Tropical Ecology **53**(1): 25-32, 2012 ISSN 0564-3295

www.tropecol.com

Impact of human-related disturbance on *Eriochrysis rangacharii* Fischer, a rare keystone endemic grass (Nilgiris, southern India): a preliminary assessment

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Abstract: We assessed the factors influencing the perceived decline of *Eriochrysis rangacharii*, a rare endemic swamp grass species of the Nilgiri plateau (Western Ghats of India), which had been listed as "presumed extinct" for over 100 years in the Red Data Book of Indian Plants. This grass is used by the Todas, a local ethnic community, to thatch their temple roofs. We conducted the study in 2001 - 2002 in five swamps in the Upper Bhavani region of the Nilgiris: two swamps were intensively grazed by livestock, one was burnt in 1995, one was surrounded by exotic pine plantation, and the last was an "undisturbed" control. We recorded species richness, the number of native/exotic species, and frequency of occurrence, cover, and average height of *E. rangacharii* in each swamp. Disturbance, particularly grazing, affected *E. rangacharii* and increased the proportion of invasive species.

Resumen: Evaluamos los factores que influyen sobre el decremento observado de *Eriochrysis rangacharii*, una especie de pasto rara y endémica de pantano de la meseta Nilgiri (Ghates Occidentales, India), la cual apareció enlistada como "supuestamente extinta" durante más de 100 años en el Libro de Datos Rojo de las Plantas de la India. Este pasto es usado por los Todas, una comunidad étnica local, para el techado de sus templos. Llevamos a cabo el estudio en 2001-2002 en cinco pantanos en la región de Bhavani Superior de los Nilgiris. Dos pantanos estaban pastoreados intensamente por el ganado, uno había sido quemado en 1995, uno estaba rodeado por una plantación de pinos exóticos, y la última era un control "sin disturbio". Registramos la riqueza de especies, los número de especies nativas y exóticas, y la frecuencia, la cobertura y la altura promedio de *E. rangacharii* en cada pantano. El disturbio, sobre todo el pastoreo, afectó a *E. rangacharii* e incrementó la proporción de especies invasoras.

Resumo: Os factores que influenciam o declínio percebido da *Eriochrysis rangacharii*, uma espécie gramínea endémica rara dos pântanos do planalto Nilgiri (Western Ghats da Índia), que havia sido listada como "presumível extinta" por mais de 100 anos no Livro Vermelho das Plantas da Índia,foram avaliados. Esta erva é usada pelos"Todas", uma comunidade étnica local, para cobrir os telhados de palha dos seus templos. O estudo foi conduzido em 2001-2002, em cinco pântanos na região do Alto Bhavani do Nilgiris: dois dos pântanos eram intensamente pastados, um foi queimado em 1995, outro estava cercado por uma plantação de pinheiros exóticos, e o último foi o controlo, não disturbado. Registou-se a riqueza de espécies, o número de espécies nativas / exóticas, e a frequência da ocorrência, a cobertura e a altura média da *E. rangacharii* em cada pântano. A perturbação, particularmente o pascigo, afectou *E. rangacharii*

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e aumentou a proporção de espécies invasoras.

Key words: Conservation, disturbance, *Eriochrysis rangacharii*, grassland, India, Nilgiris, swamps.

Introduction

Rare species are at greater risk of extinction than widespread and common species (Rabinowitz 1981; Rabinowitz *et al.* 1986). Rarity can be related to the inherent biology of a species with restricted ranges, low population sizes, and habitat specificity. Rarity can also be entirely human-induced by overexploitation or habitat loss. For example, any species can become more vulnerable to extinction if inherent rarity is compounded by human impact. One such inherently rare species is *Eriochrysis rangacharii* (Fischer), an endemic swamp grass species restricted to the upper montane region of the Nilgiri plateau in southern India (Fig. 1) and recorded as "presumed extinct" for over 100 years in the Red Data Book of Indian Plants (Nayar & Sastry 1987). This species has conspecifics in South America and Africa. *E. rangacharii* was recently rediscovered because it has been used in the traditional housing material of the Todas, a small pastoral community of *ca.* 1,000 people (Blasco 1971; Puyravaud *et al.* 2003). Some Todas still maintain an ancestral lifestyle of buffalo herding and use local grasses for thatching the roofs of their temples and houses, and prefer *E. rangacharii* to other grasses. The Todas noted that this grass was decreasing in abundance in the south-western part of the Nilgiris and wanted to understand the causes of its decline.

