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The impact of climate change on the changes in abundances of rice insect pests and their enemies over almost two decades in Bangladesh

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Abstract

Rice ecosystems are important for the world population for livelihood, socio-economy and nutrition. Global warming is predicted to increase/ decrease frequency of precipitation, drought-intensity and solar-radiation which affect rice ecosystems e.g., pests and their natural enemies. We discuss influence of climatic variations from almost two decades, on yellow stem borer (YSB), brown planthopper (BPH), green leafhopper (GLH) and their natural enemies (spider, lady bird beetle-LBB, green mirid bug-GMB). Light trap and sweep net catches of arthropods from different rice habitats shows a strong bi-annual periodicity for BPH, YSB and GMB. The increasing trend, in the GLH, LBB and SPIDER abundance series between 1996 and 2005 has flattened out and is decreasing from 2006 to 2012. This indicates a periodic, slowly varying population abundance characteristic. Decreasing rainfall over time reduce the last two years to about 2/3rd of the usual average rainfall over the last decades.

INTRODUCTION

RICE ecosystem is a multitrophic system with human interference e. g., farmer and competing with neighboring plants including weeds, and both are either supported and/ or attacked by viruses, bacteria, fungi, insects, mites, spiders, amphibia, birds, mammals etc. and all these species interact with each other. Each insect pest, predator and parasitoid usually has numerous natural enemies, which also have enemies again. Furthermore, those insects might produce volatiles which attract natural enemies of a particular insect and those volatiles might also attract more pests [1-6]. On the other hand, rice ecosystem also depends on and influences by non-living abiotic environment e.g., soil, water, climate, and micro-climate (e.g. rainfall, temperature, sunshine, radiation etc.). The ability of current science to make precise predictions about the impact of global changes on ecosystem interactions is limited, because models that include multiple interactive effects of global change are still relatively rare and premature [7-8]. In addition, biotic environment e.g. viruses, micro-organisms, plants and animals undergo evolution, and able to adapt to new habitats very fast [9].

A large proportion of tropical and subtropical Asia and Africa will experience unprecedented seasonal average temperatures which may reduce and extinct many insect species because tropical insects are already living at environmental temperatures close to their optimum and any increase will have adverse effects and it is very likely (> 90% chance) that, be the end of the century [10-13]. However, all those references not relate to agricultural insect pests, which are a special issue for agro-systems particularly rice ecosystem.

Spiders (a group of general predators or natural enemies) are reduced planthopper infestation ratios from 9:1 to 1.5:1 within 10 days and from 5:1 to 0.03:1 within 5 days and conservation practices that fostered spider density increases, including limited frequency of pesticide application, the need for chemical plant protection decreased as much as 80% with no measurable loss in rice yield [14]. Numerous egg, larval, and pupal parasitoids belonging to the insect orders Diptera and Hymenoptera, and predators belonging to the insect order Hemiptera, have been reported as natural enemies of rice stem borers [15]. In general, a common pests has numerous natural enemies e.g. for the cotton bollworm (*Helicoverpa armigera*) has 216 known natural enemies, divided into 25 pathogens, 121 parasitoids and 70 predators which indicates the large diversity of natural enemies (CPC, 2007 [1]). Considering the tremendous economic importance of natural enemies in agro-ecosystems, surprisingly little research has been done on the effects of climate change on them.

