Orthoptera assemblages of beech stand plots during early succession stages after clearcutting

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ABSTRACT: Open habitats in closed forests are formed by various biotic and abiotic factors. These new habitats differ from their former parent stands in light conditions and vegetation structure facilitating their colonisation by heliophilous insects. We studied interseasonal differences (2010 and 2011) in the Orthoptera assemblages on eight clearcuts in beech forests. Using a sweeping method, altogether 20 species were recorded on the clearcuts in the first year, 26 in the second. In the second year, species number and abundance were higher in all orthopterans and also in the suborder of grasshoppers (Caelifera). In the crickets (Ensifera), interseasonal differences in the species number and abundance were not significant. The species composition differed among the plots also within individual years. In the second year, the frequency increased in 22 species (84.6%) while it decreased in four. We suggest that the ground-dwelling Caelifera species are better bioindicators of the deforested plot colonisation than the arbusticolous Ensifera.

Keywords: deforestation; Ensifera; Caelifera; deciduous forest; corridors; central Europe

Forest habitats in Europe are influenced in the long run by natural disturbances and by deforestation (Bengtsson et al. 2000; Schelhaas et al. 2003). This could lead to forest fragmentation and habitat mosaic (Fahrig 2003), with small patches isolated each other by larger areas (Wilcove et al. 1986; Andrén 1994). On the other hand, forest fragmentation and deforestation can influence positively the species richness in butterflies (Tscharntke et al. 2002), birds (Bélisle et al. 2001), ants and carabids (Vele et al. 2011), orthopterans (Clayton 2002), carabides, syrphids, bees, wasps and spiders (Moretti et al. 2004). Important habitats for Orthoptera in forests are clearings (Kati et al. 2003), deforested areas (Schmidt, Schlagbauer 1965; Jenni et al. 2007; Sliacka et al. 2013), and linear corridors in forests (Jordán et al. 2003; Theuerkauf, Rouys 2006; Kaňuch et al. 2012). Deforestation may result in providing transitory favourable conditions for secondary contacts among heliophilous orthopteran subpopulations (Gerber, Templeton 1996). The forests are nonstop influenced by succession and colonisation (Brown 1997). The forest regeneration takes much more time than the response in the insects (Bazykin et al. 1997). There are differences between deforested habitats and closed-canopy forests in their colonisation by various insect species and groups such as ants, beetles and butterflies (Niemelä et al. 1993, 2007; Willott et al. 2000). The period of an increase in the species number in deforested habitats is limited (e.g. ten years in ants), followed by a decrease (Punttila 1991). Several orthopteran species have been recognised as suitable bioindicators of habitat changes (Marini et al. 2008; Fabriciusová et al. 2011; Fartmann et al. 2012). Progressive encroachment of grassland habitats causes a reduction in the species number in Caelifera (Marini et al. 2009a) while in new-formed clearcuts in coniferous and mixed forests Caelifera are dominant (Laussmann 1993; Jenni et al. 2007). Ensifera are mostly associated with

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woody plants (Detzel 1998; Ingrisch, Köhler 1998), however, the new clearcuts exhibited only a few species in the first years (Laussmann 1993; Jenni et al. 2007). While the period of an increase in the species number in coniferous forests was evident (3–5 years) (Clayton 2002; Jenni et al. 2007), it is not known how long the colonisation process of clearcuts will be in beech forests.

In the previous study we focussed our attention on differences in the species composition and abundance of Orthoptera on a series of clearcuts of three different age categories during one year. Hence, the study covered only one season, which means that the year differences were not possible to exclude (Sliacka et al. 2013). Our knowledge of the pioneer colonisation in the first years of forest succession on deforested plots allows us to hypothesise about an increase in the species number and abundance in the second year.

In this study we investigated differences in the structure of orthopteran assemblages (Ensifera and Caelifera) between the first and the second year after deforestation of beech forests.

