CLIMATE CHANGE AND ITS IMPACT ON LEPIDOPTEROUS FAUNA IN AYUBIA NATIONAL PARK-ABBOTTABAD

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ABSTRACT

Impacts of changing climate were assessed on lepidopterous fauna in Ayubia National Park, Galies Forest Division-Abbottabad. The maximum, minimum and mean temperature regimes of the Park were 16.3±0.08°C, 6.1±0.09°C and 11.2±0.08°C, respectively, while precipitation regime was 915.1±25.37 mm/annum. The warmest year was 2001. Monsoon was the warmest and the wettest season. The highest temperature increase was 2.4°C in minimum temperature during winter. Overall precipitation increased by 3.36%, however, precipitation decreased during spring and summer by 15.3% and 2.2%, respectively. A total of 101 butterflies and moths species were collected, which belonged to 18 families. Among these, 42 species were new in the Park area. About 70% of the species migrated from lower elevation or from dry temperate forest to moist temperate forest. Margalef Species Distribution Index (3.25) showed greater richness of species during 2011-12 compared to 1960s. Shannon Wiener Maximum Species Evenness Index (2.64) showed greater species evenness in different niches of the Park during the study period. The highest increase in species number was recorded in family Noctuidae. Temporal Temperature showed highly significant ($p<0.01$) impact on species number. There was a positive linear correlation between increasing temperature and number of insect species, as well as between precipitation and species number.

Key words: Climate change, Temperature, Precipitation, Insect fauna, Lepidoptera, Insect species, Ayubia National Park, Pakistan

INTRODUCTION

Climate change is a multidimensional global phenomenon having broad spectrum impacts. During 20th century, the mean global temperature has risen by ~0.06°C and still going on unabated (IPCC, 2007). This global warming is variable with geographical zones. Pakistan has experienced gradual increase in temperature during the last century (0.06°C) which is in agreement with global increase, however, during 1981-2005 temperature increase was greater than two times compared to the global one during this period. Moreover, temperature increase was greater in northern mountainous parts compared to southern parts (Sheikh, *et al*., 2012).

The climate change has shown considerable impacts on ecosystems worldwide (Walther, *et al*., 2002). The rising temperature affects distribution of many terrestrial species belonging to different taxa (Parmesan and Yohe, 2003;

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Hickling, *et al*., 2005), individual species, communities. In some cases rising temperature has resulted in species extinctions (Kullman, 2002), changed phenology (Roy and Sparks, 2000; Fitter and Fitter, 2002; Stefanescu *et al.*, 2003), and enhanced altitudinal ranges (Grabherr, *et al*., 1994; Pounds, *et al*., 1999).

Among different taxa, insects hold key positions in ecological systems. Richness of insect diversity can be helpful in estimation of health and level of biodiversity of habitats. Any change in number of insect species and composition may affect whole floral composition of an area as more than 65% flowering plants are pollinated by animals among which insects play the dominant role (Elzinga, 1981). Apart from ecological position of insects, they with short lifecycle, high reproductive rate and migration potential are able to respond quickly to climate changes. The sensitivity of insects to climate change (Warren, *et al*., 2001) makes them good bio-indicators which provide effective tools to understand climate change and its impacts on the biosphere of a particular area.

Temperature affects insects in different ways, e.g. it has direct effects on development, reproduction and survival of insects (Andrewartha and Birch, 1954). Apart from these biological processes, temperature and precipitation also influence daily and seasonal activities of insects. Indirectly, climate change affect abundance and distribution of insect species through altering species composition, distribution, abundance and food quality of host plants (Ismail and Hall 1998). Thus, economic status of insects can be changed with changing climate, as in prolonged growing seasons, defoliators, wood borers and bark beetles could become more detrimental. Presence of benign long seasons can lead to emergence of multivoltine insect strains and possible shift to novel host plants (Liebhold, *et al*., 1995; Ayres and Lombardero 2000, Volney and Fleming, 2000, Battisti, *et al*., 2006, Stastny, *et al*., 2006).

