Study of Limnological Status of Two Selected Floodplain Wetlands of West Bengal

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Research Article

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Abstract

Limnology is the study of all aquatic systems, both lentic and lotic fresh, fresh, and saline including lakes, wetlands, marshes, bogs, ponds, reservoirs, streams, rivers, oceans, etc. about their physical, chemical, and biological characteristics. Among this phytoplankton, Zooplankton, periphyton, benthos are a minute aquatic free-floating microscopic organism, which acts as a larger food source of larval and higher vertebrates and invertebrates including carnivorous and omnivorous fishes. They are related to the growth of juvenile fishes and are also play important role in the transfer of energy from the primary phytoplankton to higher trophic levels. The plankton community fluctuates according to the physicochemical parameters and the relative environment of the water body especially the Rotifers as they are known to change immediately along with the change in water quality .

Realizing the importance of floodplain wetlands and the paucity of literature on the limnology of this ecosystem present investigation was carried out in two floodplain wetlands having characteristics of open (Kole beel, an ox-bow lake formed near Somra Bazar in Hooghly district), and closed beel Suguna beel situated in Nadia District of West Bengal) system during the period 2011–2013.

The physicochemical parameters of the investigated beels' water and soil were, for the most part, favorable for planktonic development. It has an alkaline pH of 7.5–8.4 and is alkaline. The dissolved oxygen content and Secchi Disc transparency values indicate that the water is in excellent condition. The water was moderately hard, with only trace amounts of nutrients present. Seasonal fluctuations in the water column were apparent, and they were mainly attributable to replenished supplies and volume. The plankton population of the studied ecosystem was made up of a mixed and healthy population of diverse fauna. The greatest diversity was observed during the winter season, when favorable temperature, dissolved oxygen, and other physicochemical parameters of water, as well as optimal solar penetration, coincided. In a closed system (Suguna), the richness of planktonic structure resulted in higher fish production (1570.05 kg/ha/yr) than in an open system (Kole) (384.4 kg/ha/yr). The status of floodplain wetlands was determined to be eutrophic based on various Physico-chemical and biological parameters.

Introduction

The status of floodplain wetlands is eutrophic, and during the study period, 6 fish species, 14 phytoplankton genera, and 10 zooplankton genera were reported based on different physicochemical and biological parameters. Variation in rainfall, depth of water body, siltation, and other chemical factors are all factors due to year-to-year variations in plankton content in freshwater impoundments (Welch 1952).

Flood plain wetlands have simultaneously been described as the “kidneys of the Flood landscape” and as “biological supermarkets” (Mitsch, 1995a) illustrating the importance of their role in the ecological functioning of most river systems. River regulation in India has resulted in major changes to the flow regime, including changes to the timing and duration of small to medium-sized floods and alteration of the seasonal pattern of flooding. Such changes have altered lateral connections between the river and its flood plain and are known to affect plant community structure (Casanova & Brock, 2000), macroinvertebrate community composition (Quinn *et al*, 2000) in flood plain wetlands. As the river and its flood plains are inextricably linked, such change to the flood plain wetlands magnifies the effects of flow regulation on the ecological integrity of Australian rivers.

The structure of the floodplain plant community, both emergent and submerged, is an equally important pillar upon which to support sensible management policies. Several important consequential issues are associated with these two principal components. They are *inter alia* the quality of floodplain water, and the response of the faunal community to changes in the floodplain water, and the response of the faunal community to changes in the floodplain water, as we are aware of the sensitivity of the fauna, both invertebrate and vertebrate, to both insidious and cataclysmic environmental change.

Primary productivity is an important criterion for assessing a water body's productivity. When the nutrient status is low, primary productivity and fish production suffer as well (Singh and Desai 1980), meaning that primary productivity is inversely proportional to the nutrient concentration. Many researchers have studied the primary productivity of water bodies in various locations and at various times of the year, but they have only found one peak of primary production in reservoirs during the summer or early summer (Singh and Desai 1980). Except for the work of Sreenivasan (1964, 1968), Ganapati and Sreenivasan (1970), Kaliamurthi (1978), and Natarajan and Pathak (1979), knowledge of primary production in the tropics are still limited (1980). There is almost no detail on the ecological productivity of swamps, oxbow lakes, and other wetlands (Laal 1981 and Yadav 1988). This paper aims to investigate the relationship between primary production and planktonic structure in two eco-systems with open and closed characteristics.

