The effect of coniferous reforestation on the original Enchytraeidae fauna of a hornbeam-oak forest in Hungary

By

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Abstract. The composition and density of enchytraeid fauna was studied in a planted *Pinus nigra* stand in Hungary and comparisons were made with a neighbouring hornbeam-oak forest, regarded the original vegetation of the region, and with the enchytraeid fauna of a mixed coniferous and deciduous forest sampling site.

During one year of observation it was found that the total number of individuals in the pine forest is considerably lower than in the original fauna. There are significant differences in species composition and dominance, too. *Stercutus niveus*, dominant in the hornbeam-oak forest, does not appear in the coniferous stand, while other species are also absent or occur only sporadically in the latter site. For five species relatively subordinate in the hornbeam-oak forest it was observed that they are well adapted to the coniferous environment and occur in large numbers.

Summarizing the results, however, it seems that for the enchytraeid fauna afforestation with conifer stands, alien to the landscape, is unfavourable.

The percentage of forested areas in Hungary has risen from 12 per cent in 1925 to 18.6 per cent today. Three-fourth of the present forest stands primarily serve economic purposes. Welfare forests with recreation, conservation, game management or research functions only amount to 18 per cent. As a result of the centuries of human intervention the proportion of oak, beech and hornbeam forests is rapidly decreasing, while in the wake of afforestations the areas planted with acacia, poplar and particularly conifers have extended.

As in Hungary — with the exception of a negligible zone along the western border — conifers are alien to the landscape, the changes involved in the face of the landscape, in microclimate and in the abiotic and biotic properties and nutrient reserves of soils are considerable (BERG and STAFF, 1980; HAYES, 1965). It is known that soil microorganisms and soil animals are sensitive to changes in the environment, but data are sparse on the alteration of the original fauna to the effect of these changes in Hungary (DÓZSA-FARKAS, 1987; ZICSI, 1987).

Therefore the present investigation was directed at the description and analysis of the Enchytraeidae fauna of a planted *Pinus nigra* stand in comparison with the natural fauna of the hornbeam-oak forest, considered original. It seemed to be useful to make a parallel investigation of the enchytraeids in a test area of mixed deciduous and coniferous species in order to provide scientific (ecological) foundations for future afforestations.

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Material and method

All the three stands were planted recently (20—30 years ago), not far from Budapest, near Szendehely, Cserhát Mountains. Their vegetation characteristics are the following.

Sample plot I: hornbeam-oak forest. A stand of proper growth, rather open mixed forest with tree density of 1350 trunks per ha. Species distribution: 45.9 per cent *Quercus*, 23 per cent *Acer campestre*, 17.8 per cent *Carpinus betulus*, 3.7 per cent *Acer tataricum*, 2.2 per cent *Tilia cordata*, 2.2 per cent *Pyrus achras*, 4.4 per cent *Prunus avium* and 0.7 per cent *Fagus silvatica*.

Sample plot II: pure pinewood. 100 per cent are *Pinus nigra* with tree density of 5700 trunks per ha.

Sample plot III: mixed deciduous and pinewood. Tree density is 3120 trunks per ha, 50.5 per cent of which in *Pinus silvestris*, 36.2 per cent *Quercus cerris*, 12.9 per cent *Acer pseudoplatanus* or *campestre*, 0.3 per cent *Carpinus betulus* and 0.1 per cent *Tilia cordata*.

The three sample sites are within 200 m distance from each other and therefore the temperature, precipitation and soil moisture data measured ad site III were regarded valid for all of them. The data for the period of study are shown in Fig. 1.

