IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

# Changing Hydrological And Dependant Variable - Declining Water Bird Population In Wetland, Thattekkad

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Abstract

Changes in wetland habitat can alter the dynamics of waterbird populations. Investigated the effect of hydrological and dependant variable on the population of waterbird in Thattekkad Bird Sanctuary. Generalized linear mixed models were used to determine the effect of hydrological and dependant variable on water bird number. The research findings unambiguously point to the variations in the avian strength as some very vulnerable species perish and new species emerge owing to the fluctuation A scientific version of the existing wetlands management plan is urgently required by incorporating new rules and regulations for tackling the current problems and ecological crisis affecting the wetlands. Such a step can go a long way towards ensuring the habitat requirements of endemic macrophytes, macroinvertebrates, fish and birds. This research and observations have revealed that preservation of temporal and spatial habitat preference of endemic species must be given a higher priority for maintaining the species diversity and for erecting a bulwark against survival problems and threats of extinction.

**Key words:** Thattekkad Bird Sanctuary, Dependant variables, hydrology, water birds

## Introduction

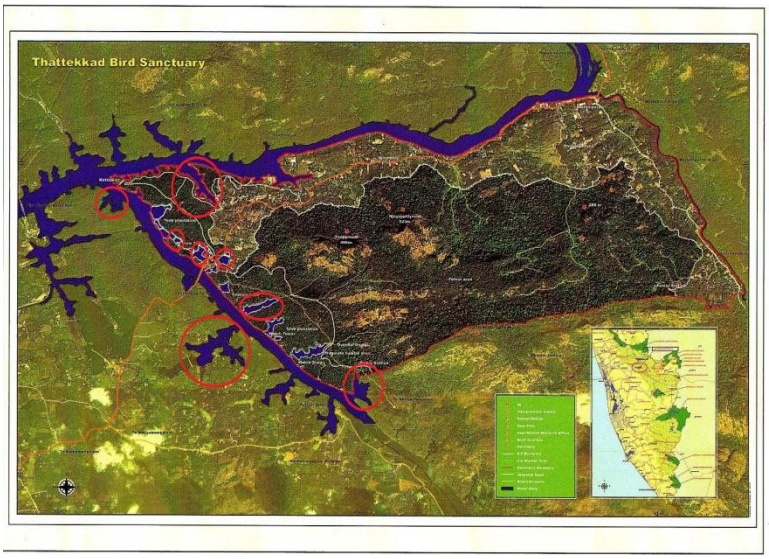
Wetlands are ecosystems with significant biodiversity and biological productivity in the world (Paracuellos and Tellería, 2004). Avian community dynamics are complex and influenced by many environmental factors and anthropogenic factors resulting in migration, breeding, and moulting of birds (Mundava *et al.,* 2012). Birds form functionally diverse group whose existence depends on interrelationship with the abiotic and biotic factors in its habitat (Sandström *et al.,* 2006*).*

Habitat fluctuations have resulted in negative impact on avian diversity around the world (Taylor and Pollard, 2008). Studies have used Avian fauna to monitor environmental fluctuations. Birds inhabit environment that are subjected to wide fluctuations and birds respond to these changes a several degrees of magnitude, mostly the changes are influenced by one or more intermediate factors or interacting effects, and the response to the changes may be immediate or through a course of time. The magnitude of response depends on the level of environmental fluctuations and immediate primary response is seen as behavioral changes and physiological changes which in turn lead to several other secondary changes influencing the population in breeding, dispersal, migration leading to spatial and temporal changes in density, geographical distribution, habitat fluctuations, sex ratios, reproductive potential, etc,. The existence of community relies on vegetation structure (Hargrove and Rotenberry, 2011), abiotic factors like temperature, turbidity and various other resources and the distribution of resources can lead to narrow foraging strata (Marra and Ramsen, 1997). Bird community structure is constrained and determined by habitat structure (Terborgh, 1985). Assessment of vegetation composition and structure of wetlands is useful tool that evaluate the impact of habitat fluctuations on the avian community. Birds are good bioindicators of alterations in the habitat as they respond to changes in the wetland productivity and stability causing avian abundance and diversity or a decline in population of one species due to habitat loss or degradation with birds of another species flourishing (Savard *et al.,* 2000). Monitoring species abundance and habitat preference and co-relationship between species abundance and habitat provide basic information for determining factors causing population fluctuation of bird species. The Density and diversity of bird populations are directly proportional to the vegetative community and food source and exhibiting a positive correlation with habitat structure complexity, and are the major factors that influence the survival rate, reproduction, breeding season, species dispersal and habitat selection (Rajpar and Zakaria, 2011).