Various limnological studies have been carried out in important wetlands of the state. It is evident from above that the limnology of the small floodplain wetlands has been neglected from a study point of view and no action regarding the proper management of these wetlands has been taken. However, the limnology of this wetland has been the subject of interesting studies.

Materials And Methods

Brief description of the study area

Saguna *beel* is a closed system (S) and the basin is solely dependent on rains for a water source. It is almost rectangular with a water spread area of 40 ha and lie between latitude 88º 4’ E and longitude 22 º 6’ N and located at Kalyani district Nadia, West Bengal. The *beel* was a defunct watercourse, which earlier had a connection with the river Hooghly.

The Kole *beel*, an open system, is a shallow saucer-shaped basin of 6-kilometer length having a total area of 81.6 ha. Kole *beel* lies between latitude 88° 7’ E and longitude 23° 2’ N and located at Somra Bazar, district Hooghly, West Bengal. The *beel* is connected with the river Bhagirathi with the braided channel.

The climate is tropical, hot, and humid with high fluctuations in temperature. The climate is of tropical monsoon type. Annual rainfall varies between 1600 mm and 2050 mm. Following APHA (1995) and Jackson, Physico-chemical parameters on soil and water were calculated every month (1973). A certified mercury-filled Celsius thermometer sensitive to 0.1° C and a digital pH meter (Hanna instruments, Portugal) were used to measure non-depth water temperature and pH in situ. A 20 cm diameter black and white Secchi disc were used to calculate Secchi depths once on each sampling day.

All water samples for chemical analysis were taken at approximately the same time of the day (i.e. between 0800 and 0900 IST). Water samples for dissolved oxygen, combined carbon dioxide, dissolved chlorides, and silica were analyzed following the methods outlined by Wetzel & Likens (1990) and Clesceri *et al*. (1998). Furthermore, one portion (15–20 ml) of each water sample was filtered through Whatman No. 41 filter paper and the filtrate was used for determining concentrations of the total were collected in a 500 ml wide-mouthed polypropylene bottle for analyzing the Physico-chemical characteristics like temperature, pH, alkalinity, dissolved oxygen, hardness, phosphate, nitrite, nitrate, chloride, sulfate, calcium, salinity, conductivity and total dissolved solids (TDS). Chemical analysis was done in the field and laboratory following the standard methods of APHA (1995).

Descriptive statistics

PROC MEANS procedure of SAS® (SAS Institute, 2010) was used to estimate the descriptive statistics, *viz*. minimum, maximum, mean, standard error, and coefficient of variation for all parameters.

Analysis of variance (ANOVA)

Analysis of variance (ANOVA) was used to discern significant differences among the parameters. PROC GLM procedure of SAS® (SAS Institute, 2010) was used which operates on both balanced and unbalanced designs. A significant source of variations was detected by GLM procedure. Boxplot of parameters was constructed by PROC GLM procedure of SAS® for parameters have shown distribution range of parameters (SAS Institute, 2010).

Result & Discussion

Water phase

Water temperature

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in water temperature (Table- 1). The Kole wetland has shown significantly higher values of water temperature in comparison with Saguna (Figure-1).

Transparency

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in transparency (Table- 1). The Saguna wetland has shown significantly higher values of transparency in comparison with Kole (Figure- 2a).

Water reaction (pH):

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in pH (Table-1). The Saguna wetland has shown significantly higher values of Specific conductivity in comparison with Kole (Figure-2b).

Total alkalinity

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Total alkalinity (Table-1). The Kole wetland has shown significantly higher values of Total alkalinity in comparison with Saguna (Figure- 3a).

Total hardness:

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Total hardness (Table-1). The Kole wetland has shown significantly higher values of Total hardness in comparison with Saguna (Figure- 3b).

Specific conductivity

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Specific conductivity (Table-1). The Kole wetland has shown significantly higher values of Specific conductivity in comparison with Saguna (Figure – 4a).

Dissolved oxygen:

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Dissolved oxygen (Table-1). The Kole wetland has shown significantly higher values of Dissolved oxygen in comparison with Saguna (Figure – 4b).