Historically, the main cause of the decline of *E. rangacharii* was probably land-use change. The area under grasslands in the upper Nilgiri plateau has been reduced by a staggering 84 % between 1849 and 1992, mainly lost to plantations of tea introduced in the 1830s (Kumar 2002). From 1939 onwards the policy was to replace the grasslands with *Acacia* and *Eucalyptus* to provide fuel-wood and other products (Blasco 1971). Grasslands were considered secondary plant communities, i.e., a result of human impact, unlike forests, which were considered primary (Champion & Seth 1968; Whyte 1968).

Most of the eastern Nilgiri plateau has been converted to agriculture, plantations, and settlements. The west of the plateau (particularly Upper Bhavani) is better protected. *E. rangacharii* still occurs there in some of the swamps but the decline noted by the Todas could be a result of several factors. Land-use change is no more an overwhelming issue but overgrazing by livestock, burning, and the impact of pine plantations, might be playing a role in the supposed species decline. The purpose of this paper was to identify factors that could be contributing to the decline. We selected five swamps of which two were grazed by cattle, one was burnt in 1995 (Toda sources), and one was adjacent to a 30-year old pine plantation; the fifth swamp, with no cattle grazing, burning or neighbouring plantations served as the control. The "control" swamp did have sporadic grazing by Toda buffaloes and a low intensity grazing pressure by wild herbivores. We assumed these characteristics represented the conditions under which the ecosystem had existed since the colonization of the Nilgiris. In other words we assumed that the "control" site represented the original conditions under which other swamps existed prior to additional disturbance brought about since the 1840s.

We could not carry out experiments on the populations, since the status of *E. rangacharii* was considered extremely precarious, and therefore, we limited ourselves to observations. Our objective was to see whether (i) swamps differed in species richness and invasibility (proportion of native species versus exotic invasive species), and (ii) whether cover, frequency of occurrence, and mean height of *E. rangacharii* would differ between swamps with various disturbance or stress regimes.

Study area

The Nilgiris form a highland plateau (with elevation ranging from 1800 to 2630 m a.s.l.) at the southern junction between the Eastern Ghats and