Keeping in view climate change and its impacts on number, composition and distribution of insect species, and consequently on overall biodiversity status and its management strategies, present study was undertaken to assess: (i) climate change over the Ayubia National Park, (ii) richness and distribution of lepidopterous species, and (iii) impacts of climate change on the lepidopterous species in the Park.

MATERIALS AND METHODS

Study Area

The study was conducted during 2011-2012 in Ayubia National Park which was located in Galies Forest Division, Abbottabad at 34°:01' to 34°:3.8'N latitude and 73:22.6' to 73:27.1'E longitude with total area of 3,312 ha (33 Km^2).

The Park harbours three types of vegetation, (i) dry Sub-Alpine meadows, (ii) Moist temperate forests, and (iii) Sub-tropical pine forests. The major forest tree species included: *Cedrus deodara*, *Pinus wallichiana*, *P. roxburghii*, *Abies pindrow,* and *Pecea smithiana.*

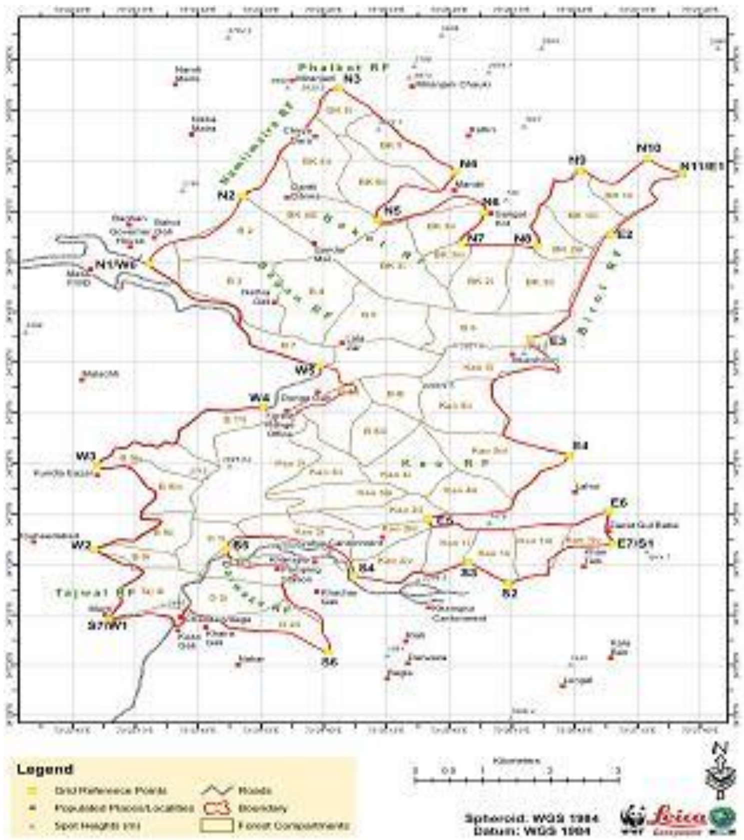

Fig.1. Map of Ayubia National Park-Abbottabad

Site selection and insect collection

Periodical field surveys were conducted during 2011-12 at thirteen sites. Butterflies and moths were collected using light traps, insect collecting nets and manual picking. The insect specimens were pinned, board-set for identification and indices for species distribution, richness and evenness were calculated.

Climate change data

Climate data was extracted from grid based data of Climate Research Unit (CRU), UK. The time series data of maximum temperature, minimum temperature, mean temperature and precipitation was extracted at grid size of

0.5x0.5 degree (50x50) km^2 for time period of 1960 to 2012. Both vertical (temporal) and horizontal (seasonal) changes in the climate were estimated. The seasons defined were: spring (March-April), summer (May-June), monsoon (July-September), autumn (October-November) and winter (December-February).

Data analyses

Species diversity and colonization indices were calculated using Margalef Species Distribution Index and Shannon's Wiener Maximum Species Diversity Index, by running Species Diversity-Richness Statistical Software, Version SDR-4. Temperature and precipitation regimes were calculated during time period of 1960-2012. Temperature and precipitation changing trends were estimated using best fitted regression models and significance of change was tested using Student's t-test. Impacts of climate change on number of insect species were estimated using 1-Way Analysis of Variance test (ANOVA) and Pearson Correlation matrices. The variation in species within family was further tested using Tukey's Honest Significant Difference (HSD) Test. The analyses of climate change and its impacts on insect species were conducted using statistical software Minitab version 15.1.

