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PRACTICAL ARTICLE

Success of active restoration in grasslands: a case study of birds in southern Brazil

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Grasslands in southeastern South America have been extensively converted to various land uses such as agriculture, threatening regional biodiversity. Active restoration has been viewed as a management alternative for recovery of degraded areas worldwide, although most studies are conducted in forests and none has evaluated the effect of active restoration of grasslands in southeastern South America. From 2015 through 2017 we monitored a federally owned tract of grassland from the beginning of the active-restoration process. We compared the bird community in this active-restoration area (AR) with a reference area (NG) in Pampa grasslands in southern Brazil. We sampled birds by point counts and surveyed vegetation structure in plots. Over the 3 years of active restoration, bird species richness and abundance were higher in AR (30 species, 171 individuals) than NG (22 species, 154 individuals). The species composition also differed between the two habitats. Grassland bird species were present in both AR and NG. The vegetation structure differed between AR and NG in five attributes: height, short and tall grasses, herbs, and shrubs. Since it has been found that active restoration is useful in promoting species diversity, we encourage studies of the use of long-term restoration efforts. Our study, even on a local scale, showed a rapid recovery of the bird community in the active-restoration compared to native grassland, and suggests the potential for recovery of the degraded grasslands of the Brazilian Pampa biome.

Key words: agriculture, conservation, grassland birds, land use, Pampa grasslands, recovery

Implications for Practice

- Active-restoration areas can adequately support bird species associated with grasslands.
- Bird communities of grasslands degraded by agriculture can recover rapidly (3 years) after active restoration.
- Active restoration can be used to manage the recovery of vegetation structure and bird communities in degraded grasslands in southern Brazil.

Introduction

Land use is the major driver of biodiversity change, and grasslands may experience large losses in biodiversity because of their sensitivity to conversion (Sala et al. 2000). Active restoration implies interventions in a degraded habitat to accelerate and influence the successional trajectory of recovery; this method is used when natural regeneration is slow and involves high costs due to human assistance (Holl & Aide 2011; Crouzeilles et al. 2017). Techniques for grassland restoration include hay transfer from conserved grassland, soil and native-species transplantation, direct seeding, removal of topsoil containing seeds of invasive species, and seed transport through cattle management (Le Stradic et al. 2014; Vieira & Overbeck 2015). Few cases have been reported in tropical and temperate grasslands (Bond & Parr 2010), but these techniques and their results have been described in the United States, Australia, and Europe (e.g. Van Dyke et al. 2004; Catterall et al. 2012; Prach et al. 2014).

Each type of area poses unique challenges and requires different restoration approaches (Gibson 2009). Grassland processes are poorly understood, experience with restoring their taxonomic and functional diversity is limited, and the general public is unaware of the importance of grassland ecosystems (Zaloumis & Bond 2011; Parr et al. 2014; Overbeck et al. 2015). All these issues must be taken into account in preserving and restoring biodiversity in agricultural environments (Bennett et al. 2006).

Birds are good indicators of environmental changes and serve to evaluate the recovery of biodiversity in habitat restoration (Latja et al. 2016), mainly because the composition of bird assemblages may change according to the vegetation successional stage (Munro et al. 2011; Batisteli et al. 2018). Birds are the focal taxa in less than 10% of restoration studies, which usually deal with plants (Brudvig 2011; Kollmann et al. 2016).

Southern Brazilian Pampa grasslands, part of the southeastern South America grasslands, are widely used for agriculture, afforestation, and livestock grazing (Overbeck et al. 2007;

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Azpiroz et al. 2012); 64% of the area has been converted, imperiling grassland biodiversity (MMA 2011). Currently, no active restoration of degraded habitats is being conducted in the Pampa grasslands, which reinforces the importance of evaluating the efficiency of recovery techniques for grassland vegetation and birds. This case study is the first evaluation of the effects of active restoration on a bird community in southern Brazilian grasslands.

We compared the structure and composition of the bird community of a site under active restoration with a native grassland area in the Brazilian Pampa biome during 3 successive years of monitoring. We also related the composition of bird species to vegetation-structure variables and evaluated differences between the active-restoration and native-grassland sites. We hypothesized that in the third year of monitoring, the bird community in the active-restoration site would resemble the native-grassland community more than in the first and second years of restoration. We reasoned that active restoration aims to accelerate the recovery of biodiversity and that birds respond to the rapid development of vegetation structure (Catterall et al. 2012).

