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A quantitative approach to the Red List of larger fungi in the Netherlands

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Summary – Recently a new Red List of threatened and vulnerable larger fungi in the Netherlands has been published, based on quantitative criteria. The criteria are the actual frequency of a species, expressed in number of grid units (5x5 km) reporting the specific population, and the trend, expressed as the quotient between present and former frequency. The aims and methods of this new approach are described and some examples and general results are presented. Some complications and limitations of quantitative methods are discussed. A comparison is made between the new Red List and the preliminary Red List, published in 1989 and composed on the basis of expert judgement only. It is concluded that the results of the two approaches show much resemblance to each other and that both of them are valuable tools for the conservation and management of fungi.

Zusammenfassung – Eine neue Rote Liste der gefährdeten und bedrohten Pilze Hollands, gestützt auf quantitative Kriterien, wurde vor kurzem veröffentlicht. Die Kriterien sind die jetzige Häufigkeit der Arten, ausgedrückt in der Anzahl Planquadrate (5x5 km) aufs Staatsgebiet, die einen Bestand aufweisen, und der Trend, ausgedrückt als Quotient zwischen der heutigen und der früheren Häufigkeit. Die Ziele und Methoden dieser neuen Auffassung sind beschrieben und einige Beispiele sowie quantitative Resultate sind dargelegt. Ein Vergleich zwischen der neuen Roten Liste und der vorausgehenden, aus dem Jahre 1989, die nur auf Experten-Beurteilungen basiert, wird vorgestellt. Die Schlussfolgerung zeigt, dass die Ergebnisse der beiden Annäherungswege sehr ähnlich sind und dass beide gültige Voraussetzungen für die Erhaltung und das Management der Pilze darstellen.

Résumé - Basée sur des critères quantitatifs, une nouvelle Liste rouge des espèces de macromycètes menacés a récemment été publiée en Hollande. Les critères sont la fréquence d'apparition actuelle, exprimée en nombre de carrés (5 x 5 km) dans lesquels l'espèce a été signalée, et la tendance, qui s'exprime comme le quotient des fréquences d'apparition dans le présent et dans le

passé. Les objectifs et les méthodes de cette nouvelle approche sont décrits, quelques exemples et résultats généraux sont présentés. L'auteur commente quelques difficultés et limites rencontrées en utilisant ces méthodes. Une comparaison est établie entre la nouvelle Liste rouge et celle publiée en 1989 qui était basée uniquement sur des critères qualitatifs comme l'appréciation d'experts. On peut conclure au fait que les deux approches sont intéressantes car montrant des similitudes dans leurs résultats. Ce sont les deux des outils pouvant être utilisés dans les travaux sur la conservation et la gestion des champignons.

Introduction

Red Lists, comprising enumerations of threatened organisms, are edited at regular intervals by the International Union for Conservation of Nature (e.g. IUCN, 1993). Such lists provide surveys on the status of species belonging to particular groups of organisms on a global scale. The status of a species depends in principle on the size and trend of the population or distribution area. It has become a good custom to compose comparable Red Lists for smaller geographical units, mostly nations or federal states.

No IUCN list for fungi is available at present, but Red Lists have been edited independently in several European countries. Surveys of such lists have been published by Arnolds & De Vries (1993) and Lizon (1993). On the basis of the available national and regional lists an attempt has been made to compose a preliminary Red List of larger fungi in Europe (Ing, 1993). Quite recently attention for threatened fungi has strongly increased in North-America as well, stimulated by concern on both the disappearance of old-growth forests with their associated organisms and the effects of mass harvesting of edible mushrooms (Pilz & Molina, 1996). In the pacific northwestern states 234 fungal species were listed as deserving special concern and extensive surveys are planned to find high priority sites for species management.

The status of national Red Lists varies from country to country. In Austria (Krisai, 1986) and Finland (Rassi & Väisänen, 1987) Red Lists of fungi were, together with lists of other organisms, edited by the government and therefore they have an official status. In most other countries Red Lists were published on the initiative of mycological societies, other groups of experts, or individual mycologists. So far the composition of Red Lists of fungi has been based on subjective, qualitative criteria, in fact the combined field knowledge of experienced mycologists who estimated which species are rare and/or decreasing. This informal approach has some disadvantages: (1) The reliability of the conclusions may be disputed by officials, as well as by other mycologists (e.g.

