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Detrimental effects of low atmospheric humidity and forest fire on a community of western Himalayan butterflies

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Abstract: Compared to previous years, the period from October 2008 to March 2009 showed marked reductions in species number and population size in the butterfly community of the Maheshkhan Reserve Forest, Nainital District, Uttarakhand. Desiccation of pupae due to abnormally low atmospheric humidity after the failure of seasonal rains appears to have been a major cause of this reduction. The drop in humidity also appears to be linked to the unusual spread of fires affecting broadleaf forests, one of which in May 2009 wiped out the remaining Maheshkhan butterfly community.

Keywords: Climate change, forest fire, Himalaya, Kumaon, Lepidoptera, pupal desiccation.

INTRODUCTION

The Kumaon Himalaya adjoin the western border of Nepal, and along with the Garhwal Himalaya further west comprise the Indian state of Uttarakhand. In Nainital District of the Kumaon Himalaya the Gagar range is southernmost, rising from the Gangetic plain at roughly 400m elevation to Naini Peak near the town of Nainital at an elevation of 2600m. Rainfall is heavy, between 2029mm and 3048mm (80 to 120 inches) annually (Osmaston 1927) with 80% of the precipitation received during the south west monsoon between June and September, while 20% arrives during the remainder of the year, mostly during a fortnight of winter rains in January or February.

Maheshkhan Reserve Forest (roughly at $29^0$26'7"N & $79^0$35'40"E) lies west of the town of Bhowali, extending from the crest of the Gagar range and Gagar Peak (2400m) to the village of Shyamkhet (roughly 1800m). The forest comprises of a mix of Chir Pine (*Pinus roxburghii*) and dense subtropical evergreen forests of Himalayan oaks (*Quercus floribunda*, *Q. leucotrichophora* and *Q. glauca*) and other species (*Alnus nepalensis*, *Rhododendron arboreum*, *Pieris ovalifolia*, etc.). This forest is the headwaters of the Khalsa River, which is a perennial rain-fed tributary of the Gola River.

Besides many butterfly species, the forest is home to mammals such as Sambar and muntjacs, leopards, common langurs, yellow-throated martens, with occasional reports of Himalayan Black Bear.

The Maheshkhan forest has been visited sporadically during the spring and summer months since 1986. During the 24 years, the forest was visited more than 100 times during the summer months from March to June. During the summer months, there are often swarms of butterflies in the ravines and along streams of this forest. As soon as the south west

monsoon reaches and the rainy season begins in June, the butterflies stop congregating at water. Evidence from my breeding experiments indicates that there are broods of most species during the rainy season, but not as numerous as the spring and summer broods. The individuals comprising these broods do not congregate at water and are not as frequently seen as the dry season spring and summer broods.

Weather parameters, particularly atmospheric humidity, are known to have a decisive effect on biodiversity. This is usually amply illustrated with the textbook comparison of faunal diversity of hot deserts on one hand, with tropical rainforest communities on the other. Butterflies, too, occur in greater variety and profusion in areas of heavy rainfall as compared with low rainfall areas. For example within India the northeastern states are home to over a thousand species of butterflies, compared to the plains of Uttar Pradesh with less than a hundred, or the Thar Desert with less than 50 species (Peile 1937). While the effect of humidity on such extensive landscapes is well known, relatively little is known about factors that limit the abundance and distribution of butterfly species within smaller landscapes, such as hillsides or forests. In this study, an attempt is made to evaluate the effect of reduced atmospheric humidity on butterfly populations in the Maheshkhan Reserve Forest in the Kumaon Himalaya.

MATERIALS AND METHODS

Data pertaining to butterfly population trends in this forest area has been generated through observations made during past visits since 1986. During 2009, a rigorous survey was made for 65 days during March to May. The forest was surveyed from 1000 to 1400 hr, after which butterfly activity is greatly reduced. Since dawn and dusk is the period of activity for most Grypocera (Hesperiidae), these are not included in this paper, although a few species were observed during the daytime.

OBSERVATIONS

The observations were mainly made during the summer months from April to June when butterflies congregate in the ravines and along streams of this forest and are consequently easily observed. Certain species like *Lasiommata schakra* (Kollar) do not visit water, but these butterflies were encountered along paths and elsewhere in the forest. Also, not much attention was paid to groups such as *Yphthima* Hübner; *Mycalesis* Hübner; *Eurema* Hübner, etc. A single specimen of the recently described taxon *Ypthima kedarnathensis* Singh was recorded in Maheshkhan (Smetacek 2010). A list of butterfly species observed in Maheshkhan Reserve Forest since 1989 is given in Table 1. However, *Y. kedarnathensis* has not been included in Table 1 pending confirmation of its taxonomic status.

