Indian Forester, 143 (9) : 950-955, 2017
http://www.indianforester.co.in
ISSN No. 0019-4816 (Print)
ISSN No. 2321-094X (Online)

ABUNDANCE TRENDS IN PAPILIONID BUTTERFLIES OVER A DECADE: IMPLICATIONS AND CONSERVATION LESSONS FOR BUTTERFLIES IN KERALA, INDIA

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ABSTRACT

Changes in abundance of butterfly species across temporal scales is an area in ecological research which has hardly been investigated in the Indian context. In this study, we have attempted to analyse the butterfly count data recorded at the Kerala Forest Research Institute, Peechi, India. Correlations between the weather parameters and the butterfly abundance were sought and the species relation to these variables were analysed. Correlation between the species and weather variables in the first round of sampling was tested against the second round of sampling conducted after a gap of ten years. Finally, linear regression was performed to ascertain the relationship between the variables. The results of this study indicate that identifying patterns of change in the abundance of butterfly species in response to abiotic factors is crucial to understanding the complex nature of butterfly communities.

Key words: Papilionidae, Abundance, Weather, Correlation, India.

Introduction

Although habitat degradation has been known to be one of the major threats to tropical insects, ongoing studies increasingly implicate climate change as an equally significant factor in the delicate organism-habitat equilibrium. Being exothermic organisms, butterflies are greatly influenced by their thermal environments. Hence, changes in climate will be reflected by corresponding variations in range, phenology, voltinism and activity patterns. Butterflies are thus suitable bio-indicators and evidence for climate-driven changes in their abundance and range have been steadily accumulating over the past decades (Weiss *et al*., 1988; Sparrow *et al.*, 1994; Spitzer *et al.*, 1997; Parmesan *et al*., 1999; Roy and Sparks, 2000; Hill *et al*., 2003; Jaworski and Hilszczański, 2013; Warren *et al*., 2014).

Several studies on the various aspects of this sensitive butterfly- habitat- climate equation conducted in the past two decades have provided insights into this rather grey area of butterfly research. Studies by Roy *et al.* (2001) on British butterflies found strong associations between population fluctuations and weather. Investigations by Dennis and Spark (2007) on butterfly abundance data in United Kingdom between 1864-1952 found significant correlations between abundance and summer and winter temperatures and precipitation. Kwon *et al.* (2010) evaluated the changes in butterfly abundance in Korea between 1988 and 2007 and detected differing trends between northern and southern species. In a study on butterflies in North California, Forister *et al.* (2010) highlighted the influence of both climate and land use changes on species richness patterns. Zografou *et al.* (2014) examined the community composition and species richness of butterflies in response to climate change in the Mediterranean region.Using comprehensive time series data of British butterflies, Oliver *et al* (2015) showed that the persistence of drought-resistant butterfly species in a habitat is effectively achieved by both habitat restoration and low habitat fluctuations.

In contrast to temperate fauna, the long term monitoring of weather effects on tropical butterfly fauna is limited by paucity of relevant data. Sampling of butterflies in permanently established study plots over temporal scales is the current trend in several tropical regions. Here, we examine the changes in butterfly abundance in Peechi, India by revisiting transects between 2008-2011 that were initially surveyed between 1998-2001. Recording of butterflies on data collection rounds 1 and 2 which were ten years apart was carried out by the same observer along the same transect route using standard protocols.

Material and Methods

The study was carried out in a 0.5 ha butterfly garden established in Kerala Forest Research Institute campus (10.52° N, 76.35°E) located in 28 ha reserve forest

Troides minos was sensitive to changes in humidity, rainfall and wind speed.

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area adjacent to Peechi-Vazhani Wildlife Sanctuary at Peechi, Thrissur, Kerala. Butterfly surveys were conducted between 10.00 and 16.00 hours under suitable conditions using the line transect method (Pollard and Yates, 1993). The counts were taken between 10.00 and 15.30 local time only when the weather was sunny and the temperature was above 18C^0. The sampling was conducted along an 800m concrete path established in the butterfly garden and the transect route was walked at a constant pace of one km/h and all adult butterflies found within approximately 5 m on both sides and in front of the observer were recorded. Butterfly census were conducted eight times a month for the six sampling years and averaged to obtain the average monthly counts. Counts of individuals belonging to the family Papilionidae were used in the analyses. Meteorological data which included relative humidity (%), total rainfall (mm),wind speed (m/s), total solar radiation (mJ/m^2)and mean temperature (^{o}C) was obtained from the weather station located in the study area.