Methods

Study Area

We worked in two grassland sites (native and active restoration) located in a 50,000-ha Brazilian Army reserve in the Brazilian Pampa biome. The sites are in Rosário do Sul Municipality in the Central Depression geomorphologic province in the state of Rio Grande do Sul, Brazil, where 17% of grasslands have been degraded, mainly by agricultural activity (Andrade et al. 2015).

The Active Restoration Site (AR; 30°04′32.65″S, 55°04′36.01″W) is approximately 400 ha in area; it was planted in soybeans for more than 10 years and was abandoned in 2013 after the last crop was harvested. Expert botanists and agronomists carried out the restoration experiment (the first in the Pampa grasslands) as part of a Degraded-Area Recovery Project (PRAD) coordinated between the Brazilian Army and federal research institutions. Prior to restoration, the area contained lovegrass (*Eragrostis plana*), the main invasive exotic plant species in the Pampa grasslands, and shrubs (*Baccharis* spp. and *Senecio* sp.), which shaded out the grassland vegetation of interest. The restoration techniques, beginning in 2015, included fallowing, mechanical mowing, controlled cattle grazing ($\leq$1 head/ha), cattle-exclusion periods, and cattle as transport and dispersal agents for native-plant seeds. For this last, before the cattle were herded to the restoration site they were allowed to graze in a native grassland area (described below).

The Native Grassland Site (NG; 30°06′08″S, 55°03′50″W) was considered the reference area (benchmark grassland). The site covers 700 ha, approximately 4 km from the AR, and was used to produce native seeds for the cattle to introduce them into the AR. The NG was stocked with 1 head/ha of cattle, a type of management used since the 17th century on Pampa grasslands (Andrade et al. 2015). Livestock has long been part of the natural landscape of the grasslands, and extensive grazing is important for grassland biodiversity (Veldman et al. 2015).

Bird Sampling

We sampled birds in the breeding season (austral spring–summer, November–January) in 2015–2017. We sampled the AR four times, twice in 2015 before (restoration zero stage) and after mechanical mowing, once in 2016, and once in 2017. We sampled the NG three times, once each year in the same period as the AR samples. At each site we recorded all birds seen and/or heard in 10 point counts of 5 min and 100-m radius, 300 m apart and previously marked in Google Earth Pro (Bibby et al. 2000; Fontana et al. 2018). Point counts were initiated shortly after sunrise and once in each breeding season. All surveys were completed by T.W.S. in favorable and similar weather conditions. Birds in flight were not considered. We followed Azpiroz et al. (2012) for bird species representative of grasslands in southeastern South America, and we used global (IUCN 2017) and regional (DOE 2014) lists of threatened species.

Vegetation Sampling

We surveyed five quadrat plots of vegetation ($n = 100$) in each bird point count in each sampling period (2015–2017). We surveyed three vegetation variables: vegetation height, percent visual obstruction, and percent vegetation cover. Vegetation cover was classified in nine categories: short and tall grasses, herbs, shrubs, *Eryngium* spp., *Baccharis* spp., exposed soil, water, and cattle dung (Bencke & Dias 2010 unpublished data; Fuhlendorf et al. 2006). Grass height strongly influences the presence of grassland birds (Azpiroz & Blake 2016) and woody vegetation (including *Eryngium* and *Baccharis*) provides resources for them (Dias et al. 2014). The five 1×1–m quadrats were arranged with one at the center of the point count and one in each cardinal direction (north, south, east, west), 50 m distant from the central point. For all variables, we used a 1 m^2 plastic frame divided into 16 quadrants (each 0.25×0.25 cm; Daubenmire 1959). Vegetation height (cm) was measured in the center and at the four corners of the quadrat. To evaluate visual obstruction, we placed the frame vertically in the plot, and the observer distant 4 m recorded the number of quadrants filled by vegetation (Robel et al. 1970). For vegetation cover, we positioned the frame horizontally on each quadrat and counted the number of quadrants filled with the nine categories mentioned above. To obtain a mean value for vegetation variables at the point-count level, we calculated the mean for each of the five quadrats per point count. All vegetation sampling was conducted by T.W.S.