Orton, 1994); (2) It is impossible to compare between different national lists since the applied criteria are variable. For instance, the number of species included in lists of European countries varies from 123 tot 1032 without bearing a distinct relation between these numbers on the one hand and the richness of the mycoflora or prevailing ecological conditions on the other (Arnolds & De Vries, 1993). Therefore it is also difficult to assess the international status of a particular species; (3) It is impossible to evaluate Red Lists periodically on a formal basis, which is a desire of nature conservation organisations and governmental agencies. These organisations are interested in the efficiency of their policies and measures, e.g. the effects of habitat protection or reduction of environmental pollution on organisms, *in casu* fungi. For this purpose more or less objective criteria for the status of species are necessary.

The aims of this paper are to present an outline of the quantitative methods used and to deal with some results of the newly published Red List of larger fungi in the Netherlands and to compare them with the preliminary list of 1989, based on partially different methods and criteria.

Material and methods

In the Netherlands the first, preliminary Red List of larger fungi was published in 1989, based on expert judgement by a small group of experienced mycologists (Arnolds, 1989). This list had no formal status but drew the attention of mycologists, nature conservationists and governmental agencies to the fact that many species were considered as declining and threatened. Its publication stimulated also the gathering of additional data on distribution and ecology of rare fungi (e.g. Jalink, 1989).

The selection of species to be included in this preliminary list was based on four criteria: (1) Estimated frequency (also expressed as rarity) in the Netherlands; (2) Estimated decrease in frequency during this century; (3) Occurrence in threatened or vulnerable habitats; (4) Durable existence of habitats, since species from strongly synanthropic sites (e.g. gardens, ruderal places) and ephemeral substrates (dung, compost piles, burnt sites) were in general omitted (Arnolds, 1989).

In the early nineties the Ministry of Agriculture, Nature Management and Fisheries decided to draw up official Red Lists for various groups of organisms, with the intention to repeat this exercise with intervals of about 10 years. With the publication of these lists the government engages to carry out measures in order to reduce the numbers of threatened species in future. For Red Lists the ministry has developed a standard methodology based on measurable criteria, to be applied – with some modifications – for all groups

of organisms. The Red List of larger fungi was the fourth official list in the Netherlands after those of birds, mammals and butterflies. The drafting of the list of fungi was awarded to the Netherlands Mycological Society, which owns the data base on distribution of fungi in the Netherlands. The principal criteria for this new list were prescribed by the Ministry. The status of a species in all official Red Lists should depend exclusively on (1) the frequency or rarity expressed as the number of national grid squares (5x5 km) in which the species occurs in recent times and (2) the trend or the percentual change in frequency when the actual frequency is compared with the frequency in the past (Lina & Van Ommering, 1994). Thus the preliminary list was based on expert judgement of *estimated* frequency and decrease in combination *with* ecological criteria; the new list on *measured* frequency and decrease *without* ecological considerations.

In agreement with IUCN (1993) all species of fungi were assigned to one of four main categories, in most cases divided into several subgroups (Table 1). The position of a fungus in any of the (sub)categories of threatened species is based on a combination of rarity and decrease, as expressed in the matrix of Table 2. For instance, a species is considered as critical if it is very rare (recently found in less than 10 grid squares out of 1674 grid squares in the

Table 1: Categories of species according to IUCN (1993), adapted for the Netherlands.

1.	**Disappeared** (included in Red List)	
	EX	Extinct
	EW	Extinct in the wild
	DI	Disappeared from the Netherlands
2.	**Threatened** (included in Red List)	
	CR	Critical
	EN	Endangered
	VU	Vulnerable
	SU	Susceptible
3.	**Not threatened at present** (not included in Red List)	
	S/LR	Safe/low risk
4.	**Unknown** (not included in Red List)	
	IK	Insufficiently known
	NE	Not evaluated

Table 2: Criteria for assignation of species of larger fungi in the Netherlands to categories on the basis of trend and frequency (from Arnolds & Van Ommering, 1996, adjusted).