In the present study focused on the concordance between the landscape changes i.e. the environmental variables and the biological communities of macrophytes, macroinvertebrates fish and bird. The present work evaluates the community environment framework concordance of different communities responding to same scenario of environmental conditions independently. The strong community concordance is always a result from biotic interactions between the member species of different communities in habitating the particular area and the biotic interactions between primary producers, and the consumers, and the trophic level interactions which in turn is one of the key factors in avian reproductive success (Hanson and Riggs, 1995).

**Methods**

Thattekkad Bird' Sanctuary, is the only tropical Bird Sanctuary in Kerala and is described as the richest bird habitat in peninsular India by (Late) Dr. Salim Ali.The Thattekkad Bird Sanctuary(TBS) was established in 1983 by the Govt. of Kerala by notification No:35743/FM3/AD dated 27 August 1983.The Sanctuary is situated in the north-eastern part of Ernakulam district, spread over an extent of 25.16 $km^2$. Finite by the Periyar and Kuttampuzha watercourse on the two sides.The Sanctuary is located $10^0$ $10^1$N;$76^0$$40^1$-$76^0$$45^1$E. In the 1960s when the Boothathankettu Barrage was commissioned, vast area of natural riparian forest on either side of the river were removed and this area converted into the catchment of the Barrage creating a wetland habitat of the Sanctuary.Unlike other dams, annual draining is done for maintenance work and desilting during heavy monsoon months.Every year from June to December the shutters of the Barrage are kept open to allow the free flow of water in to river Periyar while the shutters are closed from December to June to retain sufficient water for irrigation. The periodic cycle of flooding of plain and subsequent draining leads to ecological variation in the habitat, affects the floral and faunal diversity.Right from the original habitat to the present habitat, a number of new flora and fauna invaded in to this area or were introduced in course of time making the system entirely different from what had existed earlier. Eight intensive study sites were selected for the present study. The sites identified were View Tower, Inspection Bungalow-1(IB1), Inspection Bungalow-2(IB2), Manimaruthumchal, Watch Tower, Kolambuthodu, Kadayam and Kootickal Edathukara. Each study site is distinct from others by quality, vegetation, depth, trophic structure and extent.





Site 1


Site 2


Site 3


Site 4


Site 5


Site 6


Site 7


Site 8

**Waterbird Surveys**

Water bird survey were carried out by predetermined line transect and point count method to determine the species composition, population variation, relative abundance and habitat preference. Study was conducted for a period of 35 months. Binoculars (Nikon 12 × 50 5.5$^{o}$) were used to observe birds from all the study sites. At the time of sampling, all birds seen were counted, and the habitats in which birds werelocated.Several aquatic birds left/locally extinct from the area during the reservoir's water runoff, preventing the stabilization of wetland bird species in the area, according to the report .

Hydrological and Dependent Variables

Hydrological parameters like air and water temperature, pH, TDS, EC, Humidity, water depth, and DO were noted at the collection point. Standard methods were used to study the hydrological parameters. The observed data were tabulated and analyzed statistically. The quadrat approach (1mx1m) was used to analyse aquatic macrophytes. The data were analyzed and tabulated using statistical tools. During the study period, the aquatic macroinvertebrate was studied using the quadrat method (50cmx50cm). The species were collected using a D frame net. Collections were made by a sweep from the bottom to the water surface. Fishes were captured using various fishing gears such as cast nets, scoop nets, and gill nets of various mesh sizes at the end of the barrage. Direct counting method was adopted for the analysis at the time of barrage opening. The information gathered was tabulated and analysed using statistical software.