MATERIAL AND METHODS

Study area

Eight study plots (Fig. 1) were situated in Central Slovakia (48°31'–38'N, 19°00'–19'E; in the Kremnické vrchy Mts., Javorie and Poľana Mts.; Table 1). The plots were situated in a broadleaved forest with dominant beech *Fagus sylvatica* (> 70%). Hornbeam, fir, oak and spruce (together 0–30%) were also present in the surrounding stands. In the season 2010, the mean maximum temperatures were 23.1 ± 5.4°C (May–June) and 26.9 ± 5.5°C (July–August). The mean precipitation totals were 5.1 ± 8.2 mm (May–June) and 7.3 ± 18.1 mm (July to August). In the season 2011, the mean maximum temperatures in May–June were 24.4 ± 3.9°C, in July–August 27 ± 4.5°C. The mean precipitation totals were significantly lower (2.7 ± 8.1 mm in May–June and 2.6 ± 8 mm in July– August) (http://www.weatheronline.co.uk).

Data collection

Orthoptera were collected by sweeping (250 sweeps/clearcut/visit) both in the first and second year after deforestation (2010 and 2011), hence in total we received the insects from 4,000 sweeps. The species composition and abundance in Orthoptera was recorded during two surveys (June and August) per year, with the aim to cover as rich species spectrum as possible. The sweeping line was led across a wide range of microhabitats (bare ground, herbs, grasses, *Rubus* spp., shrubs). We used a circular sweep net (35 cm in diameter). As one sweep we considered moving once back and forth in a 180° radius (Gardiner et al. 2005). The collection was conducted in favourable weather conditions (sunny-thin clouds and windless) from 10:00 to 17:00. Almost all trapped individuals and individuals observed under sweep nets were registered. With the exception of several individuals difficult to identify (such as cryptic species of the genera *Tetrix* and *Chorthippus*), the insects were released

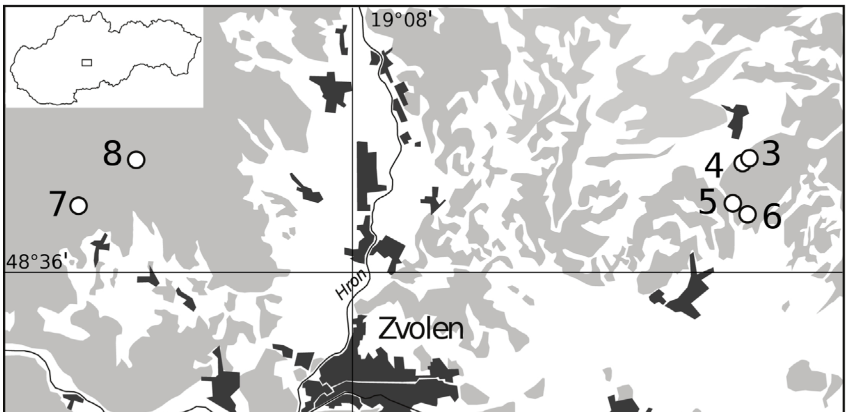

Fig. 1. Localization of eight clearcuts in beech forest in three mountain ranges in Central Slovakia

Table 1. Characteristics and environmental variables of eight studied clearcuts in beech forests

Clearcuts	1	2	3	4	5	6	7	8
Locality	Javorie Mts.		Poľana Mts.				Kremnické Vrchy Mts.	
Period of harvesting (month/year)	XI/09–II/10	XI/09–I/10	II–IV/10	II–IV/10	I–II/10	I–III/10	II–III/10	III–IV/10
Aspect	W	W	NW	W	W	W	SW	W
Altitude (m a. s. l.)	490	487	477	476	583	549	512	524
Elevation (m)	59	57	44	54	59	17	111	22
Area (m^2)	13,188	11,149	3,851	5,706	3,538	2,613	5,617	3,617
Neighbouring habitat categories and corridors (%)								
Opened canopy forest	62	53	85	81	47	49	51	46
Closed canopy forest	0	0	0	0	16	14	14	13
Selective harvested forest	0	0	0	0	4	4	0	0
Young forest	8	4	3	9	10	4	11	9
Clearcut	12	16	8	1	0	15	8	21
Grasslands	9	14	0	3	14	2	9	0
Asphalt road	0	0	2	2	5	3	4	1
Forest road	8	12	2	2	2	8	2	10
Stream	1	1	0	2	2	1	1	0
Vegetation categories								
Bare ground	2	1	9	8	7	6	15	3
Grass	12	5	21	47	26	26	4	11
Herbs (%)	24	36	40	26	36	30	60	25
Shrubs	52	50	19	10	23	33	8	9
Rubus spp.	10	8	11	9	8	5	13	52
Vegetation height (cm)	90	86	71	51	46	47	35	74

immediately after the identification. In overall, we identified 1,096 individuals (trapped by sweeping) on the species level (516 indd·4,000 sweeps^{-1} in the first year and 580 indd·4,000 sweeps^{-1} in the second year). The Orthoptera were identified and classified according to Kočárek et al. (2005).

