A Quantitative Analysis of Genetic Erosion in the Genus *Momordica* L. in South Peninsular India

K Joseph John[1]* and VT Antony[2]

[1] *Senior Scientist, National Bureau of Plant Genetic Resources, KAU P.O., Thrissur-680654, Kerala, India*

[2] *Curator, Regional Herbarium, St. Berchmans' College, Changanacherry-686101, Kerala, India*

The experience of germplasm collecting over a decade has shown that wild species of *Momordica* are subjected to varied types of threats affecting their survival in India, especially in Peninsular South India. A numerical model was used for quantifying threat of genetic erosion, with the total score indicative of the magnitude of threat. The studies revealed a grave threat for *M. dioica* in its entire range and *M. sahyadrica* in the Western Ghats of Kerala. Overall, *M. charantia* var. *muricata* faces a medium level of threat across its geographic range. Habitat loss and fragmentation brought about by population pressure and developmental activities, poor distribution and low population density of *Momordica* species coupled with inadequate *in situ* conservation efforts, and acculturation of the forest dwelling communities are the major factors attributed to their heightened threat status affecting their long-term survival in the wild.

Key Words: *Momordica* L., Quantitative Analysis, Genetic Erosion, Conservation, South India

Introduction

The genus *Momordica* L. offers wild and cultivated vegetables of high nutritional value. Six species occur in India and among them, three species, *viz.*, *M. sahyadrica* Joseph and Antony, *M. dioica* Roxb. and *M. charantia* L. var. *muricata* (Willd.) Chakrav. occur in South India (de Wilde and Duyfjes 2002; Joseph *et al.*, 2006, Joseph and Antony, 2007a,b). Except the cultivated bitter gourd (*M. charantia* L. var. *charantia*), other species occur in the wild state and are gathered by tribal communities as vegetables. This genus has a very rich ethnobotanical history with linguistic, religious, cultural and socioeconomic ramifications across its geographic range, with implications in its sustainable utilization and conservation (Joseph and Antony, 2007b). However, personal experience of germplasm collecting over a decade has revealed that these wild species are subjected to varied types of threats, affecting their survival in India especially in Southern Western Ghats and Peninsular India.

Red lists of endangered taxa have become an important and reliable tool in conservation planning when it is based on precise and scientifically sound data as in the case of developed countries in the West. As Ibisch *et al.* (2002) have stated, in the case of tropical species, the assessment of the threat status and assignment of the appropriate threat category is primarily and often exclusively based on restricted distribution The only reference to threatened status of *Momordica* is given in IUCN Red Data Book (IUCN, 1997) where *Momodica subangulata* Blume. from Wynad (Kerala) and South Canara (Karnataka) is accorded 'threatened-indeterminate status'. In fact, the species referred to as *M. subangulata* from Wynad might be *M. sahyadrica* (Joseph and Antony, 2007a), as true *M. subangulata* do not occur in Kerala (Joseph, 2005). Also, there are a few other reports expressing apprehensions of species as being 'endemic', 'endangered' or 'nearing extinction' in India (Dwivedi, 1999; Jha and Ujawane, 2002). However, these reports are primarily based on bibliographic compilations and not supported by authentic fieldwork. As the available data is highly scattered and incomplete, extensive fieldwork needs to be undertaken in order to have an objective assessment of the threat of genetic erosion of *Momordica* species.

Materials and Methods

Study Sites

An extensive ecogeographical survey was conducted during September-November, 2004 across the south Peninsular India, covering all the major areas of distribution. This region comprises agro-climatically diverse areas, namely, southern part of hot-humid Western Ghats (one of the mega diversity hotspots and highly vulnerable to anthropogenic disturbances) and drier peninsular Deccan Plateau. Observations were recorded from 42 sites spread over the states of Kerala, Karnataka, Goa and Tamil Nadu. (Fig. 1 and Table 2). The locations

**Author for Correspondence: Email: josephjohnk@rediffmail.com*

include diverse habitats like partially opened forest fragments and tribal settlements, protected areas, riverbanks, cultivated areas and commercial plantations, thus representing the entire ecogeographic range of the target species.