In 2009, the winter rains failed (Table 2), with practically no precipitation between the end of September 2008 and April 2009, resulting in a rather dry spring and summer 2009. Although there were very meager rains during the winter of 1998–1999, due to which some annuals did not germinate the following spring causing a drop in numbers of a butterfly species dependent on them (Smetacek 2002), the effects on butterfly populations then were by no means so widespread or as severe as experienced during spring and summer 2009 due, evidently, to the failed winter rains. The State Government officially declared the district to be affected by drought in 2009.

I had the good fortune to visit the forest rather frequently in spring and summer 2009, due to which it was possible to track the presence or absence of the butterfly species that make up the community there. As the season progressed, it became evident that the reduced number of species and butterflies was not solely a matter of delayed emergence caused by the lack of sufficient atmospheric humidity, but a matter of desiccated pupae resulting in the death of butterflies before they could emerge. This became evident when all the overwintering pupae I had bred the previous autumn dried out and died by April 2009. Even pupae formed by larvae in April 2009, which should have emerged the following month, dried out and died. Upon opening the pupae, I found fully developed but desiccated moths that had not managed to emerge (Unfortunately, it was not possible to identify them since the wings had not expanded). Only a single overwintering *Hyles nicaea lathyrus* (Walker) (Lepidoptera: Sphingidae) pupa from the cold desert of Ladakh survived to emerge on 19 May. No doubt,

Table 1. Butterflies recorded from Maheshkhan Reserve Forest, Nainital District, between 1989 and 2009 and their status in general and in summer 2009.

Species	Earlier status	Status in summer 2009	Remarks
Papilionidae			
Atrophaneura aidoneus Doubleday	Not rare	Not rare	Stable population. Larval food plant (LFP) *Aristolochia dilatata*.
Byasa polyeuctes Doubleday	Absent	Not rare	Highly unstable population. LFP as above.
Byasa dasarada Moore	Common	Common	Population reduced over the years. LFP as above.
Papilio agestor Gray	Not rare	Not rare	Stable population. LFP *Persea duthiei.*
Papilio protenor Cramer	Not rare	Not rare	Only spring brood recorded. LFP *Zanthoxylum*.
Papilio demoleus Linnaeus	Recorded once		Straggler from low elevation.
Graphium sarpedon Linnaeus	Rare	Absent	Not regularly seen at water.
Graphium cloanthus Westwood	Rare	Absent	Might be commoner at canopy level.
Pazala cashmirensis Rothschild	Common	Common	Stable population. LFP *Machilus duthiei.*
Pieridae			
Pieris brassicae Linnaeus	Common	Common	Not frequently met within the forest.
Artogeia canidia Sparrman	Common	Common	More frequent than *Pieris brassicae* within the forest.
Aporia soracta Moore	Recorded	Absent	Recorded during the 1980s.
Aporia agathon Gray	Very common	Not rare	Normally swarms, much reduced population in the year 2009. LFP *Berberis chitra*.
Delias belladonna Fabricius	Common	Rare	A few in April 2009. Flies before *D. sanaca.*
Delias sanaca Moore	Very common	Absent	Normally swarms. Entirely absent in the year 2009.
Gonepteryx rhamni Linnaeus	Common	Common	Common in early spring. Stable population in the year 2009. Overwinters as an imago.
Eurema hecabe Linnaeus	Not rare	Not rare	Recorded occasionally within the forest.
Colias fieldii Ménétries	Common	Not rare	Somewhat scarcer in 2009 than in previous years.
Anaphaeis aurota Fabricius	Not rare	Not rare	Migrant
Catopsilia pomona Fabricius	Not rare	Not rare	Migrant
Pontia daplidice Linnaeus	Not rare	Absent	Highly susceptible to drought.
Nymphalidae			
Parantica aglea Cramer	Rare	Absent	Infrequent in the forest in good years.
Parantica sita Kollar	Rare	Absent	Rarely met in spring.
Euploea mulciber Cramer	Rare	Absent	Very occasionally seen in the forest.
Danaus chrysippus Linnaeus	Rare	Absent	Stragglers from lower elevation.
Danaus genutia Cramer	Rare	Absent	Stragglers from lower elevation.
Satyrinae			
Mycalesis francisca sanatana Moore	Not rare	Absent	Nomally a stable population, but none seen in the year 2009.
Zophoessa sidonis vaivarta Doherty	Not rare	Not rare	A few seen in spring 2009.
Lethe insana Kollar	Rare	Rare	A few in spring 2009
Lethe verma Kollar	Common	Rare	Very much scarcer than in other years.
Lasiommata schakra Kollar	Not rare	Not rare	A few about in spring.
Orinoma damaris Gray	Rare	Absent	A forest insect. None seen in the year 2009.
Erebia annada Moore	Not rare	Absent	None of the spring or summer broods seem to have emerged.
Erebia nirmala Moore	Very common	Not rare	Very few about in the year 2009 compared to normal years.
Yphthima nikaea Moore	Common	Not rare	As abundant as *E. nirmala* in some years. Only a few about in the year 2009.
Melanitis leda Drury	Rare	Rare	At the upper extremity of its distribution. A few were about in the year 2009.
Neope pulaha Moore	Not common	Absent	The spring brood was absent in the 2009.