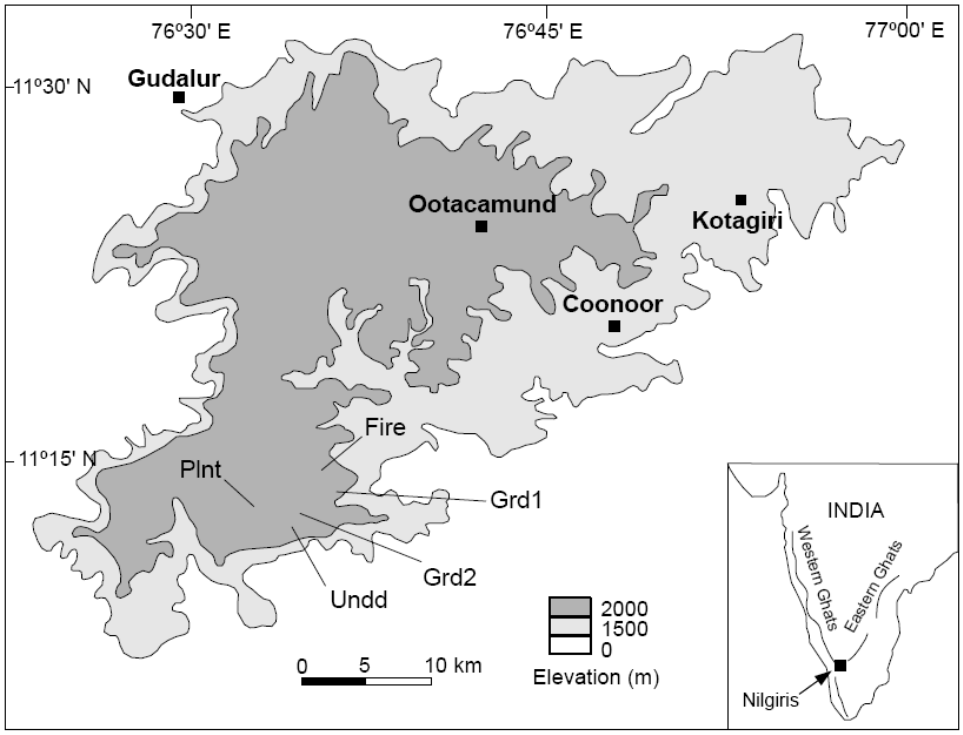

Fig. 1. Study area and location of studied swamps.

the Western Ghats mountain ranges. The plateau is flanked by steep escarpments on all sides, dropping down to the Karnataka plain to the north (*ca.* 850 m a.s.l.), the Malabar coast of Kerala to the west (*ca.* 250 a.s.l.), and the Tamil Nadu plain to the south and east (*ca.* 400 m a.s.l.).

The Nilgiri plateau covers an area of *ca.* 2,000 km^2. The climate is of the tropical montane type (Meher-Homji 1967). The mean monthly temperature varies between 5 °C in January to 24 °C in April (von Lengerke 1977) and frost occurs in valleys in winter. The dry season lasts from December to March. The mean annual rainfall recorded at Korakundah tea estate between 1996 and 2001 was 2,076 mm. The area is exposed to the southwest monsoon during June - September and to the northeast monsoon during October-November. The bedrock is composed of charnockites and granitoid gneisses (Fermor 1936 - 40 in Blasco 1971) and the soils are classified as andisols (Caner *et al.* 2000).

The vegetation is a mixture of stunted forest (locally called sholas), and grasslands. The swamps occur in valleys. The sholas are upper montane rainforests (Ashton 2003; Whitmore 1990) dominated by the *Lauraceae* with many species endemic to the Western Ghats, and a few restricted to the Nilgiri/Palni highlands (Mohandass & Davidar 2009). The predominant grassland types in the upper plateau belong to the *Chrysopogon zeylanicus* and *Arundinella* spp. savanna (Blasco 1971). In spite of their low productivity these grasslands have been used by the Toda people as grazing grounds for their buffaloes. At elevations above 2,300 m a.s.l. the *Pollinia phaeotrix* and *Arundinella fuscata* savanna occur on soils with high content of organic matter (Blasco 1971).

This study was carried out in the swamps of Kundah and Upper Bhavani Reserve Forest located about 60 km southwest of Ootacamund, Nilgiri district, in the state of Tamil Nadu, India (Fig. 1). The study sites were located between 11° 11' 53.18" - 11° 15' 20.62" N and 76° 32' 18.13" - 76° 36' 49.81" E (Table 1 and Fig. 1). Vegetation was a mixture of sholas and grassland with also extensive private tea plantations and exotic tree plantations (*Acacia mearnsii, A. dealbata*, *Eucalyptus globulus*, *Pinus longifolia*, etc.) managed by the Forest Department. The largest resident mammalian herbivore is the Sambar (*Cervus unicolor*). Elephants (*Elephas maximus*) visit the area particularly in January - March, during the dry season. Large predators include tiger (*Panthera tigris*) and leopard (*Panthera pardus*).

Table 1. Characteristics of the five swamps studied. "Fire": Peechikordhar Swamp burned in 1995, "Grad1": Onnatidhar Swamp heavily grazed by domestic cattle, "Grad2": Quartdhar Swamp heavily grazed by domestic cattle, "Plnt": Theedhar Swamp surrounded by plantations and "Undd": Keitkurshdhar Swamp with no visible human-related disturbance. Swamps were selected to have only one particular type of human-related disturbance, except for the "control".