MATERIALS AND METHODS

Light attracted rice arthropods (e.g., insect pests and predators) were collected from light trap, a permanent set-up/ device at the rice farm of Bangladesh Rice Research Institute (BRRI), Gazipur (24°0'0″N, 90°25'48″E), for detail, see [16]. The monthly pooled number of insect pests and predators were analysed. In the present study, three rice insect pests namely, yellow stem borer (YSB), brown planthopper (BPH), Green leafhopper (GLH) and one predator- green mirid bug (GMB) were analysed. Also, rice insect pest, GLH and natural enemies- lady bird beetles (LBB) and spider (SPIDER) were collected by 100 complete hand sweep-net (double stroke) from three rice ecosystems (rice field, either rain-fed or irrigated, seedbed and ratoon - regenerated rice plant from left over portion of rice plant after harvest) thorough out the year on weekly basis (depend on availability of these three ecosystems during sampling; note this, those ecosystems should be available otherwise not taken). Furthermore, rainfall (mm), temperature (maximum and minimum in °C), sunshine hours (h) and radiation ((MJ/m²)) were recorded and data were collected from nearest weather station or weather station at the BRRI Farm, Gazipur. Almost two decades data were collected during January 1996 to December 2012.

The population size (monthly abundance) for a generic population y at time t is denoted by y_t. The population growth rate at time t is calculated as

$$r_{y,t} = \log(1 + (y_t - y_{t-1})/(1 + y_{t-1}))$$

Where, log denotes the natural logarithm and y_{t-1} denotes the abundance the month before.

For the populations in the light trap data set we consider the YSB, the BPH, the GLH and the GMB, and the corresponding growth rates are thus

$$r_{ysb,t} = \log(1 + (ysb_t - ysb_{t-1})/(1 + ysb_{t-1})),$$

and similarly for $r_{bph,t}$, $r_{glh,t}$, and $r_{gmb,t}$.

For the populations in the sweep-net data set we consider the GLH, LBB and SPIDER and the corresponding growth rates $r_{glh,t}$, $r_{lbb,t}$, and $r_{spider,t}$. The population rates are also expressible in terms of differences of monthly log abundances

$$z_{y,t} - z_{y,t-1} = r_{y,t}$$

Where, $z_{y,t} = \log(1 + y_t)$ is the log abundance, conditioned on presence of the population.

The variation of the y_t over time has an "explosive" property pattern which itself may be difficult to describe. The logarithmic (i.e. log) abundance is more easily understood and described in terms of the "energy" in the community abundance process. The variation of log-abundance or monthly growth rate will hence be the basis for the investigation.

RESULTS AND DISCUSSION

A. Light trap data

Monthly abundance values for four different species populations are shown in Fig. 1. The population abundances for YSB, BPH, GLH and GMB are shown for the period from January 1995 to December 2012 for the light trap data.

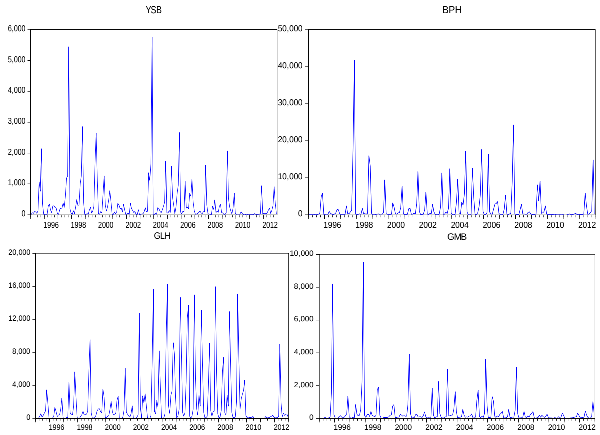

Fig. 1. Light trap data monthly abundance values of YSB, BPH, GLH and GMB during the time period from January 1995 to December 2012.

The corresponding log-abundance processes $z_{ysb,t}$, $z_{bph,t}$, $z_{glh,t}$, $z_{gmb,t}$ are shown in Fig. 2.