Species	Earlier status	Status in summer 2009	Remarks
Nymphalinae			
Polyura dolon Westwood	Rare	Absent	None seen in 2009.
Sephisa dichroa Kollar	Not common	Absent	None seen in 2009.
Limbusa patala Kollar	Not common	Absent	None seen in 2009.
Auzakia danava Moore	Not common	Absent	None seen in 2009.
Athyma opalina Kollar	Common	Not common	A few about in spring 2009.
Neptis mahendra Moore	Not common	Absent	None seen in 2009.
Neptis sappho Pallas	Common	Absent	Normally several about, but none in the year 2009.
Neptis soma Moore	Common	Absent	Also entirely absent in the year 2009.
Neptis sankara Kollar	Common	Absent	Quite frequent at water normally, none seen in 2009.
Neptis ananta Moore	Not rare	Absent	Rather less common than other Neptini, none seen in the year 2009.
Neptis narayana Moore	Common	Very rare	Only a single individual seen in the year 2009.
Cyrestis thyodamas Kollar	Common	Not rare	A few about in spring 2009.
Pseudergolis wedah Kollar	Rare	Absent	None seen in the year 2009.
Junonia iphita Cramer	Common	Rare	Much reduced in numbers in the year 2009.
Vanessa cardui Linnaeus	Not rare	Rare	A few about in spring 2009.
Vanessa indica Herbst	Common	Rare	Much less frequently met than in other years.
Vanessa canace Linnaeus	Common	Common	Several, perhaps belonging to a single batch of eggs, on the wing together in summer 2009.
Aglais cashmirensis Kollar	Not rare	Absent	None seen in 2009, although this is normally a common insect.
Symbrenthia niphanda Moore	Rare	Absent	Only recorded once in 1998. Absent in the year 2009.
Childrena childreni Gray	Not rare	Absent	Several usually about in summer. None about in the year 2009.
Issoria issaea Doubleday	Rare	Absent	Recorded occasionally, but not usually met within the forest. None about in the year 2009.
Phalanta phalantha Drury	Very rare	Absent	Straggler from lower elevation.
Acraea vesta Fabricius	Common	Absent	A large brood usually emerges in summer. None in the year 2009.
Libythea lepita Moore	Common	Absent	Several usually about in early spring. None about in the year 2009.
Lycaenidae			
Dodona durga Kollar	Extremely common	Common	The only butterfly about in any numbers in the year 2009, but still, much fewer than in other years.
Dodona dipoea Hewitson	Common	Common	More or less as common as in other years.
Dodona eugenes Bates	Common	Common	More or less as common as in other years.
Dodona ouida Moore	Rare	Absent	None seen in the year 2009.
Abisara fylla Doubleday	Rare	Rare	A few about in early spring.
Acytolepis puspa Horsfield	Not rare	Absent	None seen in the year 2009.
Arletta vardhana Moore	Rare	Absent	None about in the year 2009.
Udara albocaerulea Moore	Rare	Absent	None about in the year 2009.
Celastrina argiolus Linnaeus	Common	Absent	None seen in the year 2009, although this is normally quite a common butterfly.
Celastrina huegelii Moore	Common	Common	Common about its LFP, *Princepia utilis* and thistle flowers.
Celastrina gigas Hemming	Common	Common	Found in company with *C. huegelii*. Similarly abundant.
Aricia agestis Denis & Schiffermuller	Rare	Absent	None seen in the year 2009.
Pseudozizeeria maha Kollar	Common	Absent	Surprisingly, none seen in the year 2009.
Lampides boeticus Linnaeus	Very common	Common	A migrant.

