degrees of freedom. Bold type indicates significant results.

	Disturbed plot mean ± SE	Undisturbed plot mean ± SE	df	p-value
FRic (log transformed)	-39.96 (± 0.92)	-38.75 (± 1.22)	11	0.345
FEve	0.66 (± 0.02)	0.69 (± 0.02)	11	0.218
FDiv	0.73 (± 0.02)	0.81 (± 0.02)	11	**0.003**
Rao's Q	0.02 (± 0.001)	0.02 (± 0.002)	11	0.078

Figure 1

Average species evenness and richness of disturbed and undisturbed plots in 2018 and 2020.

In disturbed plots, all biomass was trimmed to the soil surface and a glyphosate herbicide (Roundup©) applied to the remaining stems to ensure death of the resident vegetation from 2016 - 2018. Plots were allowed to regenerate from 2018 - 2020. Undisturbed plots had no standing vegetation removed. Species evenness and richness was recorded in the summer of 2020. Error bars represent standard error.
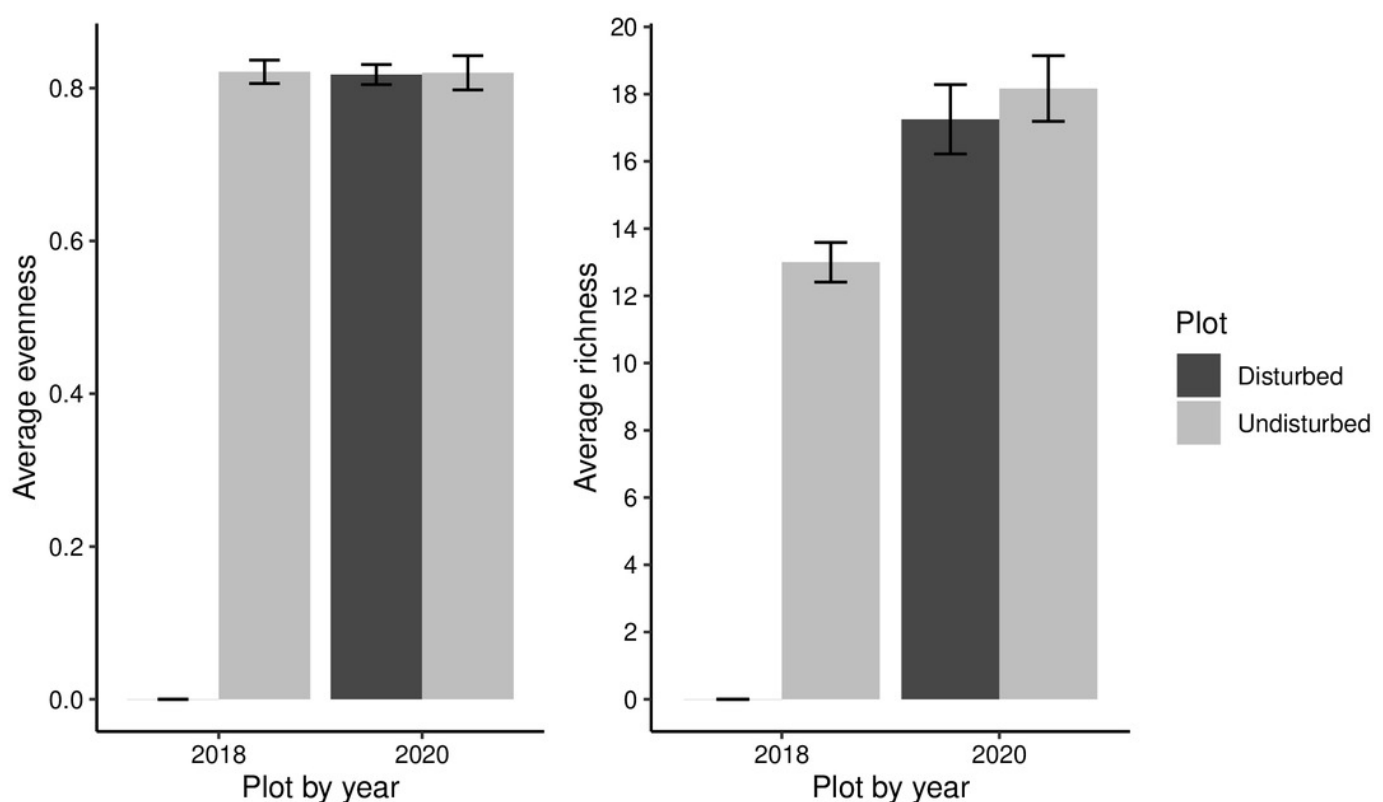
Figure 2

Metric multidimensional scaling (MDS) of disturbed and undisturbed community composition.

