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Effect of Climate Change on Butterfly Population of Selected Coniferous Forests of Murree Hills and Adjacent Areas, Pakistan

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A B S T R A C T

Climatic changes occurring worldwide are a great threat to biodiversity and species richness of many groups of organisms thus affecting agriculture and food security. Present study deals with the butterfly populations of the coniferous forests of Murree Hills and adjacent areas of Pakistan. Inter comparisons have also been made of the current datasets with the previous archives. With a relatively short life-cycle and host-plant reliance, butterfly communities show quick response to climate change. The moist Himalayan temperate forests of Murree Hills and adjoining areas are home to many exotic species of butterflies. The weather records of the previous two decades have shown reduction in precipitation and an increase in temperature and extreme weather events. In this short span of time 14 species of butterflies have disappeared from the study area. The study shows that the remaining species are threatened due to introduction of invasive species new to this area and increased predator population. In total 46 species with Shannon index of 1.3 were recorded in the present study. One species has been recorded for the first time

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FM conceived and designed the study. HBS performed field studies. CMN, HBS and GN analyzed the data and wrote article.

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Species richness, Butterflies, climate change, Murree Hills, Shannon index.

INTRODUCTION

According to the Fourth Assessment Report of the UN International Panel on Climate Change, the climate of the planet earth is changing in an accelerated way (IPCC, 2007). The records indicate that the previous decade was the warmest after 1850. Due to the hike in global temperatures and change in weather pattern the crop production is severely affected thus threatening the food security in many regions of the world (Stern, 2007; Maragila *et al*., 2009). Large scale variations have been recorded in crop yield as a result of climate change (Whittmer *et al*., 2008; Supit *et al*., 2010; Olesen *et al*., 2011). These changes in agriculture have been attributed to alteration in flowering, blooming time, and availability of the plant pollinators, colour, and size and shape of many crop plants (Slingo, 2009). Recently a study conducted on apple orchards in Kotli Satian Hills, Punjab, Pakistan has indicated that the fruit production has sharply declined due to climate change in the area (Asghar *et al*., 2012). Since fruit tree farming serves as a primary source of income for the farmers of the area, the decline in fruit production has greatly affected the economics of the area.

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Climate change is also a major threat to biodiversity not only causing changes in plant phenologies but also resulting in pole ward shifts in birds and butterflies. In terrestrial ecosystem 28,586 significant biological changes are related with climate change (Richardson and Poloczanska, 2008). Many species will not be able to cope with the effects of changing temperature and precipitation regimes. Thomas *et al.* (2004) predicted that 15-37% of species are committed to climate change induced extinction in the next 50 years.

With a relatively short life-cycle and host-plant reliance, butterfly communities showed quick response to climate change. Domenech (2009) conducted a project based on the methodology developed by Pollard and Yates (1993) and permitted a precise recognition of changes in butterfly abundance by following itineraries to observe butterflies in their environment and later relate these observations to various environmental variables. The role of the butterfly as a biodiversity indicator is well known for climate change in particular (Parmesan *et al.*, 1999; Stefanescu *et al.*, 2003).

Butterflies are often used to study the effects of climate change because of their sensitivity to climatic variables. Temperature strongly affects butterflies throughout their life histories. Direct or indirect effects of temperature have been observed in choice of oviposition sites, egg-laying rates, larval development and survival rates, and range shifts and expansions (Davies *et al.*, 2006). Precipitation influences larval development and