Species	Earlier status	Status in summer 2009	Remarks
Heliophorus sena Kollar	Common	Absent	A local butterfly found near its LFP, *Rumex hastatus*. None about in the year 2009.
Euaspa milionia Hewitson	Rare	Absent	None seen in the year 2009.
Euaspa ziha de Niceville	Very common	Absent	Swarms in some years. Never absent until in the year 2009.
Chrysozephyrus ataxus Doubleday	Not rare	Absent	Not a single one seen in the year 2009.
Chrysozephyrus birupa Moore	Not rare	Absent	Scarcer than *C. syla*. Entirely absent in the year 2009.
Chrysozephyrus syla Kollar	Very Common	Absent	Normally difficult to miss, but entirely absent in the year 2009.
Arhopala dodonea Moore	Common	Common	A few about at water in early spring.
Arhopala rama Kollar	Common	Common	A few about at water in spring.
Panchala ganesa Kollar	Extremely common	Very rare	Swarms by the hundred every year. Only three specimens seen in the year 2009.
Spindasis nipalicus Moore	Not rare	Rare	Regular visitor to water: only one seen in the year 2009.
Lycaena pavana Kollar	Not rare	Absent	None seen in the year 2009.
Chaetoprocta odata Hewitson	Rare	Absent	None seen in the year 2009.
Pratapa ctesia Hewitson	Rare	Absent	None seen in the year 2009.
Pratapa icetas Hewitson	Not rare	Absent	None seen in the year 2009.
Tajuria illurgioides de Niceville	Rare	Absent	None seen in the year 2009.
Horaga onyx Moore	Rare	Rare	A single individual seen in the year 2009.
Chliaria kina Hewitson	Rare	Absent	None seen in the year 2009.
Rapala manea schistacea Moore	Not common	Absent	Normally rather frequently met, but none seen in the year 2009.
Rapala selira Moore	Not common	Absent	None seen in the year 2009.
Rapala nissa Kollar	Not common	Absent	Regularly seen in other years, but none in the year 2009.

Table 2. District rainfall (mm.) for last five years of Nainital District (Anonymous 2010)

Year	January	February	March	April	May	June	July	August	September	October	November	December
	R/F % Dep.	R/F % Dep.	R/F % Dep.	R/F % Dep.	R/F % Dep.	R/F % Dep.	R/F % Dep.	R/F % Dep.	R/F % Dep.	R/F % Dep.	R/F % Dep.	R/F % Dep.
2005	46.9 -8	71.4 68	27.1 -33	24.8 6	33.5 -41	67.9 -69	467.3 -14	292.2 -40	404.0 48	14.5 -80	0.0 -100	7.9 -53
2006	4.4 -91	0.3 -99	62.3 55	10.8 -54	102.3 81	108.4 -51	295.0 -46	317.4 -35	88.4 -68	15.9 -78	4.3 -14	13.4 -20
2007	152.7 259	121.6 202	33.7 44	71.7 27	198.4 -9	262.8 -52	420.5 -13	259.1 -5	11.7 -84	0.0 -100	2.2 -87	
2008	10.2 -80	4.5 -89	0.9 -98	22.3 -5	38.5 -32	333.6 52	495.9 -9	527.0 9	353.1 29	11.5 -84	4.7 -6	0.0 -100
2009	0.6 -99	14.3 -66	3.2 -92	22.2 -5	51.4 -9	62.6 -71	226.2 -59	493.7 2	301.0 10	194.1 164	24.7 394	2.8 -83

being a xerophytic species, it found nothing unusual in the dryness of spring and summer.

The Chir Pine forest patches in the Reserve Forest burnt twice in 2009: once in April, when the humus of the previous year burnt and again a fortnight later in May, when the trees shed their resinous needles. In one major fire in May, even the broadleaf forest burnt over most of the area, after which butterfly populations dropped almost to zero and I discontinued observations. The fact that forest fires in broadleaf forests resulted in an almost total decimation of the butterfly population, while regular annual fires in Chir Pine forests in the adjoining areas do not greatly affect butterfly populations, strongly suggests that the butterfly populations concerned do not depend on Chir Pine forest for survival. Once broadleaf forests begin to

burn, the effect on insect biodiversity is devastating.