Swamp	Fire	Grd1	Grd2	Plnt	Undd
Local name	Peechikordhar	Onnatidhar	Quartdhar	Theedhar	Keitkurshdhar
Disturbance	Fire	Grazed	Grazed	Plantation	Undisturbed
Latitude (N)	76° 35' 29.29"	76° 36' 10.37"	76° 34' 28.92"	76° 32' 34.87"	76° 34' 9.48"
Longitude (E)	11° 14' 37.93"	11° 13' 53.33"	11° 12' 53.89"	11° 13' 11.17"	11° 12' 23.22"
Elevation (m)	2258	2218	2215	2259	2224
Area (ha)	0.9	2.8	3.3	1.8	4.2
Total number of species					
Number of species by geographic range	51	63	65	46	49
Invasive / ubiquitous	3	9	6	3	4
Asia - Pantropical	19	28	31	21	22
Indian subcontinent	5	4	4	4	3
Western Ghats – Sri Lanka	9	8	10	6	8
Western Ghats	11	10	10	8	8
Nilgiris / Palnis	4	4	4	4	4

Methods

The study was conducted from September 2001 to February 2002 in five swamps with various disturbance regimes. We considered swamps grazed by wild herbivores and by the Toda buffaloes as representative of recent (previous 1,000 years) environmental conditions. Thus, a swamp that was apparently not affected by human activities other than that of the Todas' was chosen as a control and was called "undisturbed" (UNDD). Among the four remaining swamps, two swamps were regularly grazed by cows belonging to both a tea estate and staff of the Forest Department, and noted as GRD1 and GRD2. One swamp had been subjected to fire in 1995 according to Toda elders and was designated as FIRE. Another swamp (PLTN) was surrounded by exotic tree plantation (*Pinus patula*); pine plantations tend to create acidic soil conditions and, therefore, alter biological processes downstream (Dames *et al*. 2002). The areas of the swamps were obtained from the Forest Department of Tamil Nadu (Table 1).

A cumulative species-area curve was constructed for each swamp starting from the first sample unit of 0.5 m^2. In all swamps the species accumulation curve reached a horizontal asymptote, indicating a satisfactory sampling of species richness. All plants were identified to species using various regional floras (Bor 1960; Fyson 1932; Gamble 1935; Matthew 1999). Botanical nomenclature followed Nair & Henry (1983). Species identification was confirmed by consulting herbaria collections at the Botanical Survey of India, Coimbatore, and Survey of Medicinal Plants and Collection Unit, Ootacamund. A sample specimen of each species was deposited at Department of Ecology and Environmental Sciences, Pondicherry University. Dr. Cope of the Kew Herbarium Garden confirmed the identification of *E. rangacharii*. Geographic distribution of species was based on Fyson (1932), Nair & Henry (1983), Matthew (1999) and ENVIS (http://bsienvis.nic. in/). Floristic similarity was estimated with the Jaccard index.

In each swamp, three samples in the form of 1 x 60 m transects were laid in random directions and locations (but with no overlap) and were divided into 60 1 m^2 plots to make measurements. We defined the frequency of a species as the number of 1 m^2 plots where the species occurred. The percentage of ground covered by *E. rangacharii* and the height of *E. rangacharii* were measured in each of the 1 m^2 plots. The percentage cover (called "cover") was visually estimated as belonging to different classes: 0 - 1 %, 1 - 10 %, 10 - 25 %, 25 - 50 %, 50 - 75 %, and above 75 %. Maximum height

Table 2. Comparison of floristic similarity amongst the five swamps studied using the Jaccard index. Refer to Table 1 for definition of abbreviations.

	Undd	Grd1	Fire	Grd2	Plnt
Undd	1.00				
Grd1	0.60	1.00			
Fire	0.59	0.63	1.00		
Grd2	0.70	0.75	0.66	1.00	
Plnt	0.61	0.60	0.59	0.68	1.00

of *E. rangacharii* within every 1 m² plot was measured with a steel tape.

Means of frequency, cover, and height of *E. rangacharii* were plotted to identify differences among the swamps. Following this examination, swamps were grouped in two groups: "Grazed" and "Ungrazed" to conduct Mann-Whitney U tests in order to check differences between the two treatments. We could not evaluate the effects of fire or of adjacent pine plantations as we lacked replicate swamps with these treatments. The statistical analysis was performed with R (R Development Core Team 2010).