Data analysis

Correlation matrix: As the first step to understanding the relationship between species abundance of Papilionidae and environmental variables, a correlation matrix involving all the variables in question were plotted.

Wilcoxon signed rank test: Since we were tracking variations between two sampling rounds for butterfly abundances, a Wilcoxon signed rank test was done to figure out which species have distinct variations across the two samplingrounds carried out ten years apart. Since the Wilcoxon Signed rank test was non parametric and does not require knowledge about the underlying distribution, it was preferred over the Paired student's T-test.

Linear regression: To finally ascertain the relationship between the variables, a linear regression was carried by keeping the *Troides minos* population as the dependant variable and the environmental parameters as the independent variables. To select the optimum combination of dependant variables, all possible combination were tried using the LEAPS and MASS packages in R and the set of variables with maximum adjusted R-squared was selected.

Results and Discussion

From the correlation matrix it was seen that certain variable combinations like rainfall and *Troides minos* species abundance were highly correlated (Table 1). Of special interest was the fact that wind and temperature showed a negative correlation with species abundance indicating that rising temperature and wind speed result in decrease in butterfly abundance/sightings. When

Table 1: Correlation matrix of species and weather variables.

Species*	Relative humidity (%)	Total Rainfall (mm)	Wind speed (km/h)	Solar radiation (mJ/m^2)	Temperature (^{o}C)
Ari	-0.420	-0.365	0.518	-0.0004	-0.023
Pan	0.384	0.388	-0.368	-0.415	-0.299
Hec	-0.464	-0.326	0.224	0.362	0.362
Min	0.538	0.572	-0.517	-0.361	-0.405
Sar	0.235	0.180	-0.104	-0.130	-0.086
Dos	-0.077	-0.136	0.061	0.170	0.108
Aga	0.166	0.119	0.014	-0.329	-0.268
Ant	-0.456	-0.258	0.295	0.559	0.458
Nom	0.038	-0.079	-0.074	0.031	0.148
Cly	-0.014	-0.091	-0.039	0.109	0.169
Pot	0.276	0.379	-0.355	-0.276	-0.179
Dra	-0.034	0.061	-0.130	-0.070	-0.019
Hel	0.200	0.338	-0.428	-0.266	-0.030
Pom	0.163	0.472	-0.333	-0.189	-0.241
Lio	0.203	0.198	-0.172	-0.094	-0.183
Dem	-0.091	-0.216	0.005	0.080	0.236
Par	0.064	0.087	-0.089	0.046	0.065
Cri	0.201	-0.022	-0.142	-0.181	-0.071
Bud	0.371	0.376	-0.182	-0.418	-0.442

*Species codes: Ari-*Pachliopta aristolochiae*, Pan-*Pachliopta pandiyana*, Hec-*Pachliopta hector*, Min-*Troides minos*, Sar-*Graphiums arpedon*, Dos- *Graphium doson*, Aga-*Graphium agamemnon*, Ant-*Graphium antiphates*, Nom-*Graphium nomius,* Cly-*Chilasa clytia,* Pot- *Papilio polytes,* Dra- *Papilio dravidarum,* Hel-*Papilio helenus,* Pom- *Papilio polymnestor,* Lio- *Papiliolio medon,* Dem- *Papilio demoleus,* Par- *Papilio paris,* Cri- *Papilio crino,* Bud- *Papilio buddha* considering individual species, only three species namely Troides minos, *Pachliopta aristolochiae* and *Graphium antiphates* showed significant correlations to weather variables. However, *Troides minos* was conspicuous being the only species showing sensitivity to three weather parameters- significant positive correlation to humidity and rainfall and a significant negative correlation to wind speed. *Pachliopta aristolochiae* on the other hand shows a positive correlation with wind speed while *Graphium antiphates* was positively correlated to solar radiation.

Wilcoxon Signed rank test

From the Wilcoxon Signed rank test (Fig. 1) we found that *Troides minos* abundance had changed significantly across the two sampling rounds. Among the weather parameters, total solar radiation, temperature, relative humidity and wind speed have decreased over the two data sets while the rainfall showed a marginal increase. The abundance of *Troides minos* was seen to decrease between the two data collection rounds. Of the factors that decreased over the two sampling rounds, the decrease in humidity was 5.2 % while solar radiation decreased by 20.7%.