**Result**

Thattekkad Bird Sanctuary supports a wide variety of flora and fauna because of its distinct geographical location. So far 98 species of aquatic macrophytes belonging to 42 families, with 44 and 54 species belonging to aquatic and non-aquatic taxa, respectively.The growth of macrophytes was adversely affected by change in water level or dewatering. Most of the macrophytes did not achieve or complete their life cycle due to the fluctuations of habitat. Death and decaying of macrophytes due to changes in hydrological parameters resulted in habitat loss, habitat isolation and fragmentation of aquatic organisms for some periods.

A total of 37 species of aquatic macroinvertebrate belongings to 14 orders were reported. Hydrological fluctuation severely depleted macrophyte associated macroinvertebrates fauna in TBS, altered the entire ecosystem structure and function.And 42 species of fish have been recorded in TBS. The entire TBS fish population is affected by the closure and opening of the Barrage. The decline of fish populations in the TBS could have a negative impact on the population of piscivorus birds. Overfishing for personal use and commercial purposes, as well as changes in waterways, were listed as major threats in the rivers surrounding Thattekkad.

Additionally TBS is an important bird area that support large number of resident and migratory water bird : around 16,198(40 species) were counted during the study periods, respectively.

The hydrological parameters such as atmospheric temperature, water temperature and pH displayed only slight variations in the two changes of the habitat. But rainfall, humidity, water depth, TDS, EC and DO recorded marked difference in the two changes of the habitat (wet and dry periods). The water–logging environment resulted in the deterioration of water quality in the study sites. The quality of water is depleting rapidly with the changes in the habitat of TBS annually and this affect the entire biota of the wetland. Therefore studies on the present environmental conditions of the TBS wetlands are very relevant for protection of the biotic community from a big loss due to habitat fluctuation.

Statistical analyses were performed using 'glmmADMB', 'car',' 'gridExtra', bbmle,' ggfortyfy' (Tableau public, 2021).

The data set consists of 13 variables and 280 observations. Among them, the response variable and eleven regressors are numerical data, and the variable season which represents the fluctuations in the water level due to opening and closing of the Bhoothathankettu Barrage. It is a category variable with two levels opening and closing.

**Table 1. Dependent and Independent Variable**

| Independent variables | | |
|---|---|---|
| **Biotic Factors** | **hydrological Factors** | **Climatic factors** |
| 1. Number of fis | 1. P | 1. Humidit |
| 2. Number of macroinvertebrate | 2. Dissolved Oxyge | 2. Rainfall |
| 3. Number of macrophyte | 3. Dept | 3. Seaso |
| | 4. Electric conductivi | 4. Air Temperatur |
| | 5. Water Temperatur | |

Plotting dependent variable against independent variable indicated that opening and closing of Barrage have a reasonable impact on values of independent and dependent variables.