Trend	very rare	rare	rather rare	not rare
constant/ increase (+ . . 0%)	Susceptible	Safe/low risk	Safe/low risk	Safe/low risk
weak decrease (– 25%)	Susceptible	Safe/low risk	Safe/low risk	Safe/low risk
decrease (– 50%)	Vulnerable	Vulnerable	Vulnerable	Safe/low risk
strong decrease (– 75%)	Endangered	Endangered	Vulnerable	Susceptible
very strong decrease (– 100%)	Critical	Endangered	Vulnerable	Susceptible
Frequency (number of grid units)	10	50	125	

Netherlands) and at the same time the number of grid squares has been reduced by at least 75%. Species are classified as susceptible when they are very rare (less than 10 grid squares) and at the same time increasing, constant or decreasing less than 25%, or when they are still rather common (≥ 125 grid squares) but decreased over 50%.

The prescribed methods can only be carried out successfully on the basis of an extensive set of distributional data, collected over a long time span. In the Netherlands such a data base has been developed since the establishment of a working group on mapping of fungi by the Netherlands Mycological Society in 1980. The purpose of this working group with c. 200 field workers is to collect all available distributional data on fungi, including older records. An atlas with annotated maps of 370 selected species was published by Nauta & Vellinga (1995). In addition 80 distribution maps were published by Arnolds et al. (1995). The calculations for the Red List were based on all 532 000 records available in summer 1993. In the meantime this number has increased to over 750 000.

For the determination of the trend of fungal species it would have been preferable if the actual frequency (expressed as number of grid units of 5x5 km) could be compared with the frequency in the past, for instance around 1950.

However, this is impossible for fungi in the Netherlands since only few older records are available: approximately 12 000 from before 1950 (2% of all data) and about the same number from the decade 1950–1959. The number of records increased to 10 000–25 000 per year around 1980 and 70 000–100 000 per year around 1990. Therefore the data set was divided into two parts of equal size, the median being January 1, 1986. For each species the number of grid squares was calculated before and after this date. The number of grid squares since 1986 represents the actual frequency, the X-axis in Table 2. The number of grid squares before 1986 represent the former frequency. The quotient of actual and former frequency is an expression of the trend (increase or decrease) of a species, the Y-axis in Table 2. The category "disappeared" in the Red List is not determined by the year 1986, which is too recent for reliable conclusions. Disappeared species were arbitrarily defined as species not recorded since 1975.

All together 3502 of larger fungi have been observed in the Netherlands (Arnolds et al., 1995). Among these fungi, 22 species were excluded for the Red List because they were regarded as ephemeral, exotic species (e.g. *Lysurus cruciatus* (Lepr. & Mont.) Lloyd, *Clathrus ruber* Pers.: Pers.) or they grow only inside buildings (e.g. *Leucocoprinus birnbaumii* (Corda) Sing. and allies). They fall into the IUCN category "not evaluated" (Table 1). In addition, 1022 species were not considered for the Red List because their taxonomic status was unclear (296 species) or their distribution was inadequately known (726 species). To this group belong many fungi with small or obscure sporocarps, in particular small discomycetes and resupinate Aphyllophorales and Heterobasidiomycetidae. These species belong to the IUCN category "Insufficiently known" and a proportion of them may in fact fit into one of the Red List categories.

Consequently, 2475 species were, rather arbitrarily, regarded as sufficiently known to carry out calculations on frequency and trend in order to determine their category. Representative examples of calculations are presented in Table 3.

Results

The official Red List of larger fungi in the Netherlands was announced in the Governmental Gazette on November 5, 1996, with reference to the complete list in the technical report, treating material, methods and results (Arnolds & Kuyper, 1996). In addition the Ministry of Agriculture, Nature Management and Fisheries published a more popular booklet, containing the complete Red List, information on ecology of various threatened groups of fungi and on environmental factors causing a decline of the mycoflora as well as colour photo-

Table 3: Examples of calculations for the determination of the status of fungal species on the new Red List of larger fungi in the Netherlands (from Arnolds & Kuyper, 1996).

n<86: number of grid units (5x5 km) before Jan. 1, 1986.
n>86: number of grid units (5x5 km) after Jan. 1, 1986.
±%: proportional increase of decrease in number of grid units.
year: year of last recording in the Netherlands.