RESULTS

Climate Change

The results showed a mean temperature regime of 11.2±0.08°C over Ayubia National Park, during the time period of 1960-2012. The maximum temperature and minimum temperature regimes were 16.3±0.08°C and 6.1±0.09°C, respectively. The monsoon was the warmest followed by summer, while winter was the coldest. The minimum temperature remained below freezing point during winter (Table 1).

Table 1. Temperature and precipitation regimes over Ayubia National Park (1960 to 2012)

Season	Min Temp. (°C)	Max. Temp. (°C)	Mean Temp. (°C)	Precipitation (mm)
Spring	4.1±0.16	13.7±0.19	8.9±0.17	198.1±9.88
Summer	11.6±0.14	23.0±0.17	17.3±0.15	117.2±4.64
Monsoon	13.2±0.07	23.3±0.08	18.3±0.07	345.1±13.78
Autumn	4.1±0.12	16.1±0.11	10.1±0.09	47.6±3.08
Winter	-2.2±0.15	6.7± 0.13	2.2±0.13	156.2±3.94
Annual	6.1±0.09	16.3±0.08	11.2±0.08	915.1±25.37

The precipitation regime was 891.1±19.75 mm/annum. Monsoon was the wettest with precipitation regime of 345.1±13.78 mm/season, while autumn was the driest with precipitation regime of 47.6±3.08 mm/season (Table 1).

The results showed an increasing trend in maximum temperature, minimum temperature and mean temperature. The hottest year was 2001, while the coldest year was 1968, (Figure 2). The highest and the lowest variability in mean temperature within a year was recorded during 1968 and 2009, respectively. A continuous increasing trend in temperature was found after 1999.

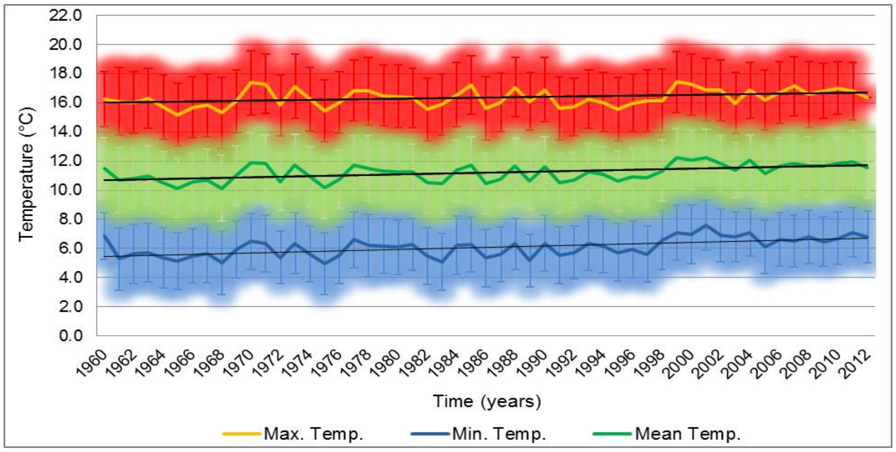

Fig. 2. Temperature changing trends over Ayubia National Park during (1960-2012)

Furthermore, a greater increase in minimum temperature was recorded compared to maximum temperature. The temperature variability, within a year, was greater in mean temperature followed by minimum temperature. The fluctuation in maximum temperature was relatively lower compared to minimum temperature and mean temperature.

A significant variability was recorded in inter-annul precipitation. The highest precipitation was received during 1983 (1145.2±25.01 mm/annum), while the lowest precipitation was received during 1971 (561.2±11.60 mm/annum). The most uneven intra-annual precipitation distribution was recorded during 2006 (Figure 3).