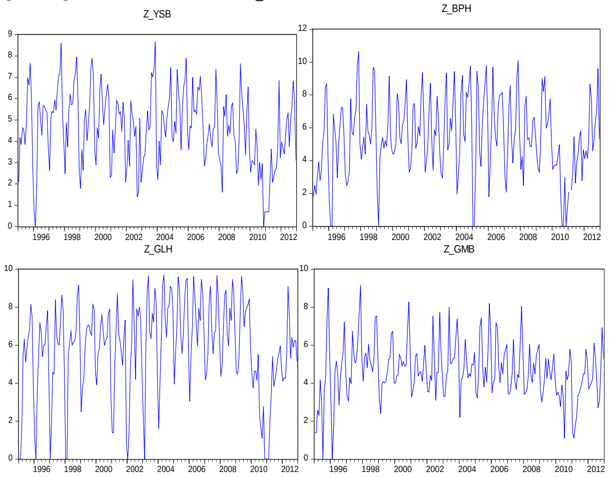

Fig. 2. Light trap data monthly energy processes $z_{ysb,t}$, $z_{bph,t}$, $z_{glh,t}$, $z_{gmb,t}$ during the time period from January 1995 to December 2012.

The extreme suppression of the abundances during the years 2009-2011 is less prominent in the GMB population (as is most easily seen in the energy processes $z_{y,t}$ in Fig. 2).

Fig. 3 shows the periodogram of the monthly log abundance series for the four insect communities. For YSB there is a strong periodicity in abundance at 12 months (=1 over frequency 0.085) corresponding to one annual "burst" of large communities of YSB. There is another strong periodicity at 6 months (=1/0.17) and in addition a weaker periodicity at 3 months (=1/0.33) (corresponding two 4 outbreaks per year of larger communities of YSB.

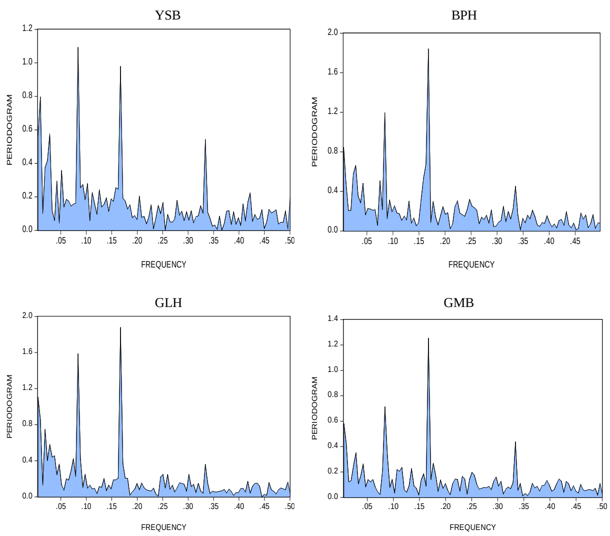

Fig. 3. Periodograms of the log abundances $z_{ysb,t}$, $z_{bph,t}$, $z_{glh,t}$, and $z_{gmb,t}$ from the time period from January 1995 to December 2012.

The BPH, GLH and GMB communities all show a similar pattern in terms of periodicity. However the bi-annual recurrence component (i.e. the 6 month periodicity; (=1/0.17)) seems to be the stronger one in all these three communities.

B. *Temperature, radiation, rainfall and sunshine*

On daily basis, the maximum temperature (°C), the temperature difference (maximum temperature minus minimum temperature) (°C), radiation (MJ/m^2) and rainfall (mm) are shown in Fig. 4.

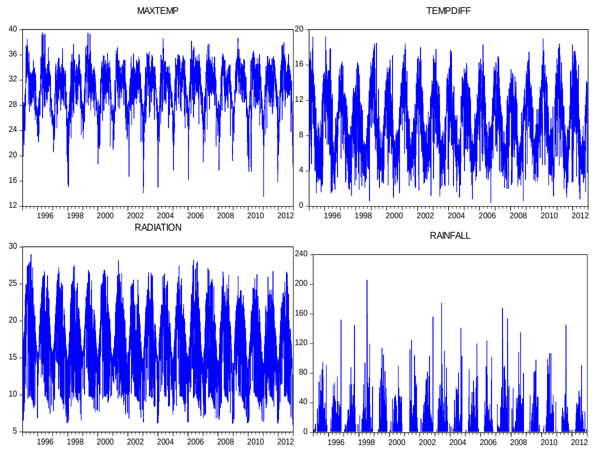

Fig. 4. Daily maximum temperatures, temperature range, radiation and rainfall for the time period January 1995 to December 2012.