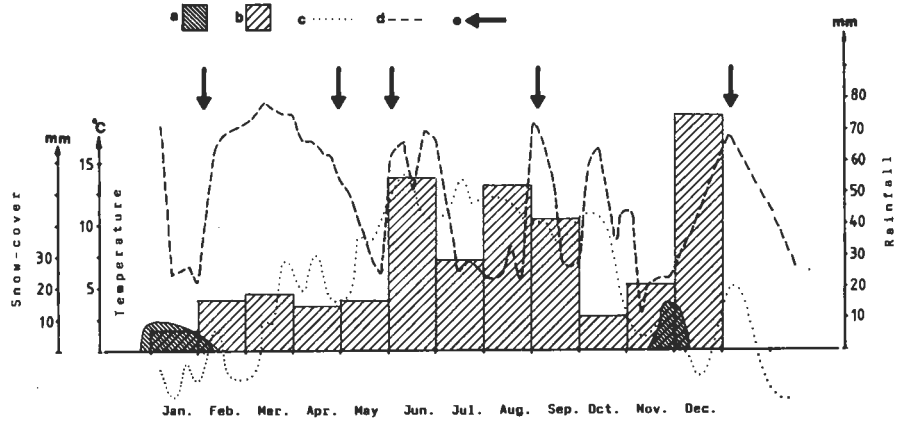

Fig. 1. Temperature and precipitation in the sampling areas (Szendehely, 1981). a=depth of snow; b=precipitation; c=soil temperature; d=soil moisture (5 cm below soil surface); e=dates of sampling

For the analysis of the enchytraeid fauna soil samples were taken season by season, on altogether five occasions from February, 1981 to January, 1982. Sampling took place on a random basis, 15—15 samples were taken from each area by a folding metal cylinder of 5.05 cm diameter. The earth core was first divided into two parts (litter and soil) and later into four parts on the spot. The division of the samples was made according the clear stratification of litter or by soil depth into the following layers: *a)* freshly fallen well-recognizable leaves; *b)* compacted, decomposed litter with obvious fungal activity; *c)* 0—2 cm soil; *d)* 2—5 cm soil.

In the site with mixed oak forest layer b was totally absent (rapid decomposition prevents accumulation).

Having taken into the laboratory, the semples were stored until analysis at 10°C in a refrigerator. The enchytraeid species were extracted by the O'CONNOR's method (O'CONNOR, 1962) and were identified alive.

Results

Abundance

The number of species identified in the three sites was 17. On two occasions only the genus was identified (*Enchytraeus* and *Achaeta*). In the case of the *Buchholzia* genus, probably the *Buchholzia appendiculata* species was found, but — since sexually mature specimens are scarce because of the characteristic asexual reproduction through fragmentation — this was designated *Buchholzia* juvenil. The species recovered and their density by sample plots are summarized in Tab. 1.

Resulting from the way of life of enchytraeids, population density presents seasonal variation. Both extremes of abundance were observed in the hornbeam-oak forest (maximum: 26 133 specimens per m^2 in winter and minimum: 1250 specimens per m^2 in spring). A previous, more detailed investigation series in a hornbeam-oak forest showed that in Hungary the enchytraeid fauna is of maximum density in spring and winter (DÓZSA-FARKAS, 1973). During our short (one-year) period of study we did not observe this expected double maximum. The spring minimum is probably explained by unfavourable climatic conditions. In this April—May the litter completely dried out and no animal was found alive in it.

The maximum density of the enchytraeid fauna was 11 633 specimens per m^2 in the *Pinus nigra* forest during the period of study. Compared to the figure of the original hornbeam-oak forest, a considerable (55.5 per cent) decrease is found. With the exception of spring, this trend is general with 30.7 per cent loss in February, 18.4 per cent in June and 51.4 per cent in September. The differences during drought derives from the fact that the thick litter cover accumulated in the pinewood does not dry out totally since the needles have a high water retention capacity. The enchytraeid fauna — which show lesser variation in abundance here than in the deciduous forest — was not damaged in spite of the drought.

Vertical distribution

The abundance data show that the location of worms changes seasonally between the various layers of litter and soil and it also differens with the sample plots. The percentage distribution of enchytraeid between the sampling plots is indicated in Fig. 2.

In April and June, in the mixed oak forest, these worms are only found in the soil, since the thin litter cover is highly susceptible to drying. In September favourable moisture conditions allowed for 6.5 per cent of the worms to live in the litter. There is a strong change in vertical distribution during the winter months, when 81 or 69 per cent of all enchytraeids are found in the litter. This phenomenon is explainable by the way of life of *Stercutus niveus*, constituting most of the enchytraeids in winter (see below) and mainly feeds on leaf litter at this time. Under snow cover they feed intensively all over the winter and even tolerate occasional frosts more easily than other worms.

It the other two sampling plots the vertical distribution of enchytraeids was different from the previous and closely resemble to each other. During the drier months worms are somewhat more abundant here and most of them are *Enchytreus* and *Buchholzia* juv.