	n<86	n>86	±%	year
1. Disappeared (not observed after Jan 1., 1975)				
Bankera fuligineoalba (Schmidt:Fr.) Pouzar	14	0	–100	1968
Boletus fechtneri Velen.	3	0	–100	1974
Cortinarius napus Fr.	1	0	–100	1902
Hydnellum caeruleum (Hornem.:Fr.) P.Karst.	16	0	–100	1956
Hygrophorus russula (Fr.:Fr.) Quél.	5	0	–100	1935
2a. Critical				
Boletus aereus Bull.: Fr.	6	0	–100	1984
Boletus calopus Pers.:Fr.	32	5	–84	>1986
Cantharellula umbonata (J.F.Gmelin:Fr.) Sing.	43	4	–91	>1986
Geastrum quadrifidum Pers.:Pers.	18	2	–89	>1986
Sarcodon imbricatus (L.:Fr.) P.Karst.	43	1	–98	>1986
2b. Endangered				
Boletinus cavipes (Opat.) Kalchbr.	71	20	–72	>1986
Boletus impolitus Fr.	18	5	–72	>1986
Clavulinopsis corniculata (Schaeff.:Fr.) Corner	66	24	–64	>1986
Cortinarius alboviolaceus (Pers.:Fr.) Fr.	79	18	–77	>1986
Hygrocybe reidii Kühner	3	1	–67	>1986
2c. Vulnerable				
Boletus parasiticus Bull.:Fr.	118	85	–28	>1986
Boletus queletii S.Schulz	9	5	–44	>1986
Clavulinopsis helveola (Pers.:Fr.) Corner	112	59	–47	>1986
Coprinus angulatus Peck	33	17	–48	>1986
Russula viscida Kudrna	6	4	–33	>1986
2d. Susceptible				
Boletus speciosus Frost	0	2	+...	>1986
Clavaria asterospora Pat.	7	7	0	>1986
Lepiota carini Bres.	1	4	+300	>1986
Leucoagaricus meleagris (Sow.) Sing.	1	1	0	>1986
Russula queletii Fr.	8	7	–12	>1986
3. Safe/low risk				
Boletus edulis Bull.:Fr.	380	379	0	>1986
Boletus erythropus Pers.:Fr.	223	183	–18	>1986
Boletus subtomentosus L.:Fr.	197	139	–29	>1986
Coprinus cortinatus J.Lange	18	14	–22	>1986
Leucoagaricus sericeus (Cool)M.Bon & Boiffard	5	11	+120	>1986
Schizopora flavipora (Cooke) Ryvarden	22	218	+891	>1986

graphs of selected species (Arnolds & Van Ommering, 1996). For the complete Red List the reader is referred to one of these publications. In this paper only some striking results are summarized.

The Red List comprises 1655 species, 67% of all considered (sufficiently known) species. In other words, only 820 species (33%) are not regarded as threatened or disappeared at present. The proportion of threatened species in larger fungi seems to be very high, but in fact is of the same magnitude as in butterflies (67%, Van Ommering et al., 1995) and reptiles and amphibians (65%, Hom et al., 1996) in the Netherlands. The susceptible species form the largest category with 628 species. For the rest 202 species of fungi are considered as disappeared, 253 as critical, 289 as endangered and 283 as vulnerable.

The distribution of Red List species over the main taxonomic groups is presented in Table 4. The majority of species (71%) belongs to the Agaricales, which is also by far the largest group. Over half of the species of Phragmobasidiomycetidae and Ascomycotina are insufficiently known and therefore not considered for the Red List. Gasteromycetes (73%) and Agaricales (69%) comprise the highest proportions of threatened species. The highest proportion of disappeared species (12%) is found in the Aphyllophorales.

Table 4: Numbers of species in the Red List of the Netherlands in different taxonomic groups of larger fungi.