There are indications of that the rainfall has been decreasing over time. This may be spotted in Fig. 4 (lower right), but is more easily seen in Fig. 5 (upper left) showing the total annual rainfall per year. As seen there has been a reduction the last two years to about 2/3 of what has been the usual average rainfall over the last decade. Also the number of rainy days over the year has changed from being rather stable at about 120 rainy days per year, it has started being rather fluctuating from year to year (Fig. 5 upper right). This also implies that the average rainfall per day during rainy days has decreased during the last three years (Fig. 5 lower left). Also the variation of rainfall for rainy days (measured as standard deviation of rainfall for rainy days) has decreased giving a more homogenous pattern of rainfall for rainy days.

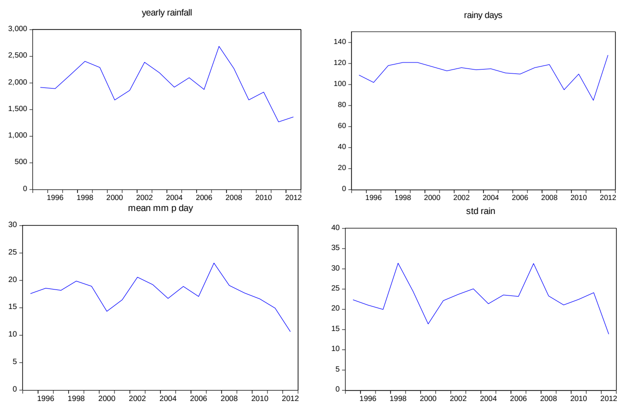

Fig. 5. Yearly rainfall (upper left; mm rain), number of rainy days per year (upper right), mean rainfall for rainy days per year (lower left; mm/day) and standard deviation of rainfall for rainy days per year over the period 1995 to 2012.

There also seems to be a tendency that the annual mean radiation has been decreasing over the years (Fig. 6) while the variation of daily radiations over the year (measured as standard deviations) seems to have been rather stable over the years (Fig. 6).

C. *Sweep-net data*

The monthly abundance values for the three populations GLH, LBB and SPIDER during the period from January 1996 to December 2012 are shown in Fig. 7. In this figure are also shown the corresponding monthly population growth rates.

Fig. 6. Yearly means of daily radiation (left) and yearly standard deviations of daily radiation, over the period January 1995 to December 2012.

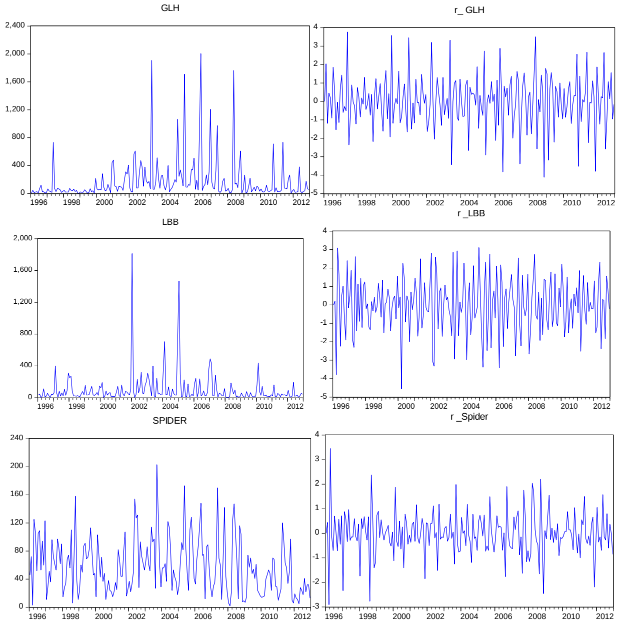

Fig. 7. Monthly abundances (left) and growth rates (right) of communities of GLH, LBB and SPIDER during the time period from January 1996 to December 2012.