Statistical Analysis

The species-richness values in AR and NG were compared via coverage-based rarefaction and extrapolation (Chao & Jost 2012) using the estimateD function of the i*NEXT* package in R (R Core Team 2018; Hsieh et al. 2019). Non-overlapping 95% confidence intervals are considered to have different species

Table 1. Bird species and number of individuals recorded in active-restoration (AR) and reference areas (NG) in Brazilian grasslands from 2015 through 2017. Y, year. *Species representative of southeastern South America grasslands (Azpiroz et al. 2012). Conservation status: [a]Vulnerable globally. [b]Vulnerable regionally. [c]Near-threatened regionally.

	AR			NG		
Family and Species	*Y1*	*Y2*	*Y3*	*Y1*	*Y2*	*Y3*
Tinamidae						
Rhynchotus rufescens (Red-winged Tinamou)*	0	1	1	0	1	0
Nothura maculosa (Spotted Nothura)*	0	0	1	0	0	0
Anatidae						
Amazonetta brasiliensis (Brazilian Teal)	0	0	0	0	0	1
Columbidae						
Zenaida auriculata (Eared Dove)	0	0	2	0	0	0
Cuculidae						
Guira guira (Guira Cuckoo)	0	0	1	0	0	0
Coccyzus melacoryphus (Dark-billed Cuckoo)	0	0	1	0	0	0
Charadriidae						
Vanellus chilensis (Southern Lapwing)*	0	0	0	0	0	2
Scolopacidae						
Gallinago paraguaiae (South American Snipe)	0	0	0	1	0	0
Jacanidae						
Jacana jacana (Wattled Jacana)	0	0	0	0	2	2
Ardeidae						
Butorides striata (Striated Heron)	0	0	2	0	0	0
Threskiornithidae						
Theristicus caerulecens (Plumbeous Ibis)	0	0	0	1	0	0
Falconidae						
Caracara plancus (Southern Caracara)*	0	0	0	1	0	0
Psittacidae						
Myiopsitta monachus (Monk Parakeet)	2	0	0	0	0	0
Furnariidae						
Furnarius rufus (Rufous Hornero)*	0	0	2	1	0	2
Synallaxis frontalis (Sooty-fronted Spinetail)	0	0	1	0	0	0
Tyrannidae						
Elaenia spectabilis (Large Elaenia)	0	1	0	0	0	0
Myiophobus fasciatus (Bran-colored Flycatcher)	0	0	1	0	0	0
Pitangus sulphuratus (Great Kiskadee)	0	1	2	0	1	1
Tyrannus savana (Fork-tailed Flycatcher)*	0	1	1	0	2	0
Hirundinidae						
Progne tapera (Brown-chested Martin)*	0	0	0	1	0	0
Troglodytidae						
Troglodytes aedon (House Wren)	1	0	0	0	0	0
Cistothorus platensis (Sedge Wren)*[c]	0	0	0	0	1	3
Mimidae						
Mimus saturninus (Chalk-browed Mockingbird)*	0	1	0	0	0	0
Motacillidae						
Anthus nattereri (Ochre-breasted Pipit)*[a, b]	0	0	0	1	0	0
Anthus hellmayri (Hellmayr's Pipit)*	0	0	0	18	10	6
Thraupidae						
Sicalis luteola (Grassland Yellow-Finch)*	12	7	6	11	6	6
Volatinia jacarina (Blue-black Grassquit)*	4	8	15	0	0	0
Sporophila pileata (Pearly-bellied Seedeater)*[b]	0	1	1	0	0	0
Sporophila caerulescens (Double-collared Seedeater)	0	0	4	0	0	0
Embernagra platensis (Great Pampa-Finch)*	11	1	1	0	1	0
Emberizoides herbicola (Wedge-tailed Grass-Finch)*	0	1	2	0	0	0
Donacospiza albifrons (Long-tailed Reed Finch)*	3	0	0	0	2	0
Paroaria coronata (Red-crested Cardinal)	0	0	3	0	0	0
Emberizidae						
Ammodramus humeralis (Grassland Sparrow)*	11	14	10	7	12	7
Zonotrichia capensis (Rufous-collared Sparrow)	0	12	11	2	0	0
Parulidae						
Geothlypis aequinoctialis (Masked Yellowthroat)	0	1	2	2	0	0