In the first year, the clearcuts exhibited high percentages of bare ground and dead wood (80%) and a certain proportion of natural regeneration (20%). Vegetation structure was recorded along four transects (30 m long, one m wide; Table 1) at all eight clearcuts in the second year. Proportions (%) of grass, herbs, shrubs, *Rubus* spp. and of bare ground and the height of the vegetation were recorded (Sliacka et al. 2013).

Percentages of six categories of surrounding habitats (open canopy forest, closed canopy forest, forest with selective harvesting 30–70%, young forest 2–8 m high, clearcut < 2 m high, grasslands) and three kinds of corridors (asphalt roads, forest roads, streams, Table 1) were recorded at eight transects (150 m in length) in 2012 using the Smith (1984) method.

Data analysis

The Ensifera and Caelifera numbers of species and abundance (Fig. 2a, b) in regard to the clearcut age were compared by the Kruskal-Wallis test. All statistical analyses and evaluations were performed in the programme R 2.13.2 (R Development Core Team 2011).

RESULTS

In the first year, the total species number found in the eight clearcuts studied was 20 species (9 En-

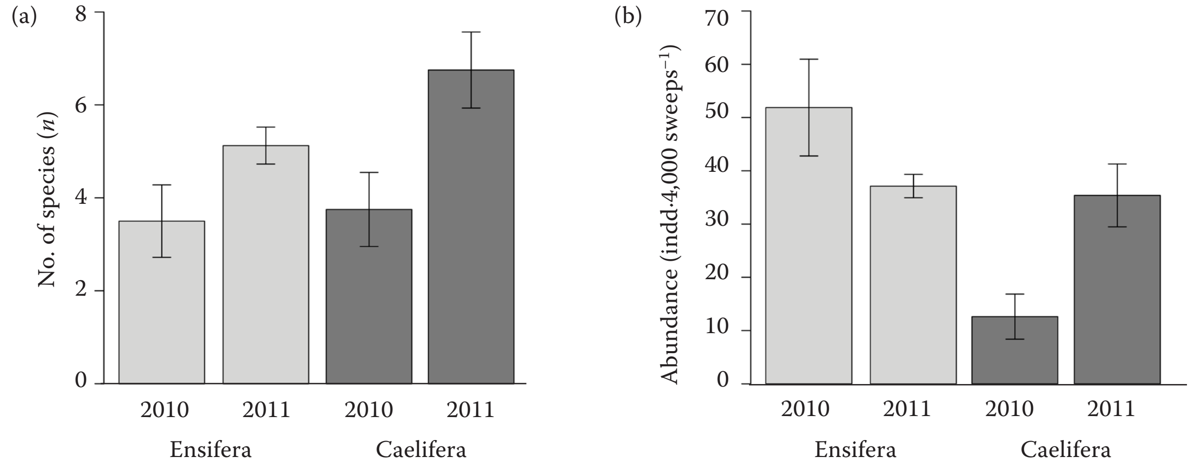

Fig. 2. Number of species (a) and their abundance (b) in Ensifera and Caelifera in eight clearcuts in the first year (2010) and in the second year (2011) after clearcutting

sifera, 11 Caelifera), in the second 26 (12 Ensifera, 14 Caelifera).

The number of Orthoptera species found in clearcuts in the second year was significantly higher than that in the first year after deforestation (Kruskal-Wallis test; χ^2 = 6.432; df = 1; P = 0.011). However, there were not any significant differences in Ensifera species between the first and the second year (Kruskal-Wallis test; χ^2 = 2.759; df = 1; P = 0.097; Fig. 2a). Contrarily, the number of Caelifera species in the clearcuts was found higher in the second year (Kruskal-Wallis test; χ^2 = 5.198; df = 1; P = 0.023; Fig. 2a).