Data points denote 2020 plant community composition in disturbed and undisturbed plots. In disturbed plots, all biomass was trimmed to the soil surface and a glyphosate herbicide (Roundup©) applied to the remaining stems to ensure death of the resident vegetation from 2016 - 2018. Plots were allowed to regenerate from 2018 - 2020. Undisturbed plots had no standing vegetation removed. Community composition was assessed in the summer of 2020.
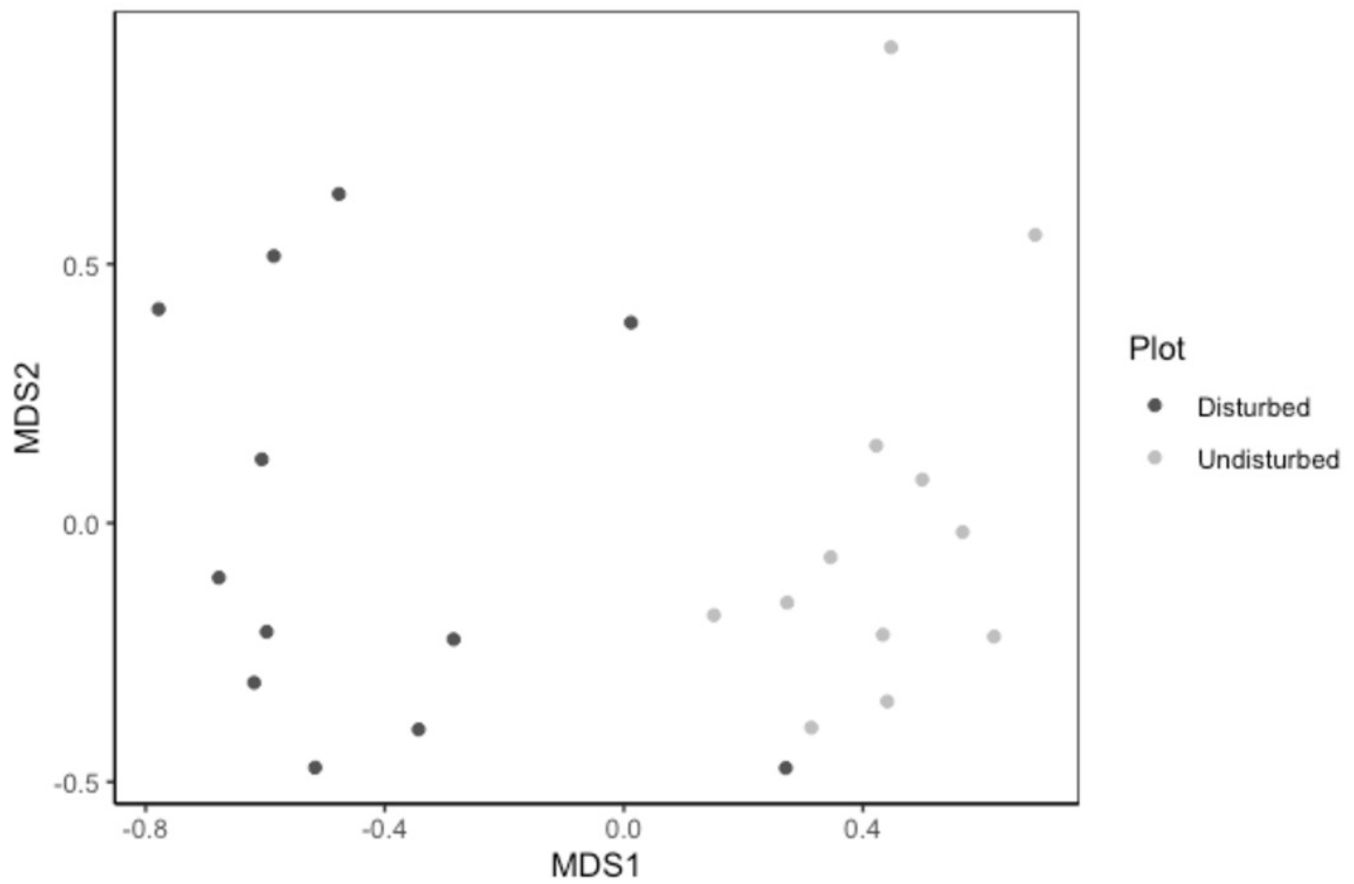
Figure 3

Mean trait values in 2020 disturbed and undisturbed communities.