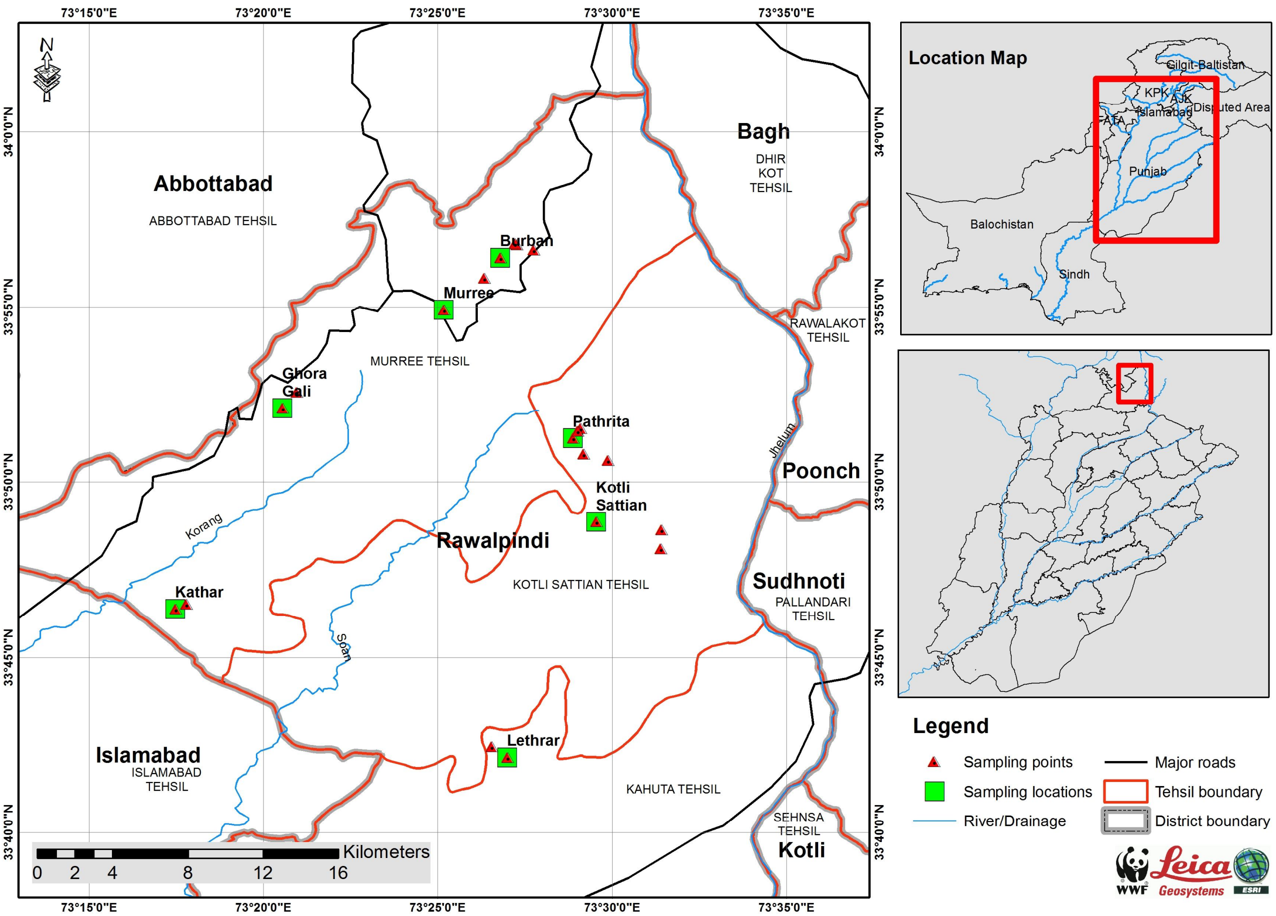


Fig. 1. GPS Map of areas under study.

survival by controlling host plant phenology (Rodriguez *et al.*, 1994). Individual host plants are usually the sole source of food for prediapause larvae because inter-plant distances often exceed larval dispersal ranges (Weiss *et al.*, 1993). Larvae are unable to travel far to locate a new host if their natal plant becomes defoliated or senescent (Hayes, 1985). If a host plant senesces before larvae reach diapause, the larvae starve unless they find another suitable plant. Starvation is the usual outcome because interplant distances often exceed larval dispersal ranges (Hellman, 2002). Butterfly habitats are easily defined and delineated because the larval stage is highly dependent upon host plants. As adults, most butterflies are generalists and can find food in the form of nectar, rotting fruit, and sap; however, larvae are usually specialist feeders and some require a specific host plant. Since larvae are closely tied to their host as their food source, the plant's distribution defines the potential distribution of the butterfly.

This distribution is further limited by climatic factors such as temperature (Crozier, 2004). Therefore impact of climate change on these plants can cause threat to butterflies. Butterflies are sensitive to climate change, understanding their responses to climate change, especially through interactions with host plants, will aid in forecasting how other species will respond and the extent of impact on agricultural productivity.

The present study aims at studying the impact of climate change on butterflies population and identifying and mitigating threats and developing conservation strategies for butterflies in Murree Hills and adjacent areas, Pakistan.