	All fungi	Agaricales	Aphyllophorales	Phragmobasidiomycetidae	Gasteromycetes	Ascomycotina
Number of species	**3502**	**1992**	**546**	**83**	**95**	**786**
Not considered	22	17	0	0	2	3
Insufficiently known	1005	281	200	860	3	461
Sufficiently known	**2475**	**1694**	**346**	**23**	**90**	**322**
Disappeared	202	128	38	1	9	26
Critical	253	176	27	0	11	39
Endangered	289	202	45	1	13	28
Vulnerable	283	219	29	1	7	27
Susceptible	628	442	75	7	23	81
Total Red Lists	**1655**	**1167**	**214**	**10**	**63**	**201**
% Red List species	*67*	*69*	*62*	*43*	*73*	*62*
Safe/low risk	820	527	132	13	27	121

Table 5: Numbers of species in different categories of the Red List of the Netherlands with preference for certain habitat types.

	wet	deciduous forests rich	deciduous forests poor	deciduous forests others	coni-ferous forest	road-sides with trees	heath-land, moors	grass-land	sea coast	synan-tropic
Sufficiently known	127	631	173	273	313	196	124	285	37	135
Disappeared	5	50	12	27	43	17	17	4	1	5
Critical	9	56	22	10	49	35	19	29	4	4
Endangered	17	56	26	19	58	31	15	43	5	12
Vulnerable	14	68	17	16	33	34	18	44	5	22
Susceptible	32	207	25	39	70	45	28	85	11	32
Total Red List	**77**	**437**	**102**	**111**	**253**	**162**	**97**	**205**	**26**	**75**
% Red List species	*61*	*69*	*59*	*41*	*81*	*83*	*78*	*72*	*71*	*56*
Safe/low risk	50	194	71	162	60	34	27	80	11	60

The distribution of Red List species over various important habitat types is indicated in Table 5. In absolute numbers, deciduous forests on relatively rich and/or calcareous soils are the richest in Red List fungi. In particular the proportion of susceptible (rare, but not significantly decreasing) species is high (33%). However, the proportion of Red List species is considerably higher in heathlands and moors (78%), coniferous forests (81%) and roadsides with planted trees (83%). Disappeared species are also best represented in heathlands and moors (14%) and coniferous forests (14%). In the Netherlands, the surface covered by heathlands and moors has strongly diminished in this century by reclamation. The remaining areas suffer of desiccation, acidification and eutrophication with negative effects on the mycoflora. The surface of coniferous forests has drastically increased in the Netherlands, but the mycoflora in this habitat type has become strongly impoverished, mainly due to deposition of airborne nitrogen (Termorshuizen & Schaffers, 1991). In particular ectomycorrhizal fungi are in decline, but also many wood-rotting fungi associated with conifers are decreasing and replaced by ubiquitous lignicolous species. Roadsides with trees on clayey soils form in the Netherlands an important habitat for ectomycorrhizal species, elsewhere known from deciduous forests on rich calcareous soils (Keizer et al., 1995). In addition, roadsides planted with trees on sandy soils are an important refugium for ectomycorrhizal fungi which were formerly widespread in deciduous forests on poor soils (Keizer & Arnolds, 1995).

With respect to functional groups, the highest proportion of declining species (categories disappeared, critical, endangered and vulnerable) is found

among the ectomycorrhizal fungi (57%), followed by biotrophic parasites (48%) and saprotrophs on soil (43%). No less than 27% of all ectomycorrhizal species are classified as critical or disappeared.

The number of species in the Red List of larger fungi has grown from 944 in 1989 (Arnolds, 1989) to 1655 in 1996 (Arnolds & Kuyper, 1996). The strong increase of 75% is caused by several factors:

(1) In 1989 a conservative selection was made of fungi to be considered for the Red List; only the more striking species were selected. In 1996 all species with sufficient distributional data were screened. Therefore the proportion of lesser known taxonomic groups increased relatively stronger: the number of Gasteromycetes in the 1996 list increased by 47%, Agaricales by 64%, Aphyllophorales by 88%, Ascomycotina by 179% and Phragmobasidiomycetidae by 400%.

(2) In 1989 most species of ephemeral habitats were omitted, but in 1996 no ecological selection was made. This led to the surprising discovery that fungi of burnt wood belong to the groups with the strongest decline. Of the 47 species in the Netherlands 45 (96%) were included in the new Red List, including 6 disappeared species (13%) and 12 critical species (26%) (Arnolds & Kuyper, 1996).

(3) The quantitative data analysis revealed that much more species are actually decreasing than assumed on the basis of a subjective expert judgement.

(4) In particular the group of susceptible species increased strongly, from 239 in 1989 to 628 species in 1996, because in the latter list all very rare species are incorporated, not only the striking ones.