Table 1. Abundance of the enchytraeid species present in the three sampling sites (individuals per m²)

	Hornbeam-oak					Pure pinewood					Mixed coniferous-deciduous				
	II.	IV.	VI.	IX.	I.	II.	IV.	VI.	IX.	I.	II.	IV.	VI.	IX.	I.
Achaeta	600	50	632	1831	2 097	—	—	—	133	—	350	450	—	533	50
Stercutus niveus	11 250	150	333	1764	21 900	—	—	—	—	—	—	—	—	67	—
Buchholzia juv.	50	—	433	333	133	5500	150	1864	233	1 198	6550	900	1165	1797	3528
Enchytreus	50	—	466	999	200	50	950	466	533	3 062	50	150	67	200	433
Enchytronia parva	—	—	100	—	33	—	—	—	—	—	—	—	33	—	—
Henlea parpusilla	—	—	—	—	—	—	200	333	133	999	50	50	33	67	300
Henlea ventriculosa	—	—	—	—	—	550	600	200	100	300	100	50	133	500	166
Henlea juv.	—	—	67	—	—	300	50	33	233	—	—	50	100	33	33
Fridericia bisetosa	—	150	133	67	—	50	200	—	67	499	—	150	67	100	333
Fridericia bulboides	—	—	—	33	—	550	50	300	67	566	50	—	—	100	33
Fridericia galba	50	100	300	266	266	—	—	—	100	—	50	—	53	100	133
Fridericia ratzeli	—	—	300	—	—	500	100	67	67	200	400	100	166	200	233
Fridericia maculata	—	—	366	233	—	—	100	—	—	—	50	50	33	—	—
Fridericia nemoralis	—	250	366	67	366	100	350	366	33	1 864	—	350	166	366	533
Fridericia paranemoralis	—	—	33	—	—	—	100	—	100	632	—	—	—	—	33
Fridericia semisetosa	—	—	—	67	—	—	—	—	—	—	—	—	—	—	—
Fridericia connata	—	200	—	133	—	—	—	—	67	—	—	—	—	—	—
Fridericia juv.	300	400	2363	2363	899	900	2000	1864	1864	2 263	500	1550	832	832	2230
Total	12 250	1250	6700	8167	26 133	8500	5750	5467	3967	11 633	8150	3800	2900	4800	7967