MATERIALS AND METHODS

Description of the study sites

Four main forests of Punjab surveyed in the present study were Murree, Katthar, Lethrar, and Kotli Satian (Fig. 1). Murree is situated at an altitude of 7500 feet (2286 meters) in the Himalayan foothills. Murree is a mountainous area, forming part of outer and lesser Himalayas, situated at 33° 35' north latitude and 73° 27' east longitude. It is bounded by River Jehlum in the East, KPK districts of Abbottabad and Haripur to the North and West, Islamabad Capital Territory to the Southwest and Kotli Satian Tehsil (town) of Rawalpindi district to the South (www.Murreehill.com). Kotli Satian is a small Tehsil to the South of Patriata (New Murree). This site is characterized by thick pine forests, is very beautiful and not visited by many people. Kotli Satian was earlier a part of Tehsil Murree but now is a separate tehsil. It is situated at 33° 48' North latitude and 73° 31' East longitude. It is at a distance of 70 km distance from Rawalpindi. Kathar Game Reserve is present in North East at a distance of 20 Km from Rawalpindi. It is included in the list of South Asia's protected areas by IUCN since 1999. It has a total area of 1,141 ha (2,819 ac). It has mixed vegetation which is dominated by herbs and shrubs. It is located at 33° 46' north latitude and 73° 17' East longitudes. Lethrar is a small village present in South of Kotli Satian. It is also a pine forest. It is situated at 33° 42' north latitude and 73° 26' East longitudes.

Dominant tree species of the area include *Pinus wallichiana, Pinus roxburghii, Cedrus deodara, Abies pindrow, Taxus baccata* and *Rhus cotinus, w*hile the shrubs include *Pyrus pashia, Berbaris lyceum, Viburnum nervosum.* These forests have rich undergrowth vegetation comprising of herbs and small shrubs. The important herbs are *Skimmia lauriola, Galium aperine, Origanum vulgare* and *Plectranthus rugosus* (Nasim, 2011).

Field surveys

Field surveys were carried out once a month starting from May, 2011 to October, 2011. The photography was done with the help of Digital Camera. Cannon Powershot (SX130). During these surveys the butterflies were counted directly and identified according to Roberts (2001). Global positioning of the study sites was carried out with the help of Global Positioning System (GPS) Garmin Etrex GPS. Due to the vast area covered by the study sites, appropriate observation points were selected from where maximum chances of observation and counting the butterflies were possible.

Methodology

Fixed transects were established in all the habitats in study areas. In each habitat a minimum of five parallel transects, spaced at least 200m apart were laid out. The length of transect was 1-2 km *i.e.* about 45-60 min walk. The transect route was divided into 5-15 sections of equal length; each section representing a change in the habitat. Transects were walked early in the morning and in the evening and throughout the day depending upon the circumstances.

Statistical analysis

The observations were tabulated and data was statistically analyzed by using Microsoft Excel. Relative Abundance of each species of butterfly was calculated. Species richness, evenness, and Shannon-Wiener Biodiversity Index for butterflies for all selected sites were calculated.

Relative species abundance, which is the proportion of individuals of a given species to the total number of individuals in the community (Stiling, 1999), has been calculated as follows:

$$\text{Relative abundance} = Pi = Ni / N$$

Where, Ni is number of individuals, and N is total population

Shannon-Weiner diversity index was Calculated using the formula (Stiling, 1999).

$$H' = - [\sum Pi \ln Pi]$$

Where, H' is diversity Index; Pi is proportion of species *i* relative to the total number of species, and LnPi is natural logarithm of this proportion. Values of the Shannon's diversity index for real communities typically fall between 1.5 and 3.5. The higher the number, the higher is the species diversity (Nolan and Callahan, 2006).

Species evenness refers to how close in numbers each species in an environment (Mulder *et al.*, 2004). Species Evenness was calculated according to Stiling (1999):

$$\text{Species Evenness} = H'/ \ln (S)$$

Where, H' is Shannon Diversity Index, and S is Species Richness.

Climate analysis

Twenty two year climate data for precipitation, cloud cover, humidity and temperature of the area was retrieved from archives of Punjab Metrological Department. The data was analyzed by plotting graphs and establishing different trends.

RESULTS AND DISCUSSION

Figure 2 show fluctuation in temperature and rain fall in Murree Hills and adjacent area over the past 20 years.