Methodology

An indirect method of quantifying genetic erosion, originally proposed by Guarino 1995 and subsequently refined by de Oliveira and Martins (2002) and Anete Keiša *et al.* (2007), was used with modifications incorporated to suit the actual field conditions pertinent to the taxa (Table 1). This model is based on assigning numerical values for various biological, environmental and socioeconomic risk factors, with the total score indicative of the magnitude of threat. The numerical values were entered in the data sheets at the collection sites itself, giving due attention to each factor.

Data Analysis

The threat of genetic erosion faced by a population in a particular site was obtained by the sum of scores attributed to each of the 16 factors. The threat due to a single factor was calculated as the sum of the scores of that factor in all the 42 sites. As the emphasis was more at the species level rather than geographical jurisdiction, the sites were further grouped under the three species. The magnitude of threat in each species is therefore reflected in the average score in that particular group.

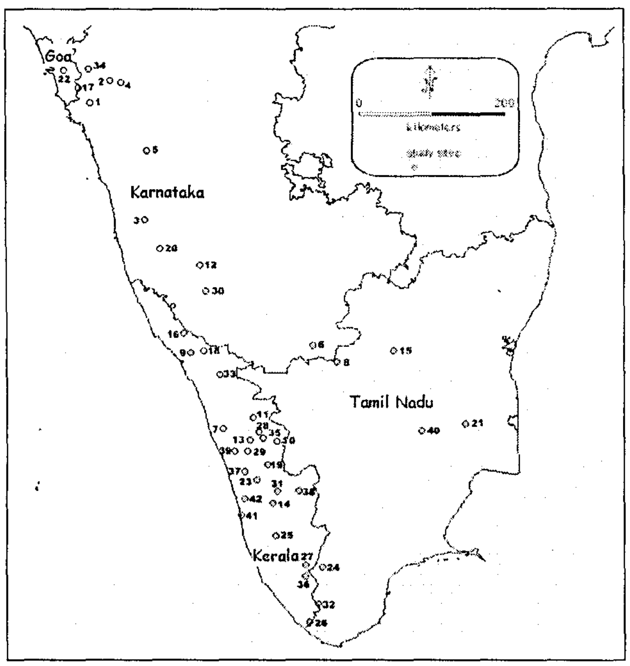

Fig. 1: Map of South India showing the study sites (Refer Table 2 for details of the sites)

Results

Threat Scores and its Spatial Pattern

Table 2 presents the sum of scores attributed to the 16 factors of risk for each of the 42 study sites. In order to clarify the comparison among threat levels faced by each study area, an arbitrary value of 1.0 was attributed to threat faced by least endangered area (KAS1 with the score of 10) and computed again the threat faced by the other sites relative to this value. The 42 sites were assigned ranks in descending order with the lowest rank (1) indicating the most threatened site. The studies showed that populations growing in each of the 42 sites that were evaluated were not subjected to same level of threat. The cumulative threat score showed a high degree of variation from the lowest score of 10.0 (KAS1) to 124.9 (KED8 and KED10) with the most threatened sites showing a 12.5-fold increase over the least threatened locality. Among the 14 most endangered sites, 10 were from Kerala (Table 2). Similarly, eight of the least threatened sites fall within the state of Karnataka and the remaining six are in Kerala, most of them falling within the jurisdiction of protected areas.

Threat at Species Level

Each of the three species is also subjected to varying levels of threat. Mean threat in *M. dioica* was 84.8 (average score from 14 sites ranging from 29.8 to 124.9) followed by *M. charantia* var. *muricata* with 64.8 (26.5-111.6) and *M. sahyadrica* with 57.7 (10.0-104.1). If the 42 study sites are divided into three groups based on cumulative threat score (most, least and medium threatened), 7 out of 14 locations in *M. dioica* (50%), 5 out of 17 (29.6%) in *M. sahyadrica* and only 2 out of 11 (18.1%) in *M. charantia* var. *muricata* fall in the most threatened group. Conversely, 7 out of 14 in *M. dioica*, 12 out of 17 in *M. sahyadrica* and 9 out of 11 in *M. charantia* var. *muricata* come under either least threatened or medium threatened group.