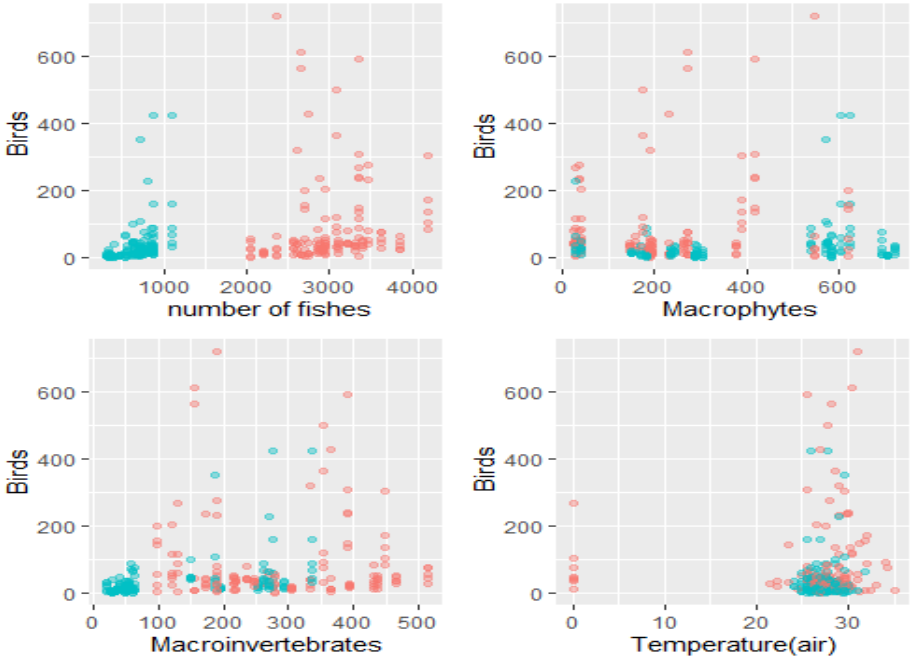



**Fig. 3.Numerical regressors against response variable**

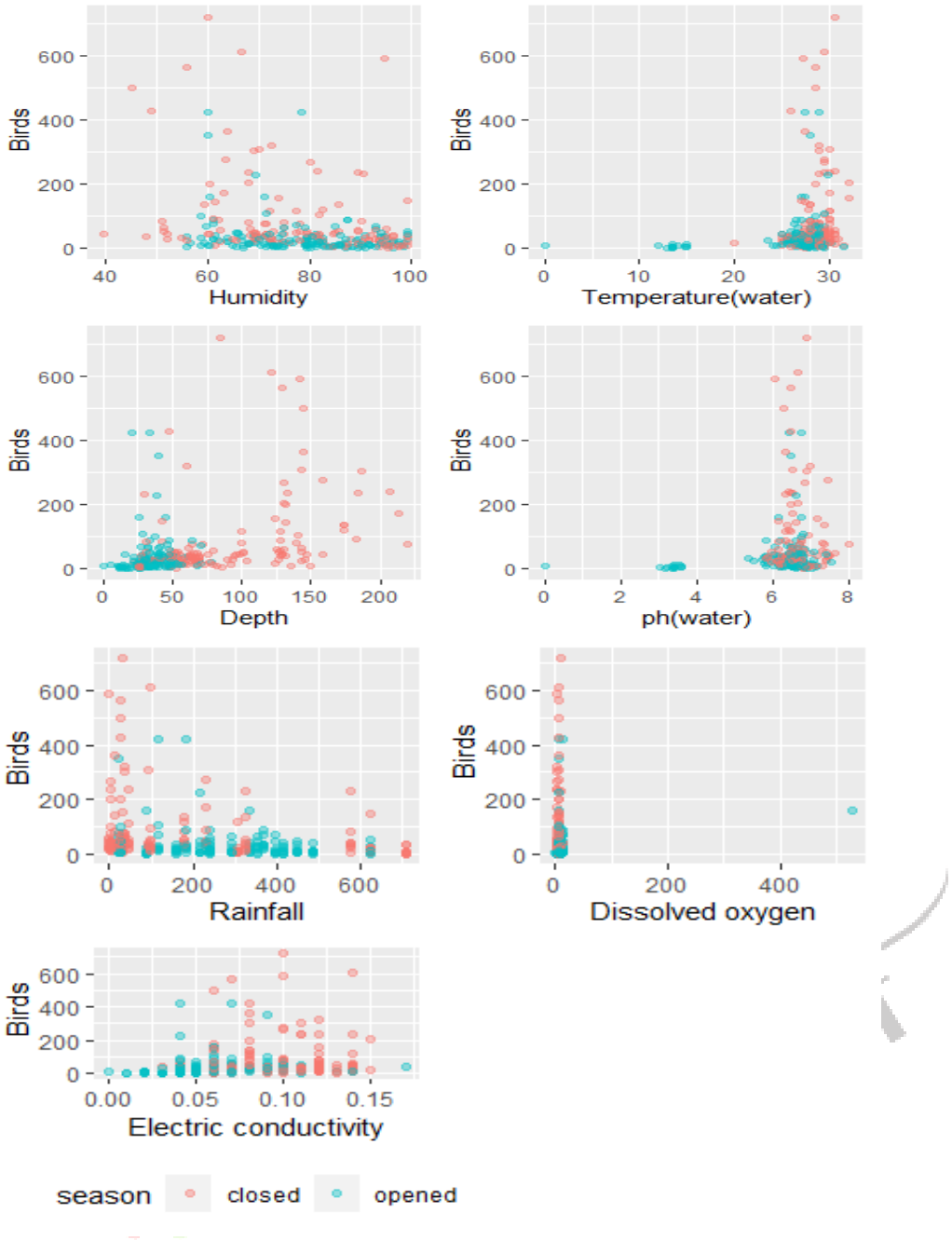



**Fig. 3. Numerical regressors against response variable**

For fitting a mathematical model between dependent variable, total number of birds on the independent variables, correlation matrix is constructed and graphically represented as correlation plot. The correlation matrix and correlation plot shows that, there is mild to small correlation between depedendent variable and independent variables. The correlation between bird population and explanatory variables viz – macrophytes, and air temperature is close to zero. Among regressors, macrophytes have a mild negative correlation with fish and macroinvetrebrates. This indicates that the habitat conditions in the TBS mainly favour the emergent and terrestrial type macrophyets. Fish have a considerable positive correlation with macroinvetrebrates, depth and EC. The pH of water, high positive correlatiion with temperature of water and mild positive correlation with fish, macroinvetrebrates and EC. The DO and air temperature have negligible correlation with dependent variables, other independent variables, and themselves.

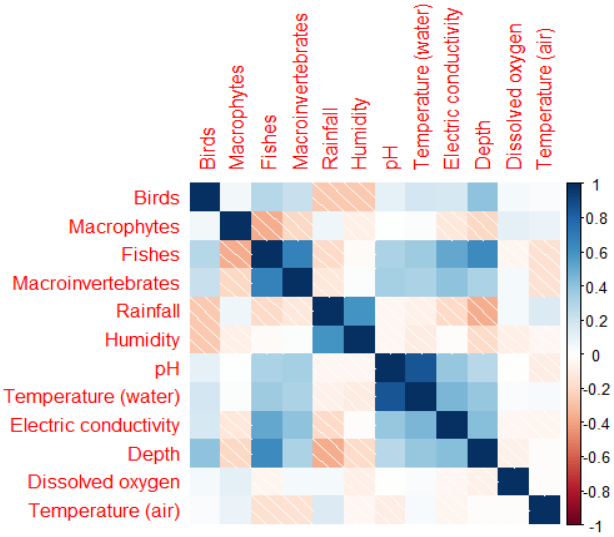



**Fig. 4. Correlation plot**

**Table 2. Summary statistics of GLMM**

| Variable | Estimate | Std. Error | Z Value | P(>\|z\|) | Level of significance |
|---|---|---|---|---|---|