DISCUSSION

The Maheshkhan Reserve Forest has changed little during the more than two decades it has been studied. Cattle, which were frequently met during the 1990s, are now absent but local women lopping broadleaf trees for cattle fodder are met more frequently than 20 years ago. On the whole it is a well preserved forest, and with perennial streams rising in some of the ravines presents a most interesting case study for what a forest should be like in order to regulate the water regime of perennial rain fed springs and streams in this area. Over the years a total of 95 butterfly species have been identified with certainty from this forest. Many are common and some which are reportedly rare or even very rare in other parts of their range, such as *Neptis narayana* and *Euaspa ziha* (Evans 1932) are common.

The only thing that changed in 2009 compared with earlier years was that the winter rains failed, although Maheshkhan got a sprinkling of snow on 12 February 2009 (Image 1). This was evidently not enough to offset the dryness experienced during March to May, which caused the State Government to declare a state of drought in the district in May. On the basis of the fact that all the pupae from different areas in Nainital district that I had overwintering indoors dried out in Bhimtal, roughly 20km away, it is reasonable to assign a similar reason to the failure of the spring and summer broods of 50 species comprising 52.6% of the total species recorded from this forest.

The most conspicuous absence was of *Delias sanaca*, which is extremely common every summer. To give an idea of the numbers involved, I discovered many dead butterflies in a small stream in the forest on 04 June 1998, presumably poisoned by pesticides infiltrating into the water from apple orchards on the other side of the hill. The figures of dead individuals from my notes are: *Delias sanaca* 200+; *Aporia agathon* 200+. There were still many more individuals of both species flying about on that and subsequent days. While *D. sanaca* presumably feeds on members of the parasitic Loranthaceae in the larval stage, *A. agathon* has been recorded on *Berberis chitra* in the area. In the summer of 2009, there were some *A. agathon* about, but very many fewer individuals than was usually the case. Both these species appear to be univoltine in the area. The eggs of *A. agathon* are laid in batches of up to a hundred. Two batches of these eggs located on leaves of *Berberis chitra* in May 2009 and left *in situ* failed to hatch out, presumably due to desiccation. One could therefore predict that there would be a reduced number of *A. agathon* about in the spring and summer of 2010.

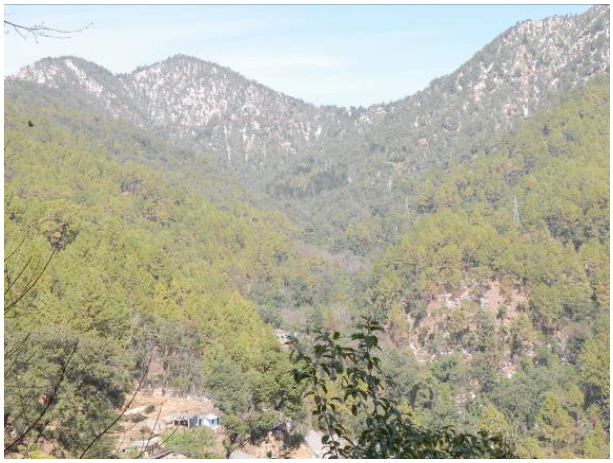

Image 1. A part of Maheshkhan Reserve Forest under a sprinkling of snow in February 2009. Light green foliage of Chir Pine; darker green of broadleaf forest, mainly Himalayan Oak. Gagar Pass (2400m) at the lowest part of the skyline.

The Neptini were another interesting discovery. For more than 20 years, I have observed the following species regularly in the forest. *N. narayana* is usually common, as common as *N. sankara*. *N. ananta* usually is about in fewer numbers. To give an idea of numbers, one might see around 20 *N. narayana* every day for a few weeks in May and June; roughly the same number of *N. sankara* and perhaps three to four individuals of *N. ananta* a day during the same period. While the larval host plants of *N. narayana*, *N. sankara*, *N. ananta* and *N. mahindra* in the area are unknown, *N. soma* feeds on *Celtis australis* (Wynter-Blyth 1957 as *N. yerburyi*). Normally this group is found in hilly regions with moderate to heavy rainfall, attaining their greatest diversity in the wetter part of North Eastern India and Indo-China. Their nearly complete absence during 2009 strongly suggests that their overwintering stages are susceptible to desiccation, which is probably a major factor restricting their range to wetter regions.