Table 1. Continued

	AR			NG		
Family and Species	*Y1*	*Y2*	*Y3*	*Y1*	*Y2*	*Y3*
Icteridae						
Pseudoleistes guirahuro (Yellow-rumped Marshbird)*	0	3	0	0	0	0
Pseudoleistes virescens (Brown-and-yellow Marshbird)*	0	1	0	0	0	0
Molothrus bonariensis (Shiny Cowbird)*	0	2	0	0	0	1
Sturnella superciliaris (White-browed Meadowlark)*	0	0	1	4	4	9
Total number of bird species	7	16	22	12	11	11
Number of grassland bird species*	5	11	11	8	9	8
Total number of individuals	44	56	71	59	46	49

richness between AR and NG. We compare the abundance of grassland species between AR and NG using repeated measures ANOVA, considering each year separately and using it as a random effect. To determine the bird species composition in AR and NG in each year, we plotted a nonmetric multidimensional scaling with the Bray–Curtis dissimilarity, using the metaMDS function. To test for differences in species composition, we fitted a permutational multivariate analysis of variance (PERMANOVA) with pairwise multilevel comparison using adonispost hoc. We also plotted vegetation variables for ordination, using the envfit function based on 9,999 permutations. All analyses were performed in the *vegan* package in R (Oksanen et al. 2017), and *pairwiseAdonis* package for PERMANOVA post hoc (Arbizu 2017), at a significance level of $\alpha = 0.05$. We used the Kruskal–Wallis test with Dunn's test post hoc to compare the vegetation variables between AR and NG, except for *Baccharis*, for which we used ANOVA. For this, we used the mean for each of the five quadrats per point count in each year. Previously, we verified the homoscedasticity of variables with the Levene test and the correlation among variables. Visual obstruction was correlated with vegetation height ($r = 0.84$) and was omitted from the analysis; water had no quadrat.

Results

From 2015 through 2017, we recorded 336 individuals of 40 bird species: AR = 182 individuals/30 species (171 individuals disregarding the zero stage); NG = 154 individuals/22 species (Table 1). Twelve species were present in both types of grassland; 22 bird species are associated with grassland habitats (AR = 16, NG = 15). At both sites, *Ammodramus humeralis* (Grassland Sparrow) and *Sicalis luteola* (Grassland Yellow-Finch) were the most abundant shared species. The most abundant exclusive species were *Volatinia jacarina* (Blue-black Grassquit) in AR and *Anthus hellmayri* (Hellmayr's Pipit) in NG. In 3 years of monitoring the AR since the zero stage, the bird species richness and abundance increased approximately 82 and 85%, respectively, and in NG remained practically constant (Table 1). We recorded three species threatened globally and/or regionally: *Sporophila pileata* (Pearly-bellied Seedeater) in AR, and *Cistothorus platensis* (Sedge Wren) and *Anthus nattereri* (Ochre-breasted Pipit), both in NG.

The estimated rarefaction richness was 30 (25.84–34.16) species in AR and 20.76 (17.47–24.06) in NG. The non-overlap in confidence intervals for the overall species richness and in each year (except at AR year 1 with NG) indicates a difference in estimated rarified species richness between AR and NG (Fig. 1). The abundance of bird species did not differ between AR and NG (ANOVA, $F_{1,3} = 0.26$, $p = 0.65$). The species composition differed significantly between all years of AR and NG (PERMANOVA, $F_{5,59} = 4.29$, $p < 0.001$), and was influenced by vegetation height, short grasses, and herbs (Fig. 2; Table 2). Of the nine vegetation variables analyzed, five differed between AR and NG: vegetation height, tall grasses, herbs, and shrubs were higher in AR; while the variable 'short grasses' was higher in NG (Table 3).

Discussion

Losses of native grasslands have been documented worldwide (Buisson et al. 2018), with approximately 24% of subtropical grasslands converted or lost (Hoekstra et al. 2005). Theoretical knowledge and management practices have been developed to more effectively conserve and restore degraded grasslands (Buisson et al. 2018). Our case study is the first to examine the bird species richness, abundance, and composition in a grassland under active restoration in South America. The results must be considered with caution, because replication was not possible and our sample was local. We found higher species richness recorded across second and third years in AR compared to NG, and also an increase of the number of species and individuals in each year. Previous studies in the United States found similar bird species richness and abundance or density between active-restoration and native grassland areas, such as in Iowa (Fletcher Jr & Koford 2002; Van Dyke et al. 2004). And wetlands of North and South Dakota (Ratti et al. 2001) and wetlands of New York also found differences in species composition (Brown & Smith 1998), similar to our study case.