| **Fishes** | 0.00088 | 0.000198 | 4.47 | 7.9e-06 | 0.001 |
| **Depth** | 0.007464 | 0.002017 | 3.70 | 0.00022 | 0.001 |
| **Rainfall** | -0.001057 | 0.00040 | -2.60 | 0.00923 | 0.01 |
| **Humidity** | -0.0184 | 0.005363 | -3.43 | 0.00059 | 0.001 |
| **Macroinvetrebrates** | 0.001411 | 0.00057 | 2.48 | 0.01330 | 0.05 |
| **Macrophytes** | 0.0008 | 0.00028 | 3.06 | 0.0022 | 0.01 |
| **Temperature*(water)*** | 0.06909 | 0.017030 | 4.06 | 5.0e-05 | 0.001 |
| **Temperature*(air)*** | 0.0276 | 0.011178 | 2.47 | 0.01346 | 0.05 |
| **Season(opened )** | 1.749290 | 0.43056 | 4.06 | 4.8e-05 | 0.001 |

Among the fitted models the GLMM with **negative binomial distribution and log link function** has the least AIC value.

## Effect of biotic factors on bird abundance

The variable number of fish, macroinvertebrates and macrophytes have statistically significant effect on number of birds. Coefficient of number of fish in the model is statistically significant with p value < 0.001. As log link function is used, unit increase in the number of fishes causes 0.00088 units increase in the value of log of number of birds. The coefficient of the number of macroinvertebrates is 0.001411 with p value 0.01330 at a level of significance 0.05. A unit increase in the number of macroinvertebrates causes 0.00088 units increase in the value of log (number of birds). The coefficient of the number of macrophytes is 0.0008 with p value 0.0022 at a level of significance 0.01.