Threat Factors

Relative contribution of each of the 16 factors of risk to the total threat of genetic erosion is presented in Table 3. The data showed a high degree of variation among the contribution of a given factor to the cumulative threat. The three most important factors were F8, F12 and F13 (distance to major population centre, taxon distribution, and extent of wild habitat of target species within study area), contributing nearly one-third to the total threat in all the three species. Least important factors were F6 and

Table 1. Checklist used for quantifying the threat of genetic erosion (adapted from Guarino, 1995; de Oliveira and Martins, 2002)

	Factor	Score
F1	Clearing of land for agriculture/forestry plantations	
	High in the immediate vicinity	10.0
	Nearby locality (5-10 Km radius)	5.0
	Not likely to occur	0
F2	Clearing of land/land conversion for big housing projects & tourism industry (over the last 20 years)	
	Increasing drastically	10.0
	Increasing marginally	5.0
	Static or non-existent	0
F3	Habitat loss due to natural calamities (landslides, riverbank erosion, floods, drought and wildfire)	
	Highly prone	10.0
	Medium	5.0
	Low or not likely to occur	0
F4	Habitat loss due to invasive alien species/weeds/cover crops	
	Extensive	10.0
	Moderate	5.0
	Not existent	0
F5	Agricultural pressure on wild habitats	
	Large-scale cultivation within habitat margins	10.0
	Subsistence cultivation areas within habitat margins	7.5
	Land suitable for cultivation, cultivated areas within 3 kms of habitat margins	5.0
	Land suitable for cultivation, cultivated areas within 3-10 kms of habitat margins	2.5
	Land unsuitable for cultivation	0
F6	Weeding practices in Plantation forestry	
	Herbicide application	10.0
	Sickle weeding of entire area	6.6
	Selective weeding in patches	3.3
	No weeding	0
F7	Extent of use of wild habitat of target species	
	Industrial exploitation	10
	Exploitation by surrounding populations	6.6
	Gathering by small local communities	3.3
	Completely protected	0
F8	Distance to major population centre	
	<20 km	10.0
	20-50 km	5.0
	>50 km	0
F9	Human population growth rate per year	
	>3%	10
	1-3%	5
	<1%	0
	5.0	
F10	Distance to developmental projects	
	<20 km	10.0
	20-50 km	5.0
	>50 km	0
F11	Acculturation of indigenous tribes, changes in economic base, livelihood options and change in food habit	
	Not dependant on wild food plants	10.0
	Losing interest	
	Highly dependant on food plants enabling protection and seed distribution	0
	B. Species specific	
F12	Taxon distribution	
	Rare	10.0
	Locally Known	5.0
	Widespread or abundant	0
F13	Extent of wild habitat of target species within study area	
	Very restricted ((<5%)	10.0
	Restricted (5-15%)	6.6
	15-50%	3.3
	Extensive (>50%)	0
F14	Conservation status of target species	
	Species not known to occur in any protected area	10.0
	Species known to occur in a protected area, but protection status poor or unknown	5.0
	Species known to occur in a protected area, and protection status good	0
F15	Extent of use of target species (harvesting of fruits leading to seed depletion)	
	Destructive (whole plant)	10.0
	Extensive (insufficient for healthy natural regeneration)	6.6
	Marginal (sustainable, but endangering in the long run)	3.3
	Protected or not used	0
F16	Harvesting of tubers for medicinal use	
	Highly destructive (>50% harvested every year)	10
	Extensive (<50% harvested every year)	6.6
	Marginal (sustainable, but endangering in the long run)	3.3
	Protected or non-existent	0