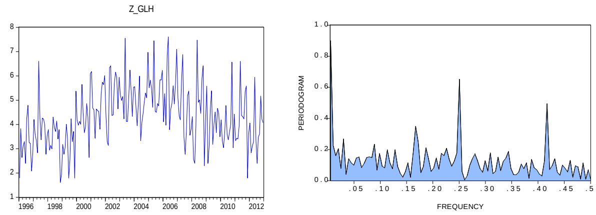

Fig. 8. The monthly log abundance (left) and periodogram of monthly log abundance (right) of the GLH population during January 1996 to December 2012.

For GLH there is a strong periodicity at 4 month (=1/0.25) and a slightly weaker at 2.4 months (=1/0.42; corresponding to 5 outbreaks per year) followed by an even weaker periodicity at about 6 months (=1/0.17).

The general increasing trend earlier reported, [16], in the GLH log abundance series between 1996 and 2005 has flattened out and has been decreasing during the time period 2006 to 2012. This may be an indication of a general slowly varying population abundance increase/decrease with periodicity of between 10 to 30 years which can be seen in the left part of the periodogram but the resolution in data (17 years) does not admit the estimation of such cycles with greater accuracy.

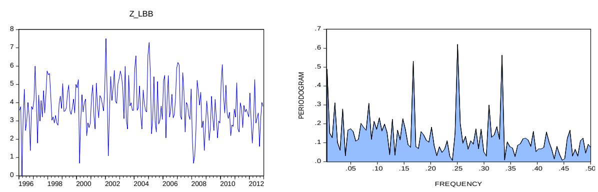

Fig. 9. The monthly log abundance (left) and periodogram of monthly log abundance (right) of the LBB population during January 1996 to December 2012.

For log abundance of LBB, there is a strong component of periodicity at 4 months (=1/0.33) and somewhat weaker components at 3 months (=1/0.33) and 6 months (=1/0.17).

Also for the LBB population the previously reported [16] increasing trend in log abundance between 1996 and 2005, has flattened out and has reverted into a decreasing trend during the time period 2006 to 2012. Again this may be an indication of a periodic, but slowly varying, population abundance characteristic.

We also look at the periodic behavior of the log abundance series of the SPIDER population (Fig. 10).

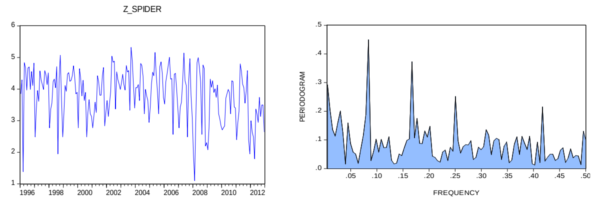

Fig. 10. The monthly log abundance (left) and periodogram of monthly log abundance (right) of the SPIDER population during January 1996 to December 2012.

For log abundance of SPIDER there is a strong periodicity at 12 months (=1/0.085) followed by a slightly weaker at 6 months (=1/0.17) and 4 months (=1/0.25) and a weaker at 2.4 months (=1/0.42; corresponding to 5 outbreaks per year).

There may be an indication in the log abundance that the general patterns have changed from year 2009 and on (Fig 10, left graph) into generally lesser abundant SPIDER populations but also less volatile over time. This can also be seen in Fig. 7 (lower left graph).

CONCLUSION

The changing behavior in the YSB, BPH, GLH, GMB populations and also SPIDER over the last three year (2009-2012) coincide with the changing characters of rainfall and radiation over the same period. Coherent results were obtained from the two data collecting methods.

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