Comparisons of specific root length, maximum height, specific leaf area, root nitrogen, and leaf nitrogen between disturbed and undisturbed communities. Error bars represent standard error. Associated statistics are found in Table 2.
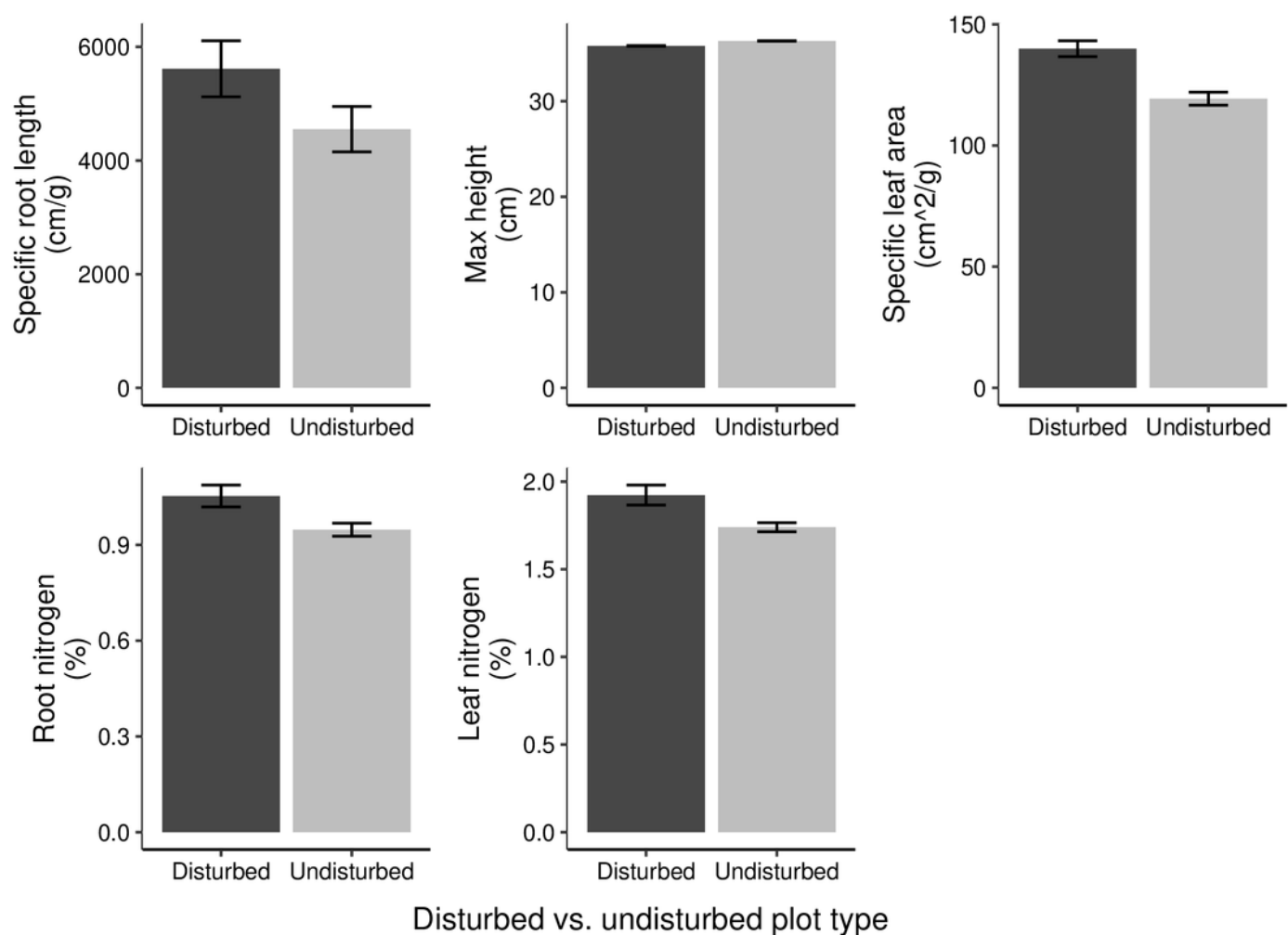
Figure 4

Estimates of functional diversity values in 2020 disturbed and undisturbed communities.

Comparisons of functional richness, functional evenness, functional divergence, and Rao's quadratic entropy between disturbed and undisturbed communities. Functional richness was log-transformed to meet the assumption of normality and was multiplied by negative one. Error bars represent standard error. Associated statistics are found in Table 3.