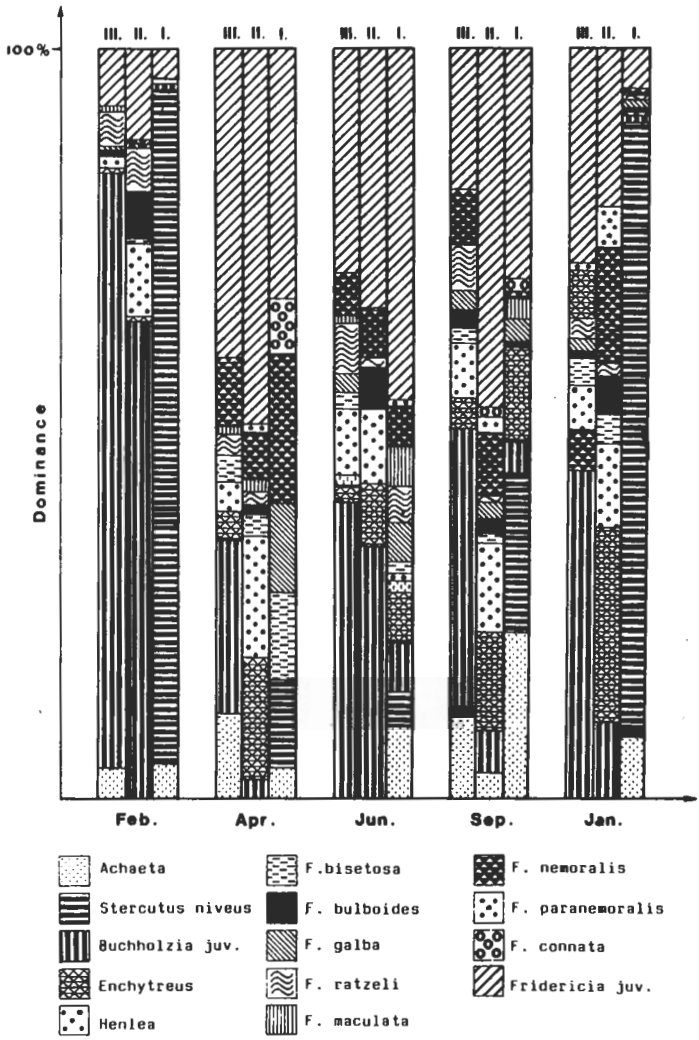

Fig. 2. Abundance of enchytraeids and their distribution in the three sites. a=fresh, well-recognizable leaves; b=highly decomposed litter; c=0—2 cm soil: d=2—5 cm soil

Dominance and diversity

The dominance conditions of the individual species for the three test areas and the dates of investigation are summarized in Fig. 3.

The most conspicuous fact is that *Stercutus niveus* only occurs (with the exception of a single datum: Sept. 1981, mixed conifers) in sampling site I (the hornbeam-oak forest) and shows an outstanding dominance in the winter months. The figure is 83.9 per cent in January, 1982, and 91.4 per cent for February, 1981.

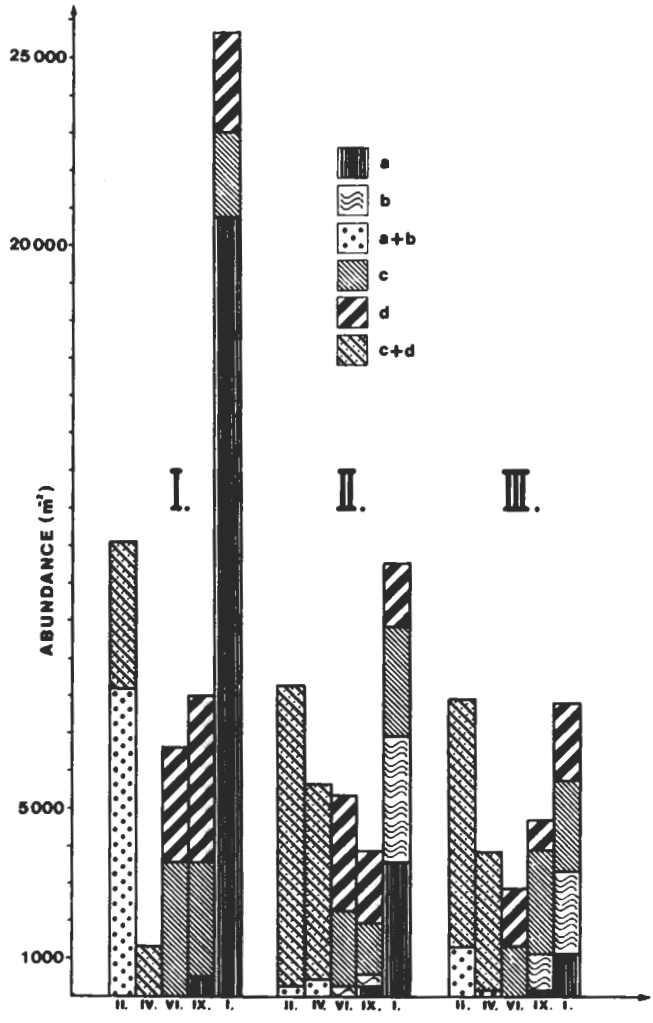

Fig. 3. Dominance conditions of enchytraeids in the period of study in the various sampling sites. I=hornbeam-oak forest; II=Pinus nigra stand; III=mixed coniferous stand

Henlea genus has also a strikingly high dominance. These worms are particularly frequent in sampling plot II, with above 10 per cent dominance and maximum value (16.5 per cent) in spring, 1981. At the same time no *Henlea* occurs in sampling plot III.

The *Enchytreus* genus, subordinate in sampling site I is also commoner in the pure pinewood (8.5—26.4 per cent), while *Buchholzia* favours mixed conifers (23.4—44.4 per cent).

Among the species collected there are two, *Fridericia galba* and *F. ratzeli*, feeding on litter. *F. galba* is active all through the year if rainfall allows, but *F. ratzeli* feeds only from late autumn to spring (DÓZSA-FARKAS, 1978). The resulting data permits the assumption that the quality of food (the composition of litter leaves) controls the occur-

rence of the two species. *F. ratzeli* is able to live in all the three sites, even conifer needles seem to be adequate food for it. *F. galba* is most often found in hornbeam-oak forests, but present in the mixed coniferous wood, too. It is absent from the pure pinewood.