Linear regression

The final model included rainfall, wind speed, humidity and temperature and excluded solar radiation due to its collinearity with temperature. This model yielded an adjusted R-squared of 0.43 and P-value well below the threshold (Table 2). The diagnostic plots for the regression also fall within the limits of a good model thereby further re enforcing its validity (Fig. 2).

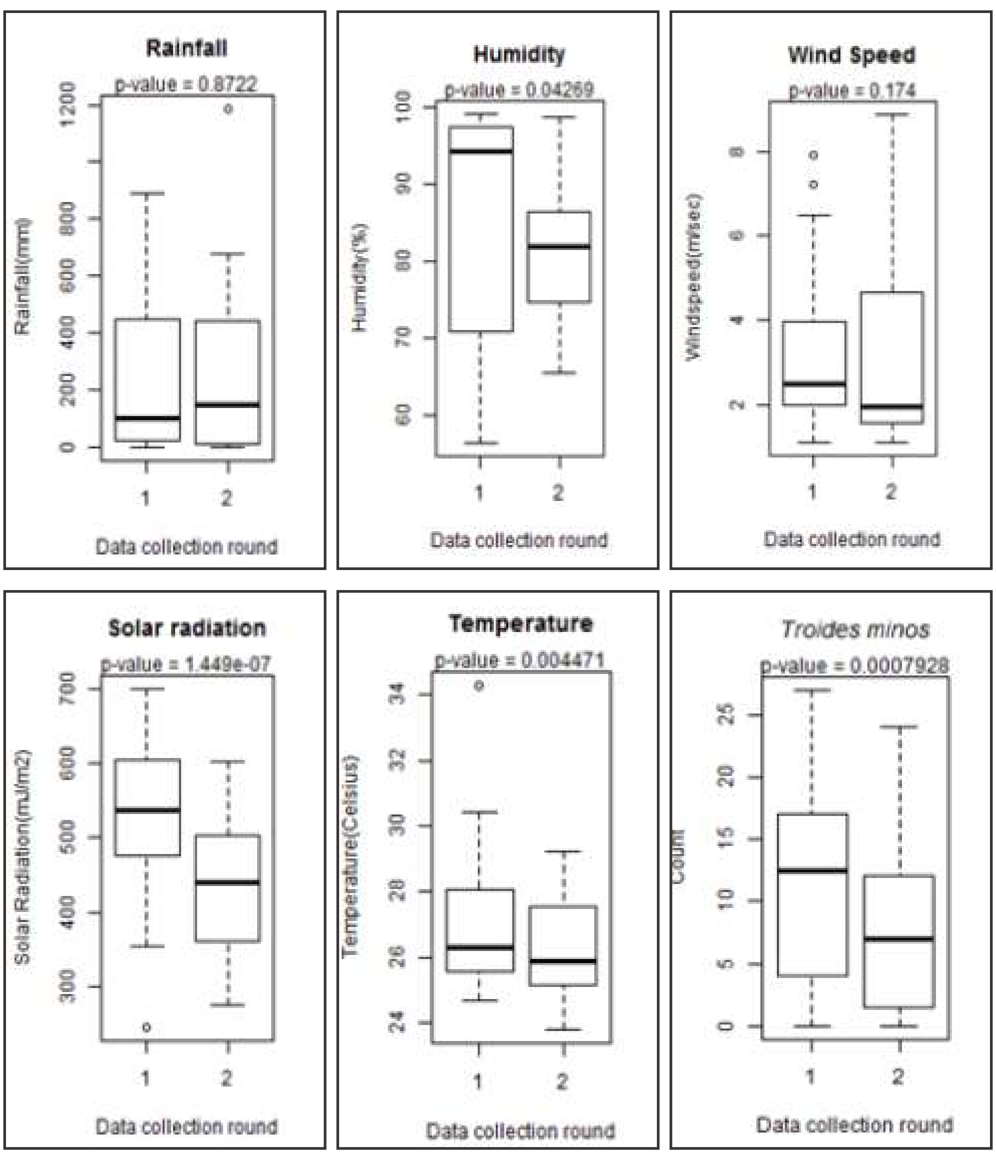

Fig. 1: Wilcoxon Signed Rank test plots.