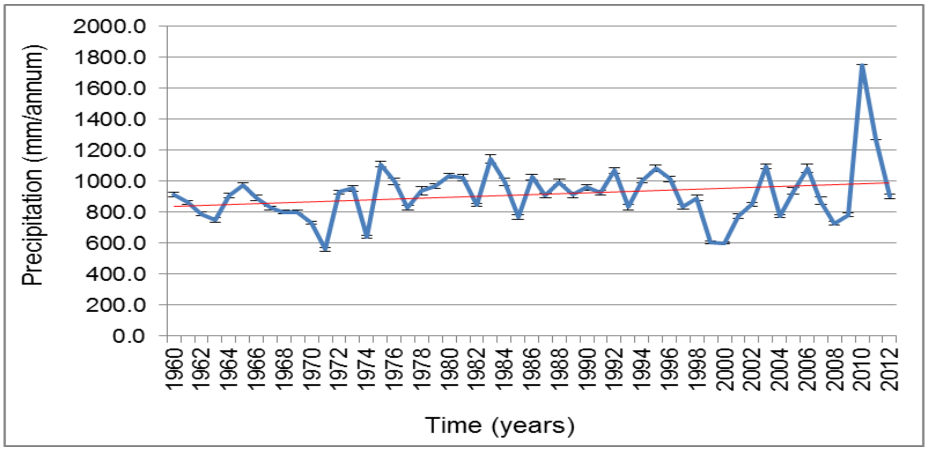

Fig. 3. Precipitation changing trends over Ayubia National Park (1960-2012)

A highly significant (p<0.01) temporal increase was recorded in mean temperature (1.0°C) and minimum temperature (1.2°C). Season-wise, the highest increase in temperature was estimated during winter, ranging from 1.3°C to 2.4°C, followed by spring (Table 2). Conversely, the lowest increase in temperature was estimated during monsoon. The increase in minimum temperature was greater compared to maximum temperature, both in terms of temporal and season-wise increase. Overall precipitation increased by 3.4% in precipitation (Table 2). Season-wise precipitation increased during monsoon, autumn and winter. Conversely, precipitation decreased during spring (15.3%) and summer (2.2%).

Table 2. Temperature and precipitation changes over Ayubia National Park (1960 to 2012)

Season	Min Temp (ΔT°C)	Max. Temp (ΔT°C)	Mean Temp (ΔT°C)	Precipitation (Δ%)
Spring	1.9**	1.0	1.4**	-15.3*
Summer	0.9*	0.3	0.7	-2.2
Monsoon	0.2	0.1	0.1	9.5*
Autumn	1.0**	0.5	0.8*	14.5
Winter	2.4**	1.3**	1.9**	20.6
Annual	1.2**	0.7*	1.0**	3.4

* Significant (p<0.05); ** Highly significant (p<0.01)

Species Abundance and Distribution

A total of 101 lepidopterous species, belong to 18 families were collected during 2011-12, in Ayubia National Park. The number of species collected during 2011-12 was 4.2 times greater compared to the number of species collected during 1960s. Forty two new species were collected during 2011-12 compared to 1960s in the Park. Among new species, about 70% species have had migrated from lower elevations or from dry temperate forest zone. The species diversity and distribution indices were also supported increase in number of insect families and species. Margalef Species Distribution Index (SDI) showed greater number of families and species diversity during 2011-12 compared to 1960s. Apart from rich species distribution, the SDI indicated a greater ecological establishment of insect species as compared to previous records. Similarly, Shannon Wiener Maximum Species Evenness Index (SEI) indicated uniform distribution of the insect species in different ecological niches of Ayubia National Park (Table 3).