The diversity and seasonal changes for the three forest associations under study are shown in Table 2. Diversity was calculated from the SHANNON formula.[1] It is obvious that in this respect the mixed coniferous forest and the pure pinewood are close in character. The dominance values show similar seasonal variation and maximal occur in the spring and autumn months.

Table 2. Diversity of enchytraeids in the three areas
(I=hornbeam-oak forest; II=Pinus nigra forest; III=mixed coniferous forest)

Date	I.	II.	III.
Feb.	0,27	0,42	0,12
Apr.	0,75	0,75	0,74
Jun.	0,64	0,61	0,99
Sep.	0,77	0,88	0,75
Jan.	0,59	0,80	0,24

Diversity in the mixed oak stand is similar in spring and autumn to that observed in the other two areas, but the difference is significant in the summer and winter months. In June the abundance of enchytraeid species is very high here, while in winter, on the opposite, there is a minimum relative to the other sites. Low diversity in winter can be explained by the outstanding dominance of a single species, *Stercutus niveus*, in this period.

The Jaccard index[2] is also suitable for the comparison between the individual stands, which shows similarity by number of species. The higher is the JACCARD index, the closer is the resemblance between the two sites (cf. Table 3; Fig. 4).

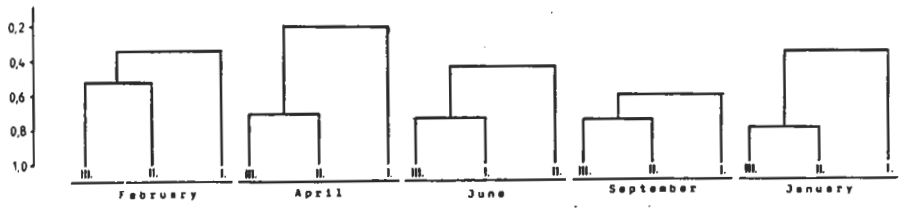

Fig. 4. Dendrograms by the Jaccard number

[1] $H_s = \sum_{i=1}^{s} \frac{n_i}{N} \cdot \log \frac{n_i}{N}$; where p_i is the number of specimens for species i, N is the number of total individuals and s is number of species.

[2] $J = \frac{c}{a+b-c}$; where c is the number of common species in the sites to be compared, a is number of total species in one of the sites and b in the other site.

Table 3. Comparison of the species numbers of enchytraeid faunae of the three forest stands by the Jaccard number

	February				April				June				September				January			
	I.	II.	III.	II—III.	I.	II.	III.	II—III.	I.	II.	III.	II—III.	I.	II.	III.	II—III.	I.	II.	III.	II—III.
I.	—	0,2	0,44	0,32	—	0,15	0,27	0,21	—	0,38	0,75	—	—	0,57	0,62	0,6	—	0,31	0,42	0,37
II.	0,2	—	0,5	—	0,15	—	0,7	—	0,38	—	0,5	0,44	0,57	—	0,75	—	0,31	—	0,8	—
III.	0,44	0,5	—	—	0,27	0,7	—	—	0,75	0,5	—	—	0,62	0,75	—	—	0,42	0,80	—	—
II—III.	0,32	—	—	—	0,21	—	—	—	—	0,44	—	—	0,6	—	—	—	0,37	—	—	—

Although there is seasonal variation over the period of study in the similarity between sampling sites, with the exception of summer, when the stands I and III are closest to each other, the highest correspondance was found between the enchytraeid faunae of sites II and III. With regard to number of species the similarity was greatest in January, 1981.

Discussion

Summarizing the results concerning the Enchytraeidae of the three sampling plots, the following conclusions are drawn: 1. there is no significant difference in species numbers, but 2. the deviations in dominance are more striking.

The results allow the statement that — disregarding the samples taken in September — *Achaeta* is missing from site II. In the investigations the members of this genus were only found in layers c and d, therefore, their absence is probably due to changes in soil quality.