Table 2. Study sites with cumulative threat score and ranking

S.No.	Site Code	Study Site	Provenance	Total Score	Ranking relative to least score		Level of threat
					Threat	Sites	
1	KAS1	Anaci	Karnataka/Uttar Kannad	10	1.0	31	Least threatened
2	KAS2	Dandeli	Karnataka/Uttar Kannad	16.6	1.7	30	
3	KAS3	Kudremukh	Karnataka/Daksin Kannad	20	2.0	29	
4	KAM1	Haliyal	Karnataka/Uttar Kannad	26.5	2.7	28	
5	KAS4	Soraba	Karnataka/Shimoga	27.4	2.7	28	
6	KAD2	Biligirirangan	Karnataka/Kodagu	29.8	3.0	29	
7	KES2	Chimmony	Kerala/Thrissur	33.3	3.3	28	
8	KAD1	Kolli Hills	Karnataka/Salem	49.8	5.0	27	
9	KES6	Aralam	Kerala/Kannur	49.9	5.0	27	
10	KEM4	Nelliampathy	Kerala/Palakkad	50.7	5.1	26	
11	KEM2	Mannarkad	Kerala/Palakkad	52.3	5.2	25	
12	KAS6	Sakleshpura	Karnataka/Hassan	53.2	5.3	24	
13	KEM3	Mayannur	Kerala/Thrissur	54	5.4	23	
14	KEM1	Illithode	Kerala/Iddukki	58.5	5.8	22	
15	TNM1	Sevaroi Hills	Tamil Nadu/Salem	57.3	5.7	21	Medium level of threat
16	KES7	Kannavam	Kerala/Kannur	59	5.9	20	
17	GAS1	Vilyan forest	Goa/South Goa	62.3	6.2	19	
18	KES3	Chandanathod	Kerala/Kannur	63.2	6.3	18	
19	KES4	Malakkapara	Kerala/Palakkad	63.2	6.3	18	
20	KAS5	Chikmagalur	Karnataka/Chikmagalur	63.2	6.3	18	
21	TND2	Melavarampatti	Tamil Nadu/Tirunelveli	66.5	6.7	17	
22	GAM1	Sanguem forest	Goa/North Goa	69	6.9	16	
23	KED2	Malayatur	Kerala/Ernakulam	71.5	7.2	15	
24	TND1	Kadayanellur	Tamil Nadu/Tirunelveli	71.5	7.2	15	
25	KEM5	Ponthenpuzha	Kerala/Kottayam	73.2	7.3	14	
26	KEM7	Amboori	Kerala/Thiruvanathapuram	76.5	7.7	13	
27	KED4	Achenkovil	Kerala/Kollam	79.9	8.0	12	
28	KED7	Thonikadavu	Kerala/Thrissur	82.4	8.2	11	
29	KES5	Kuthiran	Kerala/Thrissur	84	8.4	10	Most threatened
30	KAM2	Kushalnagara	Karnataka/Kodagu	85.7	8.6	9	
31	KED1	Neriamangalam	Kerala/Iddukki	87.3	8.7	8	
32	TNS1	Manchola	Tamil Nadu/Kanyakumari	89.8	9.0	7	
33	KES8	Tamarassery	Kerala/Kozhikode	89.9	9.0	7	
34	KAS7	Castlerock	Karnataka/Uttar Kannad	91.6	9.2	6	
35	KED9	Malamalamukku	Kerala/Palakkad	92.4	9.2	6	
36	KED3	Aryankavu	Kerala/Kollam	95.6	9.6	5	
37	KED5	Chalakudi	Kerala/Thrissur	104.1	10.4	4	
38	KES1	Pallivasal	Kerala/Iddukki	104.1	10.4	4	
39	KED6	Viyyur	Kerala/Thrissur	106.6	10.7	3	
40	TNM2	Trichi fort area	T. Nadu/Tiruchirappalli	111.6	11.2	2	
41	KED8	Chertala	Kerala/Alapuzha	124.9	12.5	1	
42	KED10	Tripunithura	Kerala/Ernakulam	124.9	12.5	1	

F16 (weeding practices in plantation forestry and harvesting of tubers for medicinal use). Factor F16 (harvesting of tubers for medicinal use) is of considerable importance to *M. dioica*, though of no significance to the other two species. Similarly, some factors like F4 (habitat loss due to invasive alien species/weeds/cover crops) are of great importance in a given geographical sub area (for example in Kerala forests), whereas of no significance in rest of the study area. Overall, there is a very similar pattern in all the three species.

Discussion

Methodology, Threat Scores, Spatial Pattern of Threat and Factors

Though the danger of genetic erosion or loss of biodiversity have long been recognized, practical means of assessing the loss, identifying factors likely to cause loss and how loss might be countered is poorly defined (Arunachlam, 1999; Anete Keiša *et al.*, 2007). Several approaches have been employed to estimate the degree

Table 3. Contribution of each factor towards total threat (species wise)