Climate change

Global climate change is caused by accumulation of greenhouse gasses in the lower atmosphere. This has increased CO_2 concentration from 280 to 384 ppm in 2009 with a mean temperature rise of 0.76°C (DaMatta *et al*., 2010). The faster the climate changes the greater would be the risk of damage to environment and its subsequent effect on crops (Shah *et al*., 2012). The recent assessment of climate change impact indicated that some regions are likely to be benefited from an increase in the agriculture productivity, while others may suffer in reduction (Lioubimtseva and Henebry, 2009; Nasim, 2012; Nasim and Shabbir, 2012 a,b).

The major impacts of climate change in South Asia include the melting of glaciers in Himalayas and consequent increase in flooding which build up the pressure over natural resources and a resulting stress over the environment, disease outbreak (Nasim and Shabbir, 2012a), impacts on soil fertility, which would end up in erosion and reduced crop growth (Ahmed *et al*., 2010). Besides many environmental and soil factors, the agricultural productivity depends upon pollinators also especially in the case of fruit trees and herbs found in the hilly areas of Pakistan. Butterflies are among important pollinator (Saeed *et al*., 2012). For this study, four main forests of Punjab were surveyed. A total of 46 butterfly species were observed (Table I). One new record was also observed from the area.

Biodiversity of butterflies, as pollinators

In Murree forest area 480 individuals were observed with maximum species richness of 26 in the month of June and Shannon index of 1.305. *Pararge schakra* was the most abundant species present. Murree has large forest division. It is divided into small sub divisions. Three main sub divisions of Murree are Ghora Gali, Bhurban and Pathrita. In sub divisions Pathriata had maximum species richness. However, *Erebia nirmala* was abundant in Bhurban. *Polyommatus eros* was observed in Bhurban, while *Celaenorrhinus leucocers* was observed in Ghora Gali. *Junonia heirta, Celastrina ladonides, Aulocera swaha*, *Heliophorus sensa* were observed in Pathriata. In Katthar, 17 species were observed with a total of 78 individuals. In September maximum species richness of 8 was observed. *Catopsilia crocale* was the most abundant species. In forest area of Lethrar 18 species were present with 89 total individuals. In October maximum species richness of 11 was observed. *Pieris brassica* was the most abundant speices in this forest. In Kotli Satian 23 species were observed with a total of 244 individuals. June and September had maximum species richness of 12. *Dodona durga* was the most abundant species.

A total of 46 butterfly species with total individuals 885 were observed. June had maximum species richness of 30. *Pieris brassica* was most abundant species and *Dodona durga* was second one in the density. Shannon index was 1.352 which shows a low level of biodiversity range. Butterflies species and numbers in different months are shown in the data tables.

Climate change and biodiversity

It is very difficult to foresee how the biodiversity is going to respond to climatic variabilities. Highly complex climate models have been developed to give an idea of the future trends for responses of various components of biodiversity in an ecosystem. Although we know that many butterflies are being affected by climate change, the impact on each species is difficult to predict. This is because the responses depend on a complex interaction between the plants and the insect, and the environmental conditions that shape their habitats.

Butterflies are very sensitive to the change of phenology of the plants in a forest ecosystem as they require plants of all heights for their life sustenance. Any climatic change affects phenological changes in plants. Phenological, temporal and seasonal changes in plants affect the life cycle of the butterflies. Any abnormal change in the life cycle of buterflies affects the butterfly populations in an area. With a relatively short life-cycle and host-plant reliance, butterfly communities show impact quickly and can act as an early warning of portending shifts in the surrounding flora and fauna (Batra, 2005).

The main factors for the change in population were temperature, altitude and plants. Along variation in butterfly populations there were differences in predator birds also. The king crow or black crow for example was present in Murree and its adjacent forests, but king crow population declined at lower altitudes.