Another striking observation is the absence of *Stercutus niveus* from areas II and III. In winter this species is abundant in the litter of deciduous forests and retreats to depth in other seasons, but their number is still large in the litter. In samples from site II, this species does not occur, while in plot III some specimens were found on one occasion (in September) with abundance: 67 specimens per m^2. Comparing this to the number of individuals in site I (1764 specimens per m^2), the huge difference is evident.

Enchytronia parva, described by ABRAHAMSEN (1972) to occur in great percentage in the northern coniferous forests, was not found either in site II. It occurs in plots I and III, but in a relatively small number (33—100 specimens per m^2).

One of the larger worms feeding on litter, *Fridericia galba*, does not generally occur in pinewood. It only occurs on one occasion (in September) in the samples, while they are permanently present in the other two areas. The maximum specimen number is 330 per m^2, observed in the hornbeam-oak forest. It seems that for *Stercutus niveus* and *Fridericia galba* conifer needles are not proper food.

Another large-body worm feeding on litter, *Fridericia ratzeli*, appears to favour plots II and III and is found there in large numbers, especially in the winter months. The highest density of individuals was observed in area II (500 specimens per m^2). In his investigations in the northern forests, ABRAHAMSEN found this species only in one area, in small numbers, but they seem to have adjusted to the available sources of nutrients quite successfully under this different climatic conditions in Hungary. In winter and early spring they are likely to play an important role in the decomposition of conifer needles (ABRAHAMSEN, 1972).

It is striking that the *Henlea* genus is almost completely missing from the hornbeam-oak stand. There is also a significant difference between plots II and III in the occurrence of both *Henlea perpusilla* and *H. ventriculosa*. Except in September, both species occur in double numbers in the coniferous forest than in the mixed ones.

In the mixed stand *Buchholzia* is present in large numbers all over the year, amounting to 23—81 per cent of all animals collected. They are less common in the pinewood, while they are scattered and infrequent in the mixed oak forest. The maximum density of individuals in the mixed stand is 6550 specimens per m^2, while the corresponding value for the mixed oak forest in only 433 specimens per m^2.

Comparing abundances, there are significant differences between the three sites. The number of enchytraeid specimens drops 30—50 per cent moving from the zonal hornbeam-oak forest to the planted pinewood. In April, because of the unfavourable moisture conditions, the animals may have retreated to the deeper soil layers or died,

therefore they occur in low abundance in the mixed oak forest. In the other two sites no such minimum was observed. This is explained by the higher moisture content of needle litter. Comparing the abundances in areas II and III, the difference is not striking, but the general trend is that there are more worms in the pinewood than in the mixed stand.

As it is known from the literature on enchytraeid, these animals prefer acidic soils rich in plant remnants and raw humus, e. g. they are abundant in coniferous woods (LOFTY, 1874). The maximum density of worms in the *Pinus nigra* stand we studied was 11 633 specimens per m^2. This figure is far below that for zonal coniferous stands. In a Norwegian pine wood, for instance, maximum density of individuals was 47 800 per m^2, in North-Wales fivefold higher, 250 000 per m^2 (O'CONNOR, 1957). It has to be emphasized, however, that none of the species described by ABRAHAMSEN and other authors as dominant in pine forests was found in our sites of study (ABRAHAMSEN, 1972). In zonal pinewoods, 70—95 per cent of the fauna there is constituted by *Cognettia sphagnetorum* and members of the *Mesenchytraeus* genus.

On the basis of the above it seems possible that the original enchytraeid fauna of hornbeam-oak forest woods is unable to adjust properly to the new environment created by the plantation of conifers. It is likely that importing dominant enchytraeids into our forests with this poor fauna and slowly decomposing litter, a favourable influence could be exerted on litter decomposition. Naturally to decide this problem, further experimentation is needed.

Investigating the number of species encountered, it seems that mixed plantation is more beneficial than monoculture. In areas with mixed stands some species are found (*Stercutus niveus, Enchytronia parva, Achaeta, F. maculata, F connata*), which are sparse in coniferous forests or do not occur at al. At the same time, the species which show high dominance in the pinewood as opposed to the mixed oak forest (*Buchholzia* juv., *F. ratzeli, F. bulboides* and *Enchytraeus*) are also present here.

In this respect, it could be more useful in economic reforestation if deciduous tree species, carefully selected, were planted together with the conifers in the new stands.

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