Ammodramus humeralis and *Sicalis luteola*, the most abundant species shared between AR and NG, occupy a range of vegetation heights and are tolerant of habitat changes (Isacch et al. 2005; Azpiroz et al. 2012). *Volatinia jacarina*, abundant and exclusive in AR, prefers tall grass, which it uses mainly for nesting (Azpiroz et al. 2012; Dias et al. 2017; Rising 2018). *Anthus*

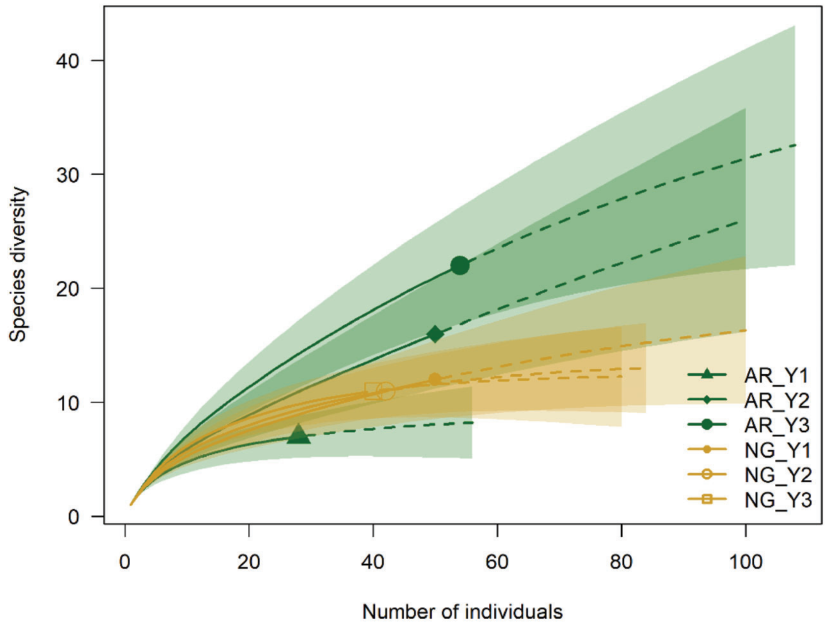

Figure 1. Coverage-based rarefaction and extrapolation species richness curve in each year (Y) of the active restoration (AR) and native grassland (NG) sites on Brazilian grasslands, from 2015 through 2017.

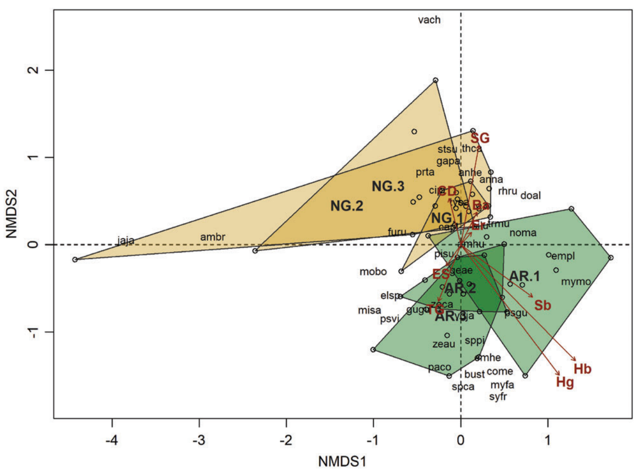

Figure 2. Nonmetric multidimensional scaling (NMDS) of the bird species in the active-restoration site (AR) and reference area (NG) from years 1 to 3 in grasslands of southern Brazil and their relationship to vegetation-structure variables (Hg, height; SG, short grass; TG, tall grass; Hb, herbs; Sb, shrubs; Er, *Eryngium* spp.; Ba, *Baccharis* spp.; ES, exposed soil; CD, cattle dung). Stress = 0.17. The first two letters of the genus and species formed the species acronyms, as in Table 1.

hellmayri was exclusive to and abundant in NG; it is restricted to grasslands, and hence sensitive to conversion of grasslands to other land uses such as croplands (Azpiroz & Blake 2009; Azpiroz et al. 2012). *Sporophila pileata*, the only threatened species recorded in AR, appeared in the second year of monitoring, probably because the abundant tall grasses in AR provide a suitable habitat; this is a tall-grass bird, with a decreasing population due to soybean expansion (Bencke & Damiani 2013).