Results

A total of 78 species belonging to 61 genera and 31 families were recorded from the five swamps. The families with the largest number of species were Poaceae, Cyperaceae and Asteraceae. Three tree species, i.e. *Rhododendron arboreum*, *Gaultheria fragrantissima* and *Pinus patula* were recorded on the edges of the swamps. The average species richness excluding trees was 53 species per swamp.

Only one species, *E. rangacharii*, was threatened and noted as "presumed extinct" in Nayar & Sastry (1987). This species occurred in all the five swamps, in 32 % of all 1 m² transect sub-samples. In all swamps, the runs-test for randomness showed that *E. rangacharii*'s distribution was aggregated or nearly aggregated (data not shown). A total of 28 species (36 % of the assemblage) were endemic to the Western Ghats - Sri Lanka hotspot (Table 1). Four species were found only in the Nilgiris/Palnis. As many as 10 invasive plants

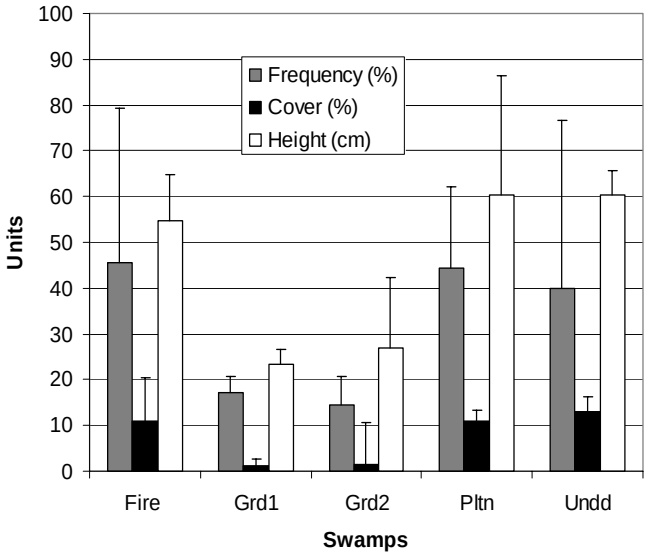

Fig. 2. Frequency, cover, and height of *Eriochrysis rangacharii* in the different swamps.

species (one of which was cultivated), i.e., 13 % of the assemblage were found in the five swamps (Table 1).

The Jaccard binary similarity coefficients (Table 2) showed that the two grazed swamps had the highest levels of species similarity inspite of being geographically closer to swamps with different types of disturbances than to each other (Fig. 1). The least similar pairs of swamps were UNDD and FIRE, and PLTN and FIRE. The numbers of both native and invasive species were highest in the grazed swamps (Table 1) which resulted in the highest species richness for these swamps. The swamp that had been burnt had intermediate numbers of native species and a low number of invasive species. Among these five swamps grazing had the strongest impact on *E. rangacharii* (Fig. 2). The two swamps with high grazing intensity were merged and variables pertaining to *E. rangacharii* were compared to those belonging to swamps with low grazing intensity. A Mann-Whitney tests indicated that grazing had an impact on frequency ($P < 0.05$), cover ($P < 0.005$) and height ($P < 0.005$).

Discussion

The Western Ghats - Sri Lanka area has been noted as a biodiversity hotspot (Myers *et al*. 2000) because it contains unique ecosystems, and rare and endemic species. The grasslands and swamps of the Nilgiris have been extensively destroyed and converted to other land uses because they were considered to be of secondary origin and not as

(a)

(b)

Fig. 3. (a) Swamp on a private property with *E. rangacharii* and not included in the study: picture taken in November 2007; and (b) The same swamp in May 2009. Regular grazing by livestock compacted the soil and eliminated *E. rangacharii* (personal observations).

important as the forests (Champion & Seth 1968; Whyte 1968). Therefore, only a few pristine swamps remain in the Upper Bhavani region of the Nilgiris. However, studies have shown that grasslands existed at least *ca.* 30,000 BP in the Nilgiris (Vasanthy 1988). Furthermore, these grasslands are the habitat of a fairly large number of endemic grasses (> 30 species) in the southern Western Ghats (Bor 1960), and of many endemic mammals and birds (Ali & Ripley 1987; Schaller 1977). This tends to confirm that the montane grasslands are ancient.