Table 2: Regression model values.

Adjusted R-Squared	Residual standard error	P-Value
0.4347	5.448	1.197e-08
	Estimates	P-value
(Intercept)	21.348117	0.1622
Rainfall	0.006905	0.375
Windspeed	-3.419536	0.191
Temperature	-0.744775	0.873
Humidity	0.114051	0.1029

Conclusion

When the abundance of Papilonidae observed during the past and current periods were compared, it was observed that a total of 1941 individuals belonging to 16 species in the first round of sampling and 1855 individuals spread across 18 species in the second.From the correlation data it was hand that *Troides minos* was sensitive to changes in humidity, rainfall and wind speed. From the regression model it can be concluded that reduction in the abundance in this species in data collection round 2 is mainly due to decreasing humidity.

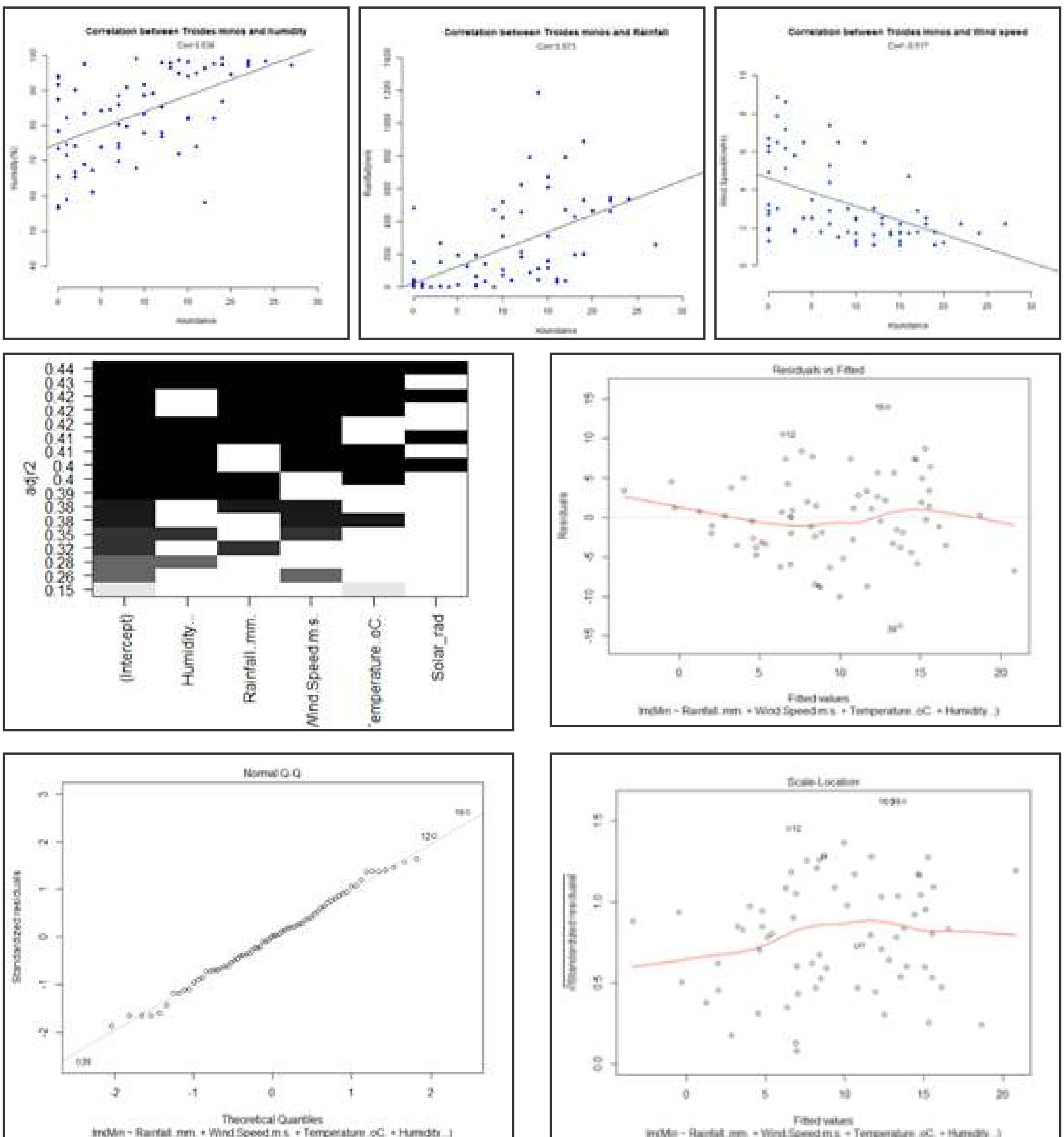

Fig. 2: Regression plots.