Of the butterflies that managed to maintain their

population levels in 2009, *Dodona dipoea* and *D. eugenes* are noteworthy, since their allies, *D. durga* and *D. ouida* seem to have suffered. The former two, although bred on bamboo in the Mussoorie area in Garhwal (Mackinnon & de Nicéville 1897–1898), have only been bred on the plant *Myrsine semiserrata* in this area (*mihi*). This plant grows in damp, shady ravines, where the larvae were apparently not only preserved from desiccation but also from forest fires.

The Troidini are of interest, since 2009 marked the re-appearance in Maheshkhan of *Byasa polyeuctes* after a gap of nearly 20 years. *Byasa dasarada* and *Atrophaneura aidoneus* were about in the usual numbers. The absence of *Troides aeacus* from Maheshkhan Reserve Forest is noteworthy, since it feeds on the same species of *Aristolochia* as the other Troidini mentioned above (*mihi*). It was seen on the northern face of the range during the 1970s and is common in pockets in other parts of the Gagar range.

The Lycaenidae as a whole appear to have suffered greatly. The Hairstreaks, comprising *Chrysozephyrus* Shirozu & Yamamoto and *Euaspa* Moore in this area, were almost wiped out, as were *Pratapa* Moore and *Tajuria* Moore. *Horaga onyx*, which feeds on *Coriaria nepanensis*, a common plant in the area, was about, for I saw and photographed one of them and there were doubtless others of this elusive species about.

Panchala ganesa swarms by the hundred in ravines during May and June. It was about in greatly reduced numbers in 2009. *Arhopala dodonea* and *A. rama*, which are on the wing throughout the year lower down at 1500m elevation, were about in their usual numbers. All these three species have been bred on Oak *Quercus leucotrichophora* in neighbouring Garhwal (Wynter-Blyth 1957) and this is presumably their hostplant in the area. Since *A. dodonea* and *A. rama* appear to have a brood during the winter months at 1500m elevation, it is likely that they have a brood later than *P. ganesa* in Maheshkhan, too, although one would not expect them to have a winter brood in Maheshkhan considering that it snows there every year in winter.

The other butterflies that feed on *Quercus leucotrichophora* in the larval stage, *Dophla patala* and *Sephisa dichroa*, failed to appear in 2009. Since the trees were healthy and only deviated from normal in shedding their leaves in May, which is a month later than usual, it is assumed that the pupae of both these Nymphalids suffered due to desiccation.

For the remaining species, not enough is known about their early stages to understand their presence or absence during the summer of 2009. It is apparent, though, that sustained low atmospheric humidity levels are capable of drastically altering the composition of a butterfly community in high humidity areas.

The observations noted above strongly suggest that butterflies such as the Neptini, some *Delias* Hübner and *Aporia* Hübner species, etc, require a certain minimum level of atmospheric humidity to survive. If this falls below a certain level for a sufficient length of time, as during the winter of 2008-2009 (Table 2), the species can be exterminated from an area, despite the continued presence of their larval host plants.

The observations noted above draw attention to the importance of humidity levels for butterfly communities. As with the example of a chain, which is as strong as its weakest link, many butterfly species appear to require a certain minimum amount of atmospheric humidity throughout the year in order to survive in an area. A dry spell of even a few months can wipe out populations in an area, even if the dry spell falls during a period when most butterflies are in their pupae, which is usually considered the stage least susceptible to desiccation.

Even more drastic than low atmospheric humidity levels is the effect of forest fires in Himalayan broadleaf forests. Chir pine patches and forests in the area burn almost every year without any major effect on the butterfly community. In 2009, for the first time, I saw broadleaf forest in the area burn: the effect was immediate and drastic, for the butterfly population was practically wiped out within the week.

CONCLUSION

Desiccation during the early stages is evidently one of the major factors preventing many butterfly species from colonising what would otherwise appear to be suitable habitat. Such species evidently require a minimum amount of atmospheric humidity throughout the year. If this requirement is not met, entire broods fail to emerge and a population can be wiped out. Atmospheric humidity levels are probably a major factor responsible for the restricted distribution of some butterflies that feed on widespread plants during the larval stage. Forest fires in Himalayan

broadleaf forests are extremely destructive to butterfly communities in the area and are probably the most potent threat to butterfly communities in the short term. In the long term, habitat destruction is probably the most serious threat, since this results in the extinction of butterfly communities from an area.

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