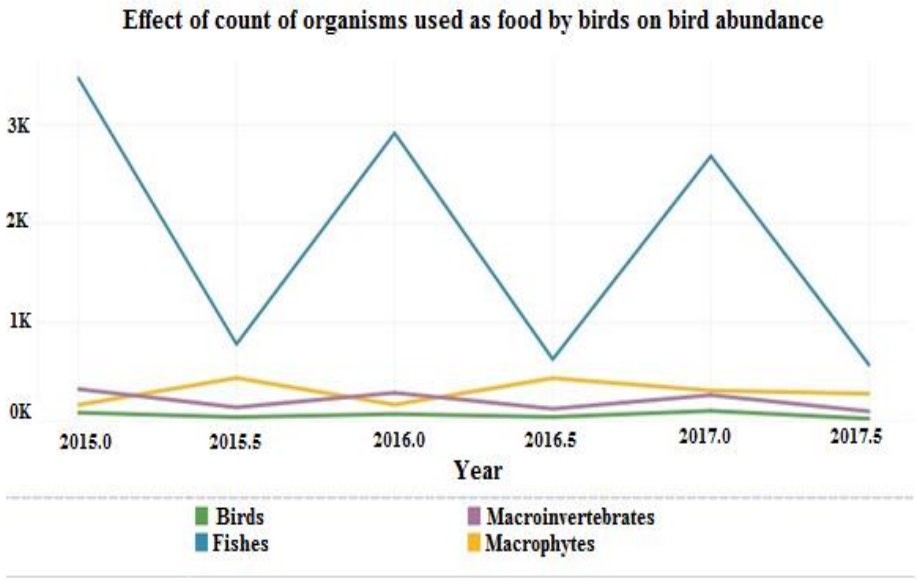



**Fig.5. Half year average of number of birds, fishes, macrophytes and macroinvertebrates from 2015 to 2017 as line plot K stands for thousand.**

Over 2015 to 2017, average of the number of fish, Macrophytes and macroinvertebrates have a tendency to decrease with seasonal fluctuations. In a year, closed season had higher values of these variables and relatively small values in open seasons.

### Effect of hydrological factors on bird abundance

Even though the variables pH, DO, and EC are evolved in a few models, their effect is not statistically significant. Depth has the coefficient 0.00746 with p-value < 0.001. The variable Temperature (water) has the coefficient 0.06909 with p-value < 0.001.