The swampy grasslands studied here fall under the broad *Sehima*/*Dichanthium* type defined by Whyte (1968). Blasco (1970) mentioned the vegetation of hydromorphic soils as a distinct type of vegetation occurring in depressions and on lake shores. The swamp species composition in the Nilgiris and the Palnis were similar according to Blasco (1971), but it was difficult for us to evaluate this assertion, as Blasco did not provide site-wise data.

Endemicity was relatively high. Among the 12 Poaceae species, 7 were endemic to the Western Ghats - Sri Lanka hotspot. By comparison, Devidas (1995) found only one out of 12 grass species endemic to the subcontinent; all other species had a wider distribution in the subcontinent and three were pantropical. In a survey of the South Indian hills, Blasco (1970) reported 66 dicots and 16 monocots (mostly herbaceous) endemic to the Nilgiris. The high proportion (36 % of the assemblage) of species endemic to the Western Ghats - Sri Lanka biodiversity hotspot found here confirms the uniqueness of the flora.

E. rangacharii is restricted to the montane swamps of the Nilgiris and is rare in the sense of Rabinowitz (1981) and Rabinowitz *et al.* (1986), due to restricted geographical distribution. However, this study shows that it commonly occurs in swamps in the Upper Bhavani region, and appears to be locally abundant. It was probably considered 'extinct' (Nayar & Sastry 1987) because the area was not adequately surveyed or because it was misidentified. Blasco (1971) had recorded the species in his book, which was written in French and was possibly ignored by Indian botanists.

Grazing affected the frequency, cover, and height of *E. rangacharii*. Both grazed swamps also contained at least 10 more species (*ca.* 20 %) than the other swamps and harbored the highest number of invasive species.

Our study shows that livestock grazing might be a threat to the species. Fig. 3 from a private property (this particular swamp was not part of this study) show that with increase in grazing pressure the swamp's physiognomy substantially changed within a span of 2 years. Soil compaction by cattle may also alter drainage and create habitat conditions that may not be suitable to hydrophytes. Even though relatively protected within the Reserved Forests, swamp grasses are used to generate income. For example, various government agencies handle projects near or within protected areas. It is a common practice for these agencies to supply cattle to their workforce to generate extra income. Cattle are sent to graze in the swampy grasslands as they remain productive all the year long. Moreover, the tea industry is converting to organic cultivation. Estates become

more dependent on cattle manure for fertilizer and also send their cattle (or the cattle of their workers), to the nearby productive swamps. Adding to this pressure, swamp grasses are collected to cover and protect tea bushes from frost during winter.

In order to preserve *E. rangacharii* and its ecosystem, basic data are still needed. The range and habitats need to be mapped. Antagonistic factors such as grazing, and alien plant invasion should be studied at the stand level with intensive sampling in order to predict this species' fate. The limited range of *E. rangacharii* still makes it vulnerable to extinction, and it should be re-classified as 'Endangered' as long as its status is not better assessed. Till then, immediate steps should be taken to preserve *E. rangacharii* and its habitat: Government agencies and organic tea estates should reduce grazing pressure on the swamps and restrict any program (planting trees, building small dams for water retention) that might affect this fragile ecosystem.

Acknowledgements

The Edhkwehlynawd Botanical Refuge (EBR) Centre Trust requested us to conduct this study. We thank Dr. Tarun Chhabra (EBR) for giving us the opportunity to undertake this study. We are grateful to the Forest Department of Tamil Nadu for granting permission to work in the Reserved Forests. We are indebted to Mr. D. Hegde, Director, Chamraj Group, for logistic support and keen interest in our efforts. Mr. J. Thimaia, Mr. M. Iqbal, and Mr. P. Dambekodi, successive Managers of the Karakundah Tea Estate, Chamraj Group, have provided crucial help without which this study would have been impossible. Dr. Ankila Hiremath and an anonymous referee gave useful suggestions for the revision of this paper.

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(Received on 25.08.2009 and accepted after revisions, on 12.01.2011)