Table 2. Vector scores of vegetation variables for the bidimensional axis of nonmetric multidimensional scaling (NMDS).

Vegetation variable	*NMDS1*	*NMDS2*	r^2	p
Height	0.60	−0.80	0.33	0.0001
Short grasses	0.18	0.98	0.12	0.02
Tall grasses	−0.37	−0.93	0.04	0.26
Herbs	0.70	−0.71	0.32	0.0003
Shrubs	0.81	−0.59	0.10	0.06
Eryngium spp.	0.67	0.74	0.003	0.91
Baccharis spp.	0.45	0.89	0.02	0.59
Exposed soil	−0.56	−0.83	0.008	0.78
Cattle dung	−0.24	0.97	0.03	0.42

Vegetation structural attributes predict the direction of plant succession and the improvement of environmental conditions and colonization by animals (Ruiz-Jaen & Aide 2005; Chaves et al. 2015). We observed differences between AR and NG in five variables of vegetation structure, which may have resulted in the difference in grassland species composition between the two habitats. The greater height in AR resulted from the conspicuous presence of shrubs and *Baccharis* spp.; this woody vegetation in grasslands provides resources for birds, increasing diversity (Dias et al. 2014). Regarding the time of restoration, in the second year of active restoration the grassland bird species richness and composition resembled the reference area, whereas we had initially hypothesized that this would occur only in the third year. A previous study in temperate grasslands of Hungary detected recovery of grass diversity within 3 years after active restoration started (Török et al. 2012). It is known that the recovery of birds is strongly correlated with vegetation structure (George & Zack 2001; Ruiz-Jaen & Aide 2005).

Table 3. Mean ± SD of the vegetation variables for the active-restoration site (AR) and reference area (NG) in the Pampa grasslands in 2015–2017. $df = 5$. [a]F value because was run ANOVA.

Vegetation variable	*AR*	*NG*	*Chi-squared*	p
Height	42.74 ± 18.96	23.32 ± 2.23	44.31	<0.001
Short grasses	31.88 ± 20.43	53.21 ± 33.27	51.41	<0.001
Tall grasses	27.06 ± 9.00	13.66 ± 9.65	35.13	<0.001
Herbs	14.45 ± 11.00	1.64 ± 1.10	47.80	<0.001
Shrubs	1.59 ± 1.11	0.007 ± 0.009	18.85	0.002
Eryngium spp.	1.13 ± 0.61	1.30 ± 0.81	9.78	0.08
Baccharis spp.	0.64 ± 0.30	0.80 ± 0.52	0.86[a]	0.51
Exposed soil	1.81 ± 1.83	0.60 ± 0.57	12.93	0.07
Cattle dung	0.34 ± 0.24	0.67 ± 0.43	11.45	0.08

Our results were positive for the bird community at the site undergoing active restoration, for having higher species richness, supporting bird species associated with grasslands, and showing rapid recovery compared with the reference area, since the number of species in AR doubled from the first to the second year of monitoring, and increased from the second to the third year of monitoring. Ideally, future research would involve long-term studies to monitor areas under active restoration and to integrate assessments of other groups of animals, to more fully understand the recovery of biodiversity in degraded areas and measure restoration success. Studies such as our field-scale and small site-specific experiments should be used to inform and support long-term and large-scale restoration efforts (Gerla et al. 2012). Active restoration, although costly, is used to accelerate the successional trajectory of degraded habitats and may be useful to recover and conserve the biodiversity, although in most cases the changes are not immediate (Holl & Aide 2011). Thus, each case should be analyzed individually and depends on the eventual goal, since studies evaluating passive restoration in grassland habitats have demonstrated positive results for recovery of the flora and fauna (e.g. Torchelsen et al. 2018; Reiley et al. 2019; Silva et al. 2019).

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