Factor	Contribution to threat (%) at species level		
	M. dioica	*M. sahyadrica*	*M. charantia* var. *muricata*
F1	7.16	8.67	7.71
F2	5.90	4.59	4.21
F3	2.53	6.12	3.50
F4	4.63	1.02	2.80
F5	6.95	9.94	9.81
F6	1.39	3.71	5.55
F7	6.98	4.38	7.42
F8	10.11	10.71	11.92
F9	2.95	2.04	2.80
F10	7.16	6.12	4.91
F11	5.90	4.08	4.91
F12	13.77	10.95	10.51
F13	10.36	7.78	10.22
F14	8.67	5.90	7.71
F15	7.51	8.08	6.01
F16	3.64	0.34	0.00

of genetic erosion that a particular taxon faces in a certain region over a given time. Maxted and Guarino (2006) have given an exhaustive account of various direct and indirect methods presently available for genetic erosion assessment. Though, ideally the magnitude of genetic erosion could be assessed directly using a molecular genetic approach, an indirect estimation of threat of genetic erosion may be the better practical option especially for wild and previously poorly studied plant species (Anete Keiša *et al.*, 2007).

The numerical scoring method of Guarino (1995) assumes significance as a practical means of indirect assessment of genetic erosion. de Oliveira and Martins (2002) have demonstrated the usefulness of this method in assessing the threat of genetic erosion faced by the wild medicinal plant 'ipecac' in the rain forests of southeastern Brazil. Anete Keiša *et al.* (2007), with their case study of wild *Vicia* spp. in Syria, have empirically tested the objectivity and efficiency of this method in detecting spatial and temporal patterns of threat distribution. They, however, caution that the practical application of an indirect genetic erosion threat assessment requires good prior knowledge of the target species, populations and territory.

The present checklist was very carefully designed, adding a few factors of prime importance and deleting some parameters perceived to be irrelevant for the target species and study areas. Factors 1-4 were included to assess the extent of habitat loss and fragmentation, whereas factors F5-F11 are aimed at elucidating the probable reasons for the same. Besides, the species-specific factors (F12-F16) give an estimate of the distribution, extent of habitat presently available, present conservation status and utilization of the specific taxon.

Habitat loss coupled with fragmentation, poor distribution and low population density of the taxon are the major reasons attributed to the high threat levels. The very limited extent of the habitat of the target taxon within the study area (F13) and extensive use of the wild habitat of target species for other purposes (F6) are perhaps true direct indicators of the present situation. Pressure for forestland (for agriculture and developmental activities) is enormous and bound to increase further as indicated by the high density of population, proximity to major population centres (F8) and developmental activities (F10). Acculturation of forest dwelling communities (F11), who have been the traditional custodians of forest biodiversity, is one factor that should not be lost sight of. In more progressed and urbanized tribal societies in Kerala, the knowledge and interest in crop husbandry and culinary preparations of wild *Momordica* are fast eroding, which will have an irreversible impact on its conservation. The consumption pattern has changed drastically as the younger generation depends heavily on store bought food (Joseph and Antony, 2007b).

The *in situ* conservation efforts (F14) have been largely unsatisfactory, not withstanding that *M. sahyadrica* has been well represented in the protected areas in the Western Ghats of Karnataka (which largely contributed towards its lesser threat status). It has been well maintained in some of the coffee plantations in Hassan and Shimoga areas of Karnataka, an excellent working model of an *in situ/on-farm* conservation, which can be adopted in other cropping systems and extended to more areas. Unfortunately, it is not the case with the other two species. Efforts at the *ex situ* conservation front has been equally disappointing, taking in to the fact the present genebank collections are very negligible and they do not represent the available diversity. Besides, exploration and collection efforts are not concentrated on the most vulnerable taxa and areas.

All the taxa are facing comparatively higher levels of threat in the geographical area of Kerala when compared to the neighbouring states. All the sites in the 'most threatened category' were mostly wastelands in the suburban areas, forest edges with high influx of tourists, or highly disturbed riverbanks. All the sites coming within protected areas fall under least threatened category, implying adequate protection levels afforded in areas within their jurisdiction. However, they are still susceptible to threats like invasive weeds (F4) as in the Kerala forests (KED1, KED3, KED10 and KEM1), though not observed in the neighbouring Karnataka forests so far.