The abundance of all orthopterans recorded in the clearcuts was significantly higher in the second year (Kruskal-Wallis test; χ^2 = 5.852; df = 1; P = 0.016). There were not found any significant differences in Ensifera abundance between the first and the second year (Kruskal-Wallis test; χ^2 = 0.468; df = 1; P = 0.494; Fig. 2b). The same was true for the most dominant species *Pholidoptera griseoaptera* (Kruskal-Wallis test, χ^2 = 3.383, df = 1, P = 0.066) with individuals representing 67.4% and 46.6% of abundance in the first and in the second year, respectively (Fig. 3). Contrarily, the Caelifera individuals in the clearcuts were significantly more abundant in the second year (Kruskal-Wallis test; χ^2 = 6.1; df = 1; P = 0.014; Fig. 2b). The most abundant Caelifera species in the second year were *Euthystira brachyptera* (15%) and *Chorthippus vagans* (10.5%) (Fig. 3).

In the first year, the most frequent species were *P. griseoaptera* (100%) and *Tetrix subulata* (75%), in

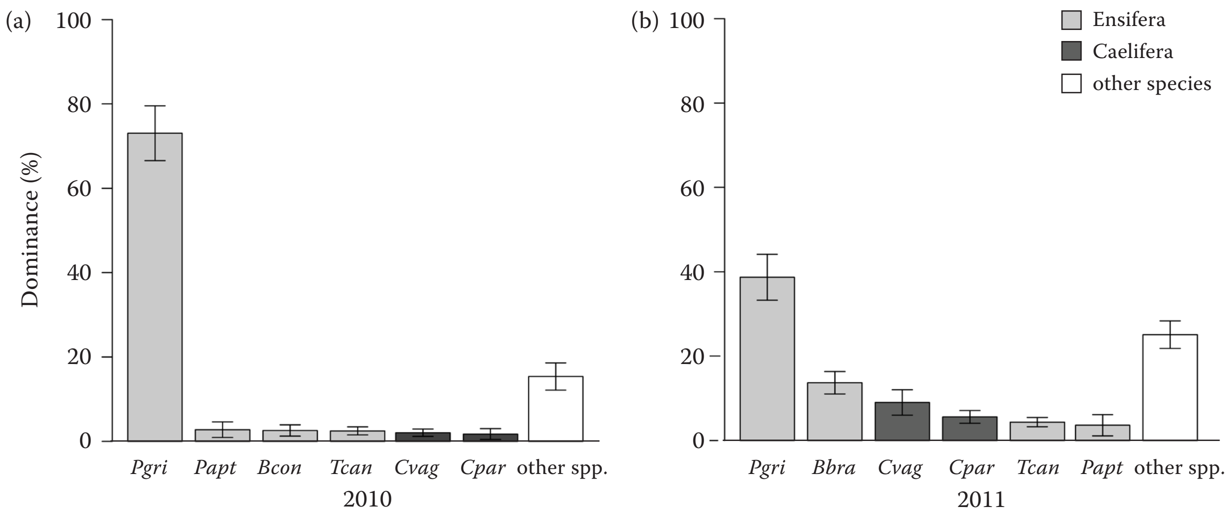

Fig. 3. Dominance of the most abundant Orthoptera species in the first year (2010) (a) and in the second year (2011) (b) after clearcutting

Pgri – *P. griseoaptera*, *Papt* – *P. aptera*, *Bcon* – *B. constrictus*, *Tcan* – *T. cantans*, *Cvag* – *C. vagans*, *Cpar* – *C. parallelus*, *Ebra* – *E. brachyptera*, other spp. – other species the second year the species *P. griseoaptera*, *Phaneroptera falcata*, *Tettigonia cantans* (f = 100%) and four Caelifera species: *T. subulata*, *E. brachyptera*, *Chorthippus brunneus*, *C. vagans* (f = 87.5%). The major part of the grassland species in the clearcuts occurred in the second year, but at a low frequency (≤ 25%), e.g. *Metrioptera roeselii* (12.5%), *Decticus verrucivorus* (12.5%), *Gryllus campestris* (25%), *Chorthippus dorsatus* (25%), *Chrysochraon dispar* (25%) and *Oedipoda caerulescens* (25%) (Table 2). On the other hand, in the second year we recorded a lower frequency than in the first year in three arbusticolous species (*Barbitistes constrictus*, *Isophya camptoxypha*, *Meconema thalassinum*) and one ground-dwelling species (*Tetrix tenuicornis*). *P. griseoaptera* was a dominant species in all eight clearcuts in both seasons (Fig. 3). From Ensifera, the typical species in the first season were *Pholidoptera aptera*, *T. cantans*, *B. constrictus* and in the second season *P. aptera*, *T. cantans*, *P. falcata*.