One method by which climate change impacts on biological systems can be mitigated is by regulating microclimatic gradients thereby providing specialised thermal regimes for organisms to persist *in situ* (Scheffers *et al*., 2014). The study area is located within a butterfly park established in the Kerala Forest Research Institute with artificially recreated landscapes and vegetation to sustain butterflies (Mathew and Anto, 2007). This may be a plausible explanation for observed decrease in solar radiation by 20.7% during the second sampling round as the large trees and lianas may have restricted sunlight penetration. Further, a decrease in humidity levels of 5.2% between the two collection rounds resulted in a decrease in abundance of *Troides minos*, thereby projecting this species as sensitive to climatic fluctuations.

Moreover, the conducive microclimatic conditions may also account for the fact that the butterfly abundance remained stable with only slight fluctuations and that all the nineteen species of Papilionidae reported from the Western Ghats which included five endemics were recorded in the area.

In the light of these findings, we suggest some conservation practices that may provide a feasible solution to the pervasive impacts of climate changevis à vis butterfly conservation in the Kerala part of the Western Ghats, a global biodiversity hotspot. The establishment of small backyard gardens in both rural and urban landscapes with native as well as exotic larval and nectar sources is a sure shot method to attract and sustain butterflies. Thus the conservation movement for butterflies should scale up from small patches to networks of patches comprising of a diversity of plants and microclimatic conditions that will ultimately provide safe refugia to a wide range of species.

Another approach would be identifying indicator butterfly species with respect to climate change as well as anthropogenic disturbance (Anto and Mathew, 2014) so that we can be better equipped to assess changes in fragile butterfly communities facing the onslaught of habitat deterioration and climate change.

Therefore, detecting patterns of change in the abundance of butterfly species is crucial in understanding the complex interplay of the abiotic and biotic factors influencing butterfly habitats and the starting point for practical and effective conservation action.

Acknowledgments

The authors thanks an anonymous referee for valuable comments. Different parts of this research were funded by grants from Ministry of Forests and Environment (KFRI. 294/98)and Department of Science and Technology (SR/WOS-A/LS-27/2007) and are gratefully acknowledged.

एक दशक में *पेपिलिओनिड* तितलियों में प्रचुरता रूझान : केरल, भारत में तितलियों के लिए जटिलताएं एवं संरक्षण शिक्षा

इगनेटियस एन्टो और मैरी एन्टो

सारांश

अस्थायी मानों के आरपार तितली प्रजाति की प्रचुरता में परिवर्तन पारिस्थितिकीय शोध में एक ऐसा क्षेत्र है, जिसकी भारतीय संदर्भ में शायद ही जांच की गई हो। इस अध्ययन में हमने केरल वन अनुसंधान संस्थान, पीची, भारत में अभिलिखित तितली गणना आँकड़ों का विश्लेषण करने का प्रयास किया है। मौसम पैरामीटरों और तितली प्रचुरता के बीच सहसंबंध खोजा गया और इन परिवर्तियों के लिए प्रजाति संबंध का विश्लेषण किया गया। प्रतिचयन के पहले चक्र में प्रजाति और मौसम परिवर्तियों के बीच सहसंबंध की जांच दस साल के अन्तरालोपरान्त किए गए प्रतिचयन के दूसरे चक्र के विरूद्ध की गई। अन्त में परिवर्तियों के बीच संबंध का पता लगाने के लिए रैखिक समाश्रयण निष्पादित किया गया। इस अध्ययन के परिणाम दर्शाते हैं कि तितली समुदायों की जटिल प्रकृति को समझने के लिए अजैव कारकों की अनुक्रिया में तितली प्रजाति की प्रचुरता में परिवर्तन के पैटर्नों की पहचान करना कठिन है।

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