Threat at Species Level

M. dioica, even though figured to have wider distribution in the Indian subcontinent as per herbarium survey (data not shown), has a very restricted distribution and poor frequency in Kerala. It occupies partial shades of well-drained low elevation forests or undisturbed riverbanks and partially opened woodlands. With urbanization and unprecedented growth of tourism industry, privately owned woodlands are being increasingly developed for commercial activities. A few plants have been spotted in the coastal lowlands of Ernakulam, Alapuzha, Kottayam, Thrissur and Palakkad districts where human population density is one of the highest in the World. Like *M. sahyadrica*, this taxon is also subject to habitat loss (but more severely due to invasive weeds). In the four forest spots, *i.e.*, Achenkovil and Aryankavu in Quilon District, Malayatoor in Ernakulam District and Neriyamangalam in Iddukki District, *Mikania* was found to be spreading alrmingly. Destructive harvest of tubers for medicinal preparations is also rampant.

Repeat collecting visits to given areas some years apart are invaluable sources of information on genetic erosion (Guarino, 1995). At Tripunithura (KED10) in Ernakulam District, the bearing female vines (spotted during September, 2001) or any of the seedlings could not be located during subsequent visits, where the introduced cover crop *Mucuna pruriens* (L) DC has covered the entire floor. At Viyyur (KED6) in Thrissur, (where around 68 individual plants were spotted in August 2001), by 2004 the population has dwindled alarmingly and an invasive cover crop, *Mimosa diplotricha* C. Wright (=*Mimosa invisa* C. Mart.) was found to be spreading rapidly preventing seedling emergence. There is no domestication attempt and this taxon has inherent problems associated with seed dormancy, dioecy and pollination and dispersal syndrome. Less than 100 mature individuals only could be located in Kerala. By virtue of its very restricted distribution in a narrow range, population pressure on the habitat and market demand leading to destructive harvest of tuber, the species is in an endangered state and needs immediate attention.

The field studies indicate *M. sahyadrica* to be out of danger in Karnataka because of the healthy populations in the various protected areas (KAS1, KAS2 and KAS3) and because of the patronage it avails in coffee estates (KAS6 and KAS5). Being a high value vegetable with many of the taboos associated with use of tubers as planting material, self-sown plants (female and few pollenizors) are well taken care of in coffee estates (Joseph and Antony 2007b). Medicinal uses are restricted to few tribes only, where fortunately, there is good population of this species and they cultivate it as a vegetable. Hence, destructive collection of tubers would not lead to endangerment. The most threatened site was KAS7 (Castle rock), a highly open forest fragment subjected to high influx of tourist activity throughout the year.

However, in the Kerala forest, it is subjected to severe threat especially from invasive weeds such as *Mikania micrantha* Kunth. and *Lantana camara* L. *Mikania* covers the entire forest floor and smothers emerging seedlings, thus preventing regeneration of seedlings and tuber sprouts. Having preference to well drained ridges and slopes of forest openings, it is also vulnerable to landslides, flash floods, and invasion of cover crops. On a conservative estimate, less than 500 plants only could be spotted throughout Kerala, out of which about 100 in a small area in Olakara range of Peechi Forest Division (type locality). Hence, the taxon is highly vulnerable in this part of the distribution range and needs protection and rehabilitation.

M. charantia var. *muricata* is by far the most well distributed species occurring throughout the range of Western Ghats. Its population is sporadic and less dense in Kerala forests whereas in Goa and Karnataka forests especially in Uttar Kannada, it has dense population. Maximum density is seen near tribal homesteads probably because of the role of man in inadvertent distribution of seeds of wild gathered fruits. Overall, this species faces a medium level of threat across its geographic range. However, the study delineates a picture of two extremes ranging from good protection expected to be afforded by a Wildlife sanctuary (KAM1, Haliyal) to the extreme threat being faced at one of the most vulnerable locations (TNM2, Trichi fort area). The rest of the sites spread across the states of Kerala, Karnataka, Tamil Nadu and Goa face intermediate levels of threat.

Conclusions

As Guarino (1995) pointed out, studies at regional levels are very important as the data on specific areas, populations and species coming out of these studies can be integrated at the national level to estimate the danger to a country's biodiversity as a whole. Collection priorities and conservation strategies are formulated based on the importance of the germplasm (utility) and more importantly the extent and prospect of genetic erosion. Studies conducted in this group of taxa revealed the threat of genetic erosion to a great extent in *M. dioica* in its entire range and *M. sahyadrica* in the Western Ghats of Kerala. *M. charantia* var. *muricata* faces a medium level of threat across its geographic range. The situation demands expeditious development and implementation of appropriate strategies for *in situ* and *ex situ* (including *on-farm*) conservation of these taxa.

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