DISCUSSION

Deforestation is followed by an increase in numbers of heliophilous insect species such as Orthop-

Table 2. Frequency and absolute abundance of 26 Orthoptera species in eight clearcuts in beech forests in the first year (2010) and in the second year (2011) after clearcutting

Species	Species abbreviation	Frequency (%)		Abundance (indd·4,000 sweeps^{-1})	
		2010	2011	2010	2011
Barbitistes constrictus constrictus (Brunner von Wattenwyl, 1878)	*Bcon*	37.5	25	12	3
Isophya camptoxypha (Fieber, 1853)	*Icam*	37.5	25	4	3
Phaneroptera falcata (Poda, 1761)	*Pfal*	25	100	2	18
Meconema thalassinum (Degeer, 1773)	*Mtha*	25	12.5	3	2
Decticus verrucivorus (Linnaeus, 1958)	*Dver*	0	12.5	0	1
Metrioptera roeselii (Hagenbach, 1822)	*Mroe*	0	12.5	0	1
Pholidoptera aptera slovaca (Mařan, 1953)	*Papt*	25	25	18	24
Pholidoptera griseoaptera (Degeer, 1773)	*Pgri*	100	100	348	207
Platycleis albopunctata grisea (Fabricius, 1781)	*Plgr*	25	37.5	7	6
Tettigonia cantans (Fussli, 1775)	*Tcan*	50	100	18	21
Tettigonia viridissima (Linnaeus, 1758)	*Tvir*	25	37.5	3	5
Gryllus campestris (Linnaeus, 1758)	*Gcam*	0	25	0	6
Tetrix subulata (Linnaeus, 1758)	*Tbip*	75	87.5	12	18
Tetrix undulata (Sowerby, 1806)	*Tsub*	25	75	5	18
Tetrix tenuicornis (Sahlberg, 1893)	*Tund*	50	12.5	7	1
Tetrix bipunctata (Linnaeus, 1758)	*Tten*	25	25	13	2
Calliptamus italicus (Linnaeus, 1758)	*Cita*	12.5	25	5	7
Oedipoda caerulescens (Linnaeus, 1758)	*Ocae*	0	25	0	4
Euthystira brachyptera (Ocskay, 1826)	*Ebra*	37.5	87.5	6	87
Gomphocerippus rufus (Linnaeus, 1758)	*Gruf*	12.5	12.5	13	8
Chorthippus biguttulus (Linnaeus, 1758)	*Cbig*	12.5	50	1	12
Chorthippus brunneus (Thunberg, 1815)	*Cbru*	37.5	50	9	17
Chorthippus dorsatus (Zetterstedt, 1821)	*Cdor*	0	25	0	7
Chorthippus parallelus (Zetterstedt, 1821)	*Cpar*	25	87.5	15	35
Chorthippus vagans (Eversmann, 1848)	*Cvag*	50	87.5	15	61
Chrysochraon dispar dispar (Germar, 1834)	*Cdis*	0	25	0	6

tera (Laussmann 1993; Jenni et al. 2007), Coleoptera (Bouget, Duelli 2004; Vele et al. 2011), Lepidoptera (Warren 1985; Willot et al. 2000) in the new-formed clearcuts.