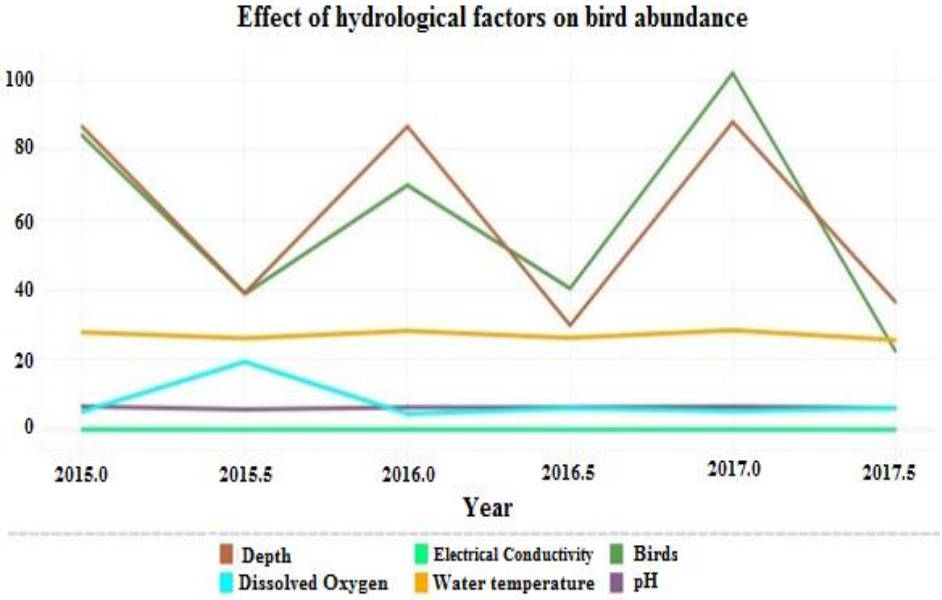



**Fig.6. Number of birds, depth and temperature (water), electric conductivity, dissolved Oxygen and pH as line plot.**

Depth increased over the years from 2015 to 2017 with seasonal fluctuations. The bird population showed fluctuation along with change in depth of water column. The DO maintains a constant level all the three years except an increase at the second half of 2015. The pH and EC have no considerable variation over the years 2105 to 2017.

### Effect of climatic factors on bird abundance

The climatic factors humidity, rainfall, season (opened/closed), temperatures (air) are included in the model as their effect is statistically significant. Humidity has the coefficient value -0.0184 in the model with p-value 0.00059 at the level of significance 0.001. Rainfall has the coefficient value -0.001057 with p-value 0.00923 at the level of significance 0.01. Coefficient of temperature (air) in the model is 0.0276 with p-value 0.01346 at 0.05 significance level.

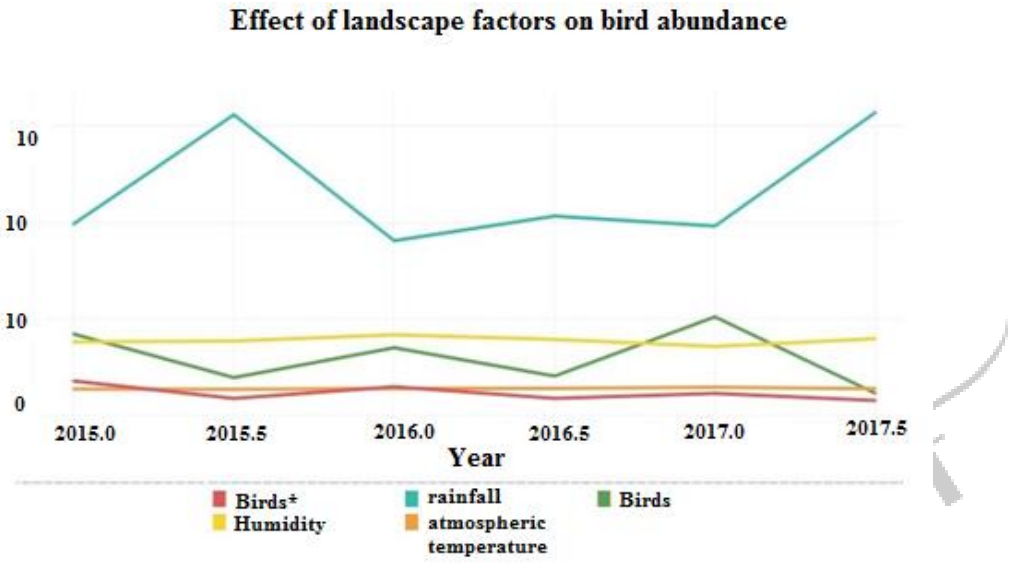



**Fig. 7. Number of birds and climatic factors -humidity, rainfall and temperature(air) as line plot. Bird* represents the all species of birds except Little cormorant and Lesser Whistling duck.**

The Humidity has a nearly constant value over all the three years except a little drop in the first half of 2017. The rainfall has a higher value over second half of every year from 2015 to 2017. In 2016, there is no considerable difference between closed and open seasons with respect to rainfall. The second half of 2017 has a sudden hike in rainfall. There is no considerable variation in air temperature over the years 2015 to 2017.

The season (opened) is highly significant in the model with p-value 0.001 at the level of significance 0.001. The coefficient value of the condition (open) is 1.749. The coefficient value of the condition (closed) merged with the intercept term which is statistically insignificant in this model. As the response variable, the number of birds becomes zero as all regressors take the value zero, it is reasonable to accept the hypothesis, intercept is zero. Hence in this model value of the intercept is assumed as zero.