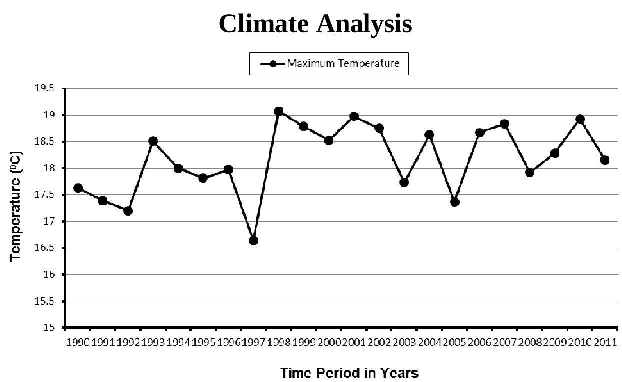
The climate of the study area can be classified as “Subtropical Moderate Climate Zone”. The average maximum and minimum temperatures in Murree are 17ºC and 9ºC, respectively. The hottest month is June when the temperature may rise to 25 ºC, while the coldest months are December and January. The annual average precipitation is 1,789 mm, most of which is received during July and August.

A total of 46 butterfly species were observed during May to October 2011. Out of these 10 species had not been reported by Hassan (1994) who has actually listed 60 species from Murree and Islamabad. However, Roberts (2001) has given these species in the inventory of 100 species he had developed from all the pre-existing records of Butterflies of Pakistan. One species (yet unidentified) is a new record from the area. It might be a new introduction as a result of changing geographical

Table I.- Butterflies species month wise distribution from May to October 2011.

Species	May	June	July	August	September	October	Total	Pi	InPi	Pi InPi
Catopsilia pyranthe	6	9	4	6	2	2	29	0.032768	-1.48455	-0.04865
Pieris brassica	10	50	10	6	5	13	94	0.106215	-0.97382	-0.10343
Danaus chrysippus	1	4	5	3	2	6	21	0.023729	-1.62472	-0.03855
Vanessa cardui		9	4	3	3	8	27	0.030508	-1.51558	-0.04624
Phalanta phalanta	4	26	10	4	7	10	61	0.068927	-1.16161	-0.08007
Catopsilia crocale		13	22	11	17		63	0.071186	-1.1476	-0.08169
Azanus uranus butler		3				5	8	0.00904	-2.04385	-0.01848
Azanus ubaldus		5	6	2	3	5	21	0.023729	-1.62472	-0.03855
Junonia orithya	5	17	6	8	15		51	0.057627	-1.23937	-0.07142
Neptis mahendra	4	14	9	7	19	15	68	0.076836	-1.11443	-0.08563
Anaphaeis aurota	4	2	2		1		9	0.010169	-1.9927	-0.02026
Pieris canidia		22	12	11	13	16	74	0.083616	-1.07771	-0.09011
Pararge schakra	4	8	19	6	5	10	52	0.058757	-1.23094	-0.07233
Gonopteryx rhamni		5					5	0.00565	-2.24797	-0.0127
Papilio philoxenus	4	26	2	1			33	0.037288	-1.42843	-0.05326
Papilio demoleus		3				1	4	0.00452	-2.34488	-0.0106
Papilio polyctor		10	3	2	8		23	0.025989	-1.58522	-0.0412
Papilio polytes					1		1	0.00113	-2.94694	-0.00333
Lethe rohria	5	5					10	0.011299	-1.94694	-0.022
Aglias cashmirensis	3	1			9		13	0.014689	-1.833	-0.02693
Colias crocea			6	3	10	12	31	0.035028	-1.45558	-0.05099
Dodona durga	8	12	4	3	33	10	70	0.079096	-1.10185	-0.08715
Colias erate		1			2		3	0.00339	-2.46982	-0.00837
Erebia nirmala		25	7		17		49	0.055367	-1.25675	-0.06958
Lethe verma		2	3				5	0.00565	-2.24797	-0.0127
Ypthima avanta			5				5	0.00565	-2.24797	-0.0127
Heliophorus sensa	2	1			2	1	6	0.00678	-2.16879	-0.0147
Danaus limniacea	2						2	0.00226	-2.64591	-0.00598
Libythea leptia	1					2	3	0.00339	-2.46982	-0.00837
Celaenorrhinus leucocers		1					1	0.00113	-2.94694	-0.00333
Argyreus huperbius	1	2			1		4	0.00452	-2.34488	-0.0106
Junonia heirta		1					1	0.00113	-2.94694	-0.00333
Ypthima sakra			2				2	0.00226	-2.64591	-0.00598
Polyommatus eros			1				1	0.00113	-2.94694	-0.00333
Aulocera swaha					1		1	0.00113	-2.94694	-0.00333
Ypthima nareda		1					1	0.00113	-2.94694	-0.00333
Celastrina ladonides	1						1	0.00113	-2.94694	-0.00333
Satyrus parisatis					1	6	7	0.00791	-2.10185	-0.01662
Zizeeria maha						1	1	0.00113	-2.94694	-0.00333
Eurema hecabe						6	6	0.00678	-2.16879	-0.0147
Ariadne merione						2	2	0.00226	-2.64591	-0.00598
Nymphalis xanthomelus		2					2	0.00226	-2.64591	-0.00598
Vanessa indica					9	2	11	0.012429	-1.90555	-0.02368
Paranara gutatta		1					1	0.00113	-2.94694	-0.00333
Lycaena phlaeas	1						1	0.00113	-2.94694	-0.00333
N. Spp					1		1	0.00113	-2.94694	-0.00333
Total individuals	66	281	142	76	187	133	885	1		-1.35283
Species richness	17	30	21	15	24	20				
Shannen index		1.3528								
lnS	1.2304	1.4771	1.3222	1.1761	1.3802112	1.30103				
Species evenness	1.0994	0.9158	1.0231	1.1503	0.9801398	1.03979				