In the first year after clearcutting, we identified many more species (20) than reported previously: one species (Laussmann 1993), three species (Jenni et al. 2007). We suggest that the rather high species numbers already in the first year after clearcutting may be explained by the fact that several Orthoptera species (e.g. *P. griseoaptera*, *M. thalassinum* and species of the genus *Tetrix*) occur in differently managed forests (open canopy forests, closed canopy forests, young forests) and their ecotones (Detzel 1998; Hochkirch et al. 2008; Diekötter et al. 2009; our unpublished data from the forests surrounding clearcuts). Furthermore, we may suppose that in formerly closed and dark forests, some insect stages are able to survive in diapause under unfavourable environmental conditions (e.g. Ingrisch 1985), lasting even decades in some arthropods (Smith 1962; Powell 2001). A high species number could be due to the regular presence of corridors (forest and asphalt roads, Table 1). These can ensure passive transport of several insect species, e.g. by traffic, plant transport (Detzel 1998), particularly by hay transport (Wagner 2004). In the first year, the clearcuts displayed more species than the surrounding grasslands, as the soil and bare ground on clearcuts dried faster than in grasslands (Sliacka, Krištín 2012). Hence, we suppose that disturbances facilitate the spreading of species from the surrounding suitable habitats, e.g. grasslands (Albrecht et al. 2010; Dziock et al. 2011) and that these species can spread and cross also unsuitable habitats, e.g. closed canopy and dark forests (Kindvall 1999). In the second year, the total number of Orthoptera species recorded in all clearcuts was 26, which was very similar (at a 96% level) to the results obtained in our study in 1–7-years-old clearcuts in this area (Sliacka et al. 2013). The variability among eight clearcuts was noticeable equally in the species number and their abundance in both years (Fig. 2). We may deduce these underlying factors: microclimate (Schmidt, Schlagbauer 1965; Schirmel et al. 2011), species composition and structure of vegetation (Guido, Gianelle 2001; Marini et al. 2008; Schirmel et al. 2010) and precipitation amounts (Brust et al. 2007).

We found that the number of Caelifera species was higher than that of Ensifera on each clearcut in both seasons – as reported also by Laussmann (1993), Jenni et al. (2007). The indicator species occurred on deforested plots already in the first year after deforestation. Among these species, *C. brunneus* was found as a pioneer species also by Laussmann (1993) and Jenni et al. (2007). This species was not found yet to occur in closed canopy beech forests (Kulfan et al. 2011, own unpublished results). In the second year of the clearcut succession, the typical indicator species was well-flying *P. falcata* (typical of high herbs and shrubs) recorded also by Marini et al. (2009a), Fartmann et al. (2012) in early and intermediate succession stages of grasslands. In the second year, typical was also higher abundance in terricolous *C. vagans* (preferring light forests and bare ground) characteristic of deforested plots (Hochkirch et al. 2008). The formation of grasslands in the second year developed along with increased abundance of the graminicolous species *E. brachyptera* and *C. parallelus* characteristic mainly for grassland assemblages (Guido, Gianelle 2001; Jenni et al. 2007; Fabriciusová et al. 2011). The following species cannot be used to indicate colonisation processes: (*i*) incidentally recorded species with low frequency and abundance, such as *I. camptoxypha, M. thalassinum*, which agrees with Dalbeck (2011); (*ii*) species always exhibiting higher abundance than the other ones, such as *P. griseoaptera,* associated with forest edges, shrubs (Guido, Gianelle 2001; Diekötter et al. 2009), fragmented beech forests (Kaňuch et al. 2011), so not suitable to use as indicators of the colonisation process; (*iii*) randomly occurring species e.g. *C. dorsatus,* shifted into the clearcut already in the first year, probably because its potential source habitat was flooded. We may suppose that the local distribution of orthopteran assemblages across the clearcuts was probably influenced by the local vegetation structure (Bergmann, Chaplin 1992; Kati et al. 2003; Marini et al. 2009b) and microclimate (Schmidt, Schlagbauer 1965).

We may conclude that the colonisation process of clearcuts by Orthoptera takes more than two years. However, not all species able to colonise the clearcuts in the second year (Sliacka et al. 2013) must necessarily occur in each clearcut at the time. In the second research season, we recorded significantly increasing numbers of Orthoptera and Caelifera species. The number of Ensifera species did not manifest relevant changes during the first and the second year. This result is consistent with the result obtained by Marini et al. (2009a) for meadow succession. We contributed to the evidence that in the first two years of the forest colonisation process, Caelifera have a higher indicator value than Ensifera. The following species cannot be suggested as indicators for the colonisation process on deforested plots: (*i*) euryoekous species with high abundance; (*ii*) species with low frequency of occurrence; (*iii*) species with limited distribution; (*iv*) alien species.

The question how long the succession without reducing the species number and abundance in orthopterans will be maintained in the colonisation process waits for further exploration. It is not clear either how long these insects will maintain their indicator value.

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