The study revealed the role the Barrage plays in density of different species in this habitat as its opening and closing trigger fluctuations in the hydrological parameters which either favour the proliferation or dwindling of species. In fact, the opening time is a boon for various life forms from the lowest rung of evolution up the higher touching the avian species and the buzz and stir of life is dominant in the newly emerging conditions. Whereas, due to closure the existing mode of life undergoes a sudden change creating unfavourable conditions and the struggle for survival sets in the habitat which is a hard time for aquatic and avian life. The expanding water body during the opening time breathes a new life into every creature and the closure causes shrinkage and the wheel of life takes the reverse order with resultant enervation and bleakness in the area.

Serious alterations with regards to the primary structural relationships existing among different species occur as a result of the opening of Barrage and the consequent change in hydrological parameters. The functioning of the Barrage unbalances the normal temporal pattern of life in this habitat. An intermediate habitat is formed during the opening condition which is a big shift from the one existing during period of closure.

## Implication for conservation of Thattekkad Bird Sanctuary

The study has shown that the environmental variables - humidity, water temperature, electrical conductivity, temperature, and pH can be used as predictor for biodiversity in TBS. The improved water quality and associated habitat-changes that favoured the growth of macroinvertebrates might have resulted in an increase in fish population which attracted the birds. The opening of the Barrage resulted in a different environmental structural relationship compared to the structural relationship during closing of the Barrage.

The primary structural stages of the wetland area are disturbed by the opening of the Barrage that results in change in the hydrological parameters. This result showed that the seasonal activity of Barrage has greatly impaired the diversity and composition of the species by altering the temporal pattern of habitat that would normally exist in the area. Opening of the Barrage resulted in intermediate habitat which is a shift from wetland condition.

There is a cyclic fluctuation that inhibits the natural restoration of the wetland characteristics. The impact of this cyclic fluctuation has resulted in loss of endemic characteristics. Species colonization and abiotic condition have been shown to influence the faunal and floral recovery affecting the avian population. But the study has recorded change in avian diversity due to replacement with new species. Species that are highly sensitive to these cyclic fluctuations perished in the struggle for survival. Conservation strategies require an undisturbed habitat. Old growth forests are very important for protection of such highly sensitive wetlands. Conservation strategies due to cyclic habitat fluctuation result in deterioration of the intermediate wetland areas of TBS.

The current management plan should be revised to optimise the habitat requirement of endemic macrophytes, macroinvertebrates fish and birds. This result further suggests that one possible way to optimise the biodiversity of Thattekkad Bird Sanctuary is management and conservation action for preservation of the temporal and spatial habitat

preference of endemic species. Management plans should focus on timely enumeration of flora and fauna of this habitat to assess the anthropogenic influence on the biodiversity in this region. A detailed inundation mapping is necessary to forecast the likely influence of Barrage activity on the entire biotic community.

Considering the fragility of the ecosystem in the study site and the conservation status of the species recorded, it is recommended that regular ecological monitoring is to be carried out to assess the status of the habitat and the related biota in TBS. Such studies could act as a sign post for future conservation efforts in TBS.

**Acknowledgement/ Declaration**

This study was financially supported by the Cochin University of Science and Technology, Kerala. The authors are thankful to the Director, School of Environmental Studies, Cochin University of Science and Technology for continuous encouragement and facilities provided for the study. Special thanks are due to The Principal Chief Conservator of Forest (PCCF), Government of Kerala, for giving the required permission to carry out the study at TBS. We are grateful to Dr. A Mohandas for the continuous encouragement, timely advice and support. Ethical approval and consent to participate in the manuscript is not applicable and also no statement of data availability in the manuscript is not applicable.

Author's contribution:- All the research work and data in the manuscript was the contribution of corresponding author. All the corrections were made by the co -author.

Competing interest:- A conflict of interest can occur when corresponding author only.

Availability of Data and Materials;-Data from the research work carried out by corresponding author and also materials by corresponding author.

Funding:- This study was financially supported by the Cochin University of Science and Technology, Kerala.

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