distribution. While looking at climate data of twenty years, it is evident that there is variability in climate pattern. In twenty two years the precipitation has decreased significantly (Fig. 2) and this has affected the plant species which in turn is responsible for butterfly loss. Similarly we can observe increase in maximum temperature (Fig. 2). This climate shift is affecting most of plant species, disturbing butterflies egg laying patterns and larvae hatching. The intensity of extreme weather conditions has also affected many species. The year 2005 which was world's warmest year, had the mean average minimum temperature of -5.5°C for February which is the minimum in past twenty years for February. The larvae of butterflies are associated with plants but cause little damage to the hosts. The adults act as incidental, wild pollinators and help in pollination of many native plants and fruit trees. The larvae as well as adults are food for many predators like lizards and birds. The butterfly diversity in an ecosystem tells how healthy it is, as butterflies are very sensitive to any change in the environment.



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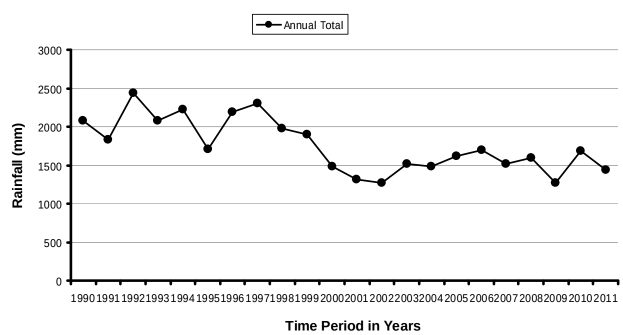

B

Fig. 2. Fluctuation pattern of maximum temperature (A) and annual rainfall (B) in the Murree Hills and adjacent area during the past 20 years.

Besides number of species, species richness and evenness also show fluctuations. Some Species which were reported fairly common by Roberts (2001) were only seen once or twice in the study area. Contrary to this some species which were previously abundantly seen in Murree Hills such as *Catopsilia crocale* are no longer seen. With climate changes other factors *i.e*. land use change, and pollution have also caused reduction in butterfly populations.

With climate change predators of butterflies have also increased. The widening of the warm season span has increased wild lizard and black crow populations which prey on butterflies (personal communication by the author).

Average annual changes in temperature and rainfall across regions are of limited value for predicting the responses of wildlife, which are affected by fine-scale climatic changes. In the short-term, measuring the distribution responses of good indicators, such as butterflies, may be useful.

CONCLUSIONS

Climate change over the course of twenty years has affected many plant and animal species in Pakistan. Murree which is home to many exotic species of plants and animals in Pakistan has lost 14 of its important butterfly species, and this list will increase if the same trend of climate change moves forward. Climate analysis shows increase in freakish weather which is great threat to biodiversity. Shannon index was 1.3 which shows an alarming situation. Butterfly species with climate change are also in stress with land use change, environmental degradation and fragmentation. Many of plant species which are food source to butterflies have been affected and shifted by climate change causing disturbance in butterflies feeding patterns. Species richness and evenness has decreased. Butterflies are sensitive to climate change, understanding their responses to climate change, especially through interactions with host plants, will aid in forecasting how other species may respond.

Statement of conflict of interest

Authors have declared no conflict of interest.

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