In addition, the number of threatened species might have increased in reality, due to decline of the mycoflora within the period 1989-1996. This possibility cannot be excluded, but there are no good indications for the validity of this supposition. Only the application of quantitative criteria can answer such questions in future.

Among the 944 species of the 1989 list, 879 were also considered for the new version. Of the 65 neglected species, 29 were not studied because they are now classified as insufficiently known. The other species are at present considered as intraspecific taxa, synonyms of other species or not indigenous (Arnolds et al., 1995).

Of the remaining 879 sufficiently known species, 795 (90%) were also incorporated in the new Red List. The 84 species which were not included are at present placed in the category safe/low risk. The different estimation of their position is in some cases caused by the application of partially different criteria. For instance, *Boletus subtomentosus* is not included in the new list in spite of its considerable decline; its frequency is at present still too high to meet the criterium of rarity (Table 3). Most species of this group, however, appeared to be more widespread or less decreased than supposed in 1989. In general a good cor-

relation exists between the classification of individual species into one of the Red List categories in 1989 and 1996: The highest proportion of fungi, placed in 1989 in the category critical, is again assigned to that category in 1996. This applies to other categories as well. Other species shifted places, for instance from critical to endangered or, less often, to disappeared, vulnerable or susceptible.

Discussion

A quantitative approach to Red Lists has several advantages above the usual approach based on expert judgement: (1) the results are in principle objective and reproducible, independent from personal views; (2) the status of species can be re-evaluated on a numerical basis from time to time; (3) lists of various regions can be compared on a solid basis when the same methods are used and (4) the results are more easily accepted by scientists and governmental agencies.

However, there are also several limitations and disadvantages to the application of quantitative criteria.

(1) This approach depends on the existence of a representative set of distributional data, collected over a long time span. It costs many efforts and much time and money to constitute and maintain such a data base.

(2) The frequency of a species is in this case expressed in the number of grid squares of 5x5 km, as an (arbitrary) unit for the number of populations. In fact within a single grid unit many populations may be found. Therefore the chosen grid size gives a conservative estimation of the true decline of a species: only when the last locality within a grid unit is lost, the species is noted as absent. For instance, *Boletus erythropus* has rather strongly decreased according to many mycologists in the Netherlands and it was listed as threatened in the preliminary Red List (Arnolds, 1989). However, the measured decline is not sufficient to meet the criteria for the new Red List (Table 3). In many areas this bolete has been decimated, but small relic populations survived in roadsides with trees, sufficient for a dot on the map.

(3) Older data are in the case of fungi always strongly underrepresented. Therefore adaptations of the methodology are necessary, which may influence the results (Arnolds & Kuyper, 1996).

(4) Changing taxonomical and nomenclatural concepts are pitfalls for a straightforward application of quantitative criteria. In some cases species have to be excluded or taken together to collective species.

(5) Data on many groups of fungi have not been randomly collected throughout the considered time span. For instance, in the first half of this century mycological activities in the Netherlands were mainly focused on the central part of the country and on forest communities. Grasslands were hardly studied, reason why the enormous decline of grassland fungi is not adequately

expressed in the new Red List. Temporarily special attention has been paid by specialists and monographers to particular taxonomic groups of fungi, which has led to the accumulation of data on these fungi in a certain period, another complication in the interpretation of quantitative data.

(6) The strong fluctuations in fruiting of many species complicate the comparison between different periods, in particular with respect to rare species. For instance, a species observed in two grid squares before 1986 and one square after that year should be classified according to the adapted criteria (Table 2) as threatened (decrease ≥50%; rarity <10% grid squares). However it is quite possible that one of the localities has not been recently visited by a mycologist in the right season. In such cases the category of a species was usually adjusted and in this case changed into susceptible, except when indications existed that one of the localities had really disappeared.

Thus, a rigid application of quantitative criteria for the assignation of species to a certain Red List category is not feasible and undesirable. The use of common sense remains necessary. In the case of the Red List of fungi in the Netherlands, expert judgement has played an additional role in the classification of 206 species, 8% of all considered species.

A comparison between Red Lists, based on newly applied quantitative methods and on previous expert judgements demonstrated that the results show much resemblance. Also Red Lists composed by a team of experienced mycologists can be useful and reliable. Both types of lists can stimulate research on distribution and ecology of fungi, the necessary basic knowledge for adequate conservation and management of fungal populations.

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