Table 3. Species distribution and evenness indices in Ayubia National Park (1960-2012)

Index	Time period	Index value
Margalef Species Distribution Index	1960s	3.46
	2011-12	3.25
ASI	-	3.52
Shannon Wiener Maximum Species Evenness Index	1960s	2.49
	2011-12	2.64
ASI	-	2.89

ASI: All sample Index

Impacts of Climate Change

The results showed significant ($p<0.05$) impact of temperature on number of lepidpoterous families ($F_{17, 630} = 34.76$; $p<0.01$) and species ($F_{21, 626} = 3.18$; $p<0.01$). The number of families increased significantly (CV= 2.23; Tukey's HSD test; $p<0.05$) during 2011-12 compared to 1960s. Similarly, overall number of species increased significantly ($p<0.05$; t-test), as well as, number of species increased significantly within families (CV= 1.96; Tukey's HSD test; $p<0.05$). Temporal temperature increase showed highly significant ($F_{1,646} = 179.03$; $p<0.01$) effect on number of species. Mean number of species per family increased significantly (CV= 0.545; Tukey's HSD test; $p<0.05$) from 1.33±0.19 per family to 5.61±1.35 per family during 1960-2012 (Figure 4). The highest increase in number of species was recorded in Noctuidae followed by Pyralidae.

Two families, Lasiocampidae and Zygaenidae, reported during 1960s were not found during 2011-12. Apart from temperature, precipitation showed significant impact ($F_{9,170}$= 5.23; p<0.01) on insect species. The number of species within families and across the families varied significantly (CV= 1.194; Tukey's HSD test; p<0.05).

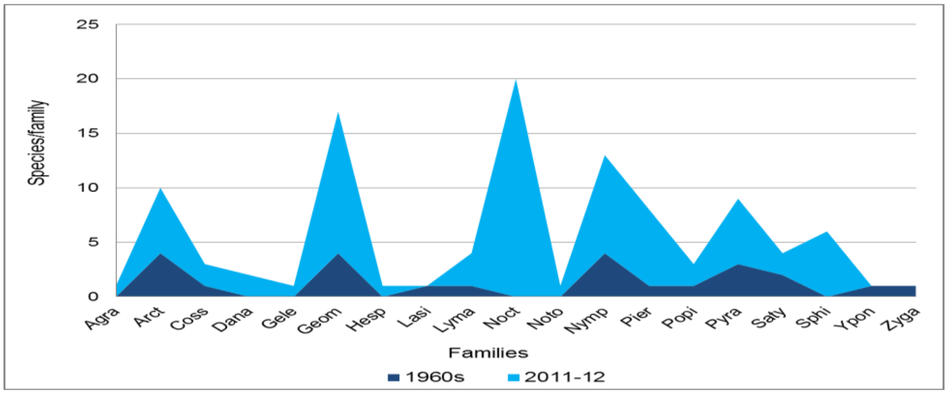

Fig. 4. Comparison of insect species belonging to different Lepidopterous families

Pearson Correlation matrix showed positive and highly significant correlation between number of species and time scale. The correlation between number of species and maximum temperature; number of species and minimum temperature; number of species and mean temperature, and between number of species and precipitation was positive but not significant (p>0.05). The lowest level of correlation was between number of species and precipitation (Table 4).

Table 5: Correlation matrix for Lepidopterous species and climate parameters

	Time scale	Maximum Temp	Minimum Temp	Mean Temp.	Precipitation
Maximum Temp	0.06 (0.39)				
Minimum Temp.	0.11 (0.10)	0.99 (0.00)			
Mean Temp	0.09 (0.19)	0.97 (0.00)	0.96 (0.00)		
Precipitation	0.02 (0.77)	0.07 (0.32)	0.05 (0.46)	0.18 (0.00)	
Species	0.31 (0.00)	0.02 (0.79)	0.03 (0.62)	0.03 (0.68)	0.01 (0.92)

Values in parenthesis () are probability; Highly significant (p<0.01)

DISCUSSION

The present results showed an increasing trend in temperature and precipitation over Ayubia National Park during 1960-2012. Previously such increasing temperature trends have been reported globally (IPCC, 2007), as well as, over different parts of Pakistan (Bukhari and Bajwa 2008; Sajjad *et al*., 2009a&b; Sheikh, *et al.,* 2012).The highest increase was recorded in minimum temperature (1.2°C), while the lowest increase was recorded in maximum temperature (0.7°C). The increase in mean temperature (1.0°C) over the Park is relatively greater compared to global mean temperature increase (0.8°C) recorded over the past 100 years (IPCC 2007). The greater increase at local level may be due to urban heat island effect and anthropogenic activities. Earlier, this phenomenon has been reported by Trenberth (1990) and Wu, *et al*. (2010). The present greater increase in minimum temperature compared to maximum temperature is in corroboration with Shiekh, *et al*. (2012) and Bukhari and Bajwa (2011). Likewise, the greater increase in winter temperature is recorded followed by spring temperature. The lowest increase is in monsoon temperature. Overall precipitation increases by 3.4%, while precipitation decreases in spring and summer. Previously, such seasonal changes have been reported by Sparks and Menzel (2002).

Climate change has wide ranging impacts on biological functions of different taxonomic groups and ecosystem health. Insects, especially butterflies and moths are important bio-indicators because every aspect of an insect's life cycle is dependent upon temperature as they are cold blooded. Hence, insects should have to respond quickly to changing climate by shifting their geographical distribution and population behaviour to take advantage of new climatically benign environments (Carroll, *et al*., 2003). Insects' quick response may be used as early warning bio-indicators for changing climate and consequently changing ecosystem health. The present findings indicate positive effect of increasing temperature and precipitation on biodiversity as lepidopterous species increased by 4.2 times during 52 years. The increase in species number is greater family in Noctuidae followed by Pyralidae. Species Distribution and Evenness Indices show greater diversity and ecological establishment of lepidopterous species in the Park with the passage of time. Some species belonging to family Lasiocampidae and Zygaenidae, recorded previously, are absent during time period 2011-12. A significant number of species (70%) migrate from lower elevations towards north or shift from dry temperate forest zone towards moist temperate forest zone. The increase in species number may be assigned to improved vegetation status and floral diversity. The results of species richness with and altitudinal migration with changing climate are in line with previous findings of Klanderud and Birks (2003).

The present findings of species migration and elevational movement under influence of changing climate are in conformity with previously records of range expansion of lepidopterous species. For instance, Parmesan, *et al.* (1999) reported 35-240 km pole-ward shift of 22 out of 35 non-migratory European butterfly species during the last century. Similarly, Hill, *et al*. (2002) found that out of 51 species of British butterflies 11 species have expanded in the northern part of their distributional range. Apart from pole-ward shifting, altitude shifts in the distribution of Czech butterflies have been reported by Konvicka, *et al*. (2003). Similarly, increase in lower elevational limits of 16 butterfly species in central Spain on an average by about 212 m in 30 years has been recorded by Wilson, *et al*. (2005). Wilson and his colleagues attributed this elevational rise to an observed 1.3°C increase in mean annual temperature. Similarly, it has been found that climate warming shifted the northern boundary of the distribution of the gypsy moth (*Lymantria dispar*) and the nun moth (*L. monacha*) by ≈500-700 km (Vanhanen, *et al*., 2007). The dry stress in dry temperate forests might have triggered migration of insect species towards moist temperate forests. Besides warming, dry stress effect has been reported in *Lymantria dispar*-larvae on *Populus* by Hale, *et al*. (2005). However, it is highly likely that the effect of dry stress, as well as heat stress, is species specific.

The present results of positive effects of increasing temperature and precipitation on lepidopterous species are broadly in corroboration with earlier works, like increase in summer temperature and mild winters decreased the mortality of over wintering stages of the mountain pine beetle, *Dendroctomus ponderosae*, in western Canada (Logan, *et al*., 2003). The present increase in winter temperature might also have contributed in reduced winter mortality of insects during diapause and thus, enhanced species richness. Such findings have been reported earlier (Ungerer, *et al*., 1999; Battisti, *et al*., 2005; Veteli, *et al*., 2005).

CONCLUSION

Based on the present findings, it is concluded that temperature is increasing over Ayubia National Park. The increase in minimum temperature is relatively greater compared to maximum temperature. Similarly, increase in winter temperature is greater compared to other seasons. Overall precipitation is found to be increased in the area but decreased during spring and summer. Biodiversity of butterflies and moths has been enriched in Ayubia National Park with the passage of time. The insect species have been migrated from lower elevations and also from dry temperate forests towards the Park. The increasing temperature and precipitation show positive correlation with lepidopterous fauna.

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