Nitrate-Nitrogen

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Nitrate (Table-1). The Kole wetland has shown significantly higher values of Nitrate in comparison with Saguna (Figure- 5a).

Phosphate-phosphorus:

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in phosphorus (Table-1). The Kole wetland has shown significantly higher values of phosphorus in comparison with Saguna (Figure-5b).

Silicate-silica

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in silica (Table-1). The Kole wetland has shown significantly higher values of silica in comparison with Saguna (Figure-6a).

Soil quality

Soil pH

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in soil pH (Table- 1). The Saguna wetland has shown significantly higher values of soil pH in comparison with Kole (Figure-6b).

Organic carbon

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in soil organic carbon (Table- 1). The Saguna wetland has shown significantly higher values of soil organic carbon in comparison with Kole (Figure-7a).

Available nitrogen

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in soil available nitrogen (Table- 1). The Kole wetland has shown significantly higher values of soil available nitrogen in comparison with Saguna (Figure – 7b).

Available phosphorus

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in soil available phosphorus (Table- 1). The Saguna wetland has shown significantly higher values of soil available phosphorus in comparison with Kole (Figure-8a).

BIOTIC COMMUNITIES

Plankton

Phytoplankton

Myxophyceae

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in phytoplankton (Table- 1). The Saguna wetland has shown significantly higher values of Myxophyceae in comparison with Kole (Figure- 8b).

Chlorophyceae

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Chlorophyceae (Table- 1). The Saguna wetland has shown significantly higher values of Chlorophyceae in comparison with Kole (Figure- 9a).

Bacillariophyceae

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Bacillariophyceae (Table- 1). The Saguna wetland has shown significantly higher values of Bacillariophyceae in comparison with Kole (Figure- 9b).

Euglenoida

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Euglenoida (Table- 1). The Saguna wetland has shown significantly higher values of Euglenoida in comparison with Kole (Figure – 10a).

Dinophyceae

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Dinophyceae (Table- 1). The Kole wetland has shown significantly higher values of Dinophyceae in comparison with Saguna (Figure-10b).

Xanthophyceae

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Xanthophyceae (Table- 1). The Saguna wetland has shown significantly higher values of Xanthophyceae in comparison with Kole (Figure-11a).

Zooplankton

Copepod

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Copepods (Table- 1). The Saguna wetland has shown significantly higher values of Copepods in comparison with Kole.

Rotifer

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Rotifers (Table- 1). The Saguna wetland has shown significantly higher values of Rotifers in comparison with Kole.

Cladocera

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Cladocera (Table- 1). The Saguna wetland has shown significantly higher values of Cladocera in comparison with Kole).

Benthic Macroinvertibrates

The occurrence of benthic organisms sharply declined from the late winter season reaching the lowest values during the monsoon. The general trend of abundance in the studied lakes followed a sequence of Gastropod > Oligochaete > Chironomids > Bivalves > others.

Gastropod

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Gastropod (Table- 1). The Kole wetland has shown significantly higher values of Gastropod in comparison with Saguna.

Bivalve

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Bivalve (Table- 1). The Kole wetland has shown significantly higher values of Bivalve in comparison with Saguna.

Oligochaete

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Oligochaete (Table- 1). The Kole wetland has shown significantly higher values of Oligochaete in comparison with Saguna.

Chironomids

The analysis of variance revealed that there was a month-wise and wetland type-wise significant difference in Chironomids (Table- 1). The Kole wetland has shown significantly higher values of Chironomids in comparison with Saguna.

Discussion

WATER QUALITY CHARACTERISTICS

Physical Attributes

Transparency

In the present study, the two selected *beel*s were found to have low transparency during the summer period (particularly May- June), which is attributed to the wind action and phytoplankton bloom. Various workers have also reported similar seasonal fluctuations in lake water transparency (Michael, 1969; Kumar, 1985).

Temperature

Kumar (1985) calculated stratified temperature in a beels eco-system in West Bengal's Nadia district. The water temperature closely matched the temperature of the atmosphere in the beel habitats studied

(Tables – 1). Variation in water temperature was quite distinct during different seasons throughout the study. According to Bhowmik (1988), maximum and minimum temperatures in West Bengal beels and baors ranged from 17.5 to 32.0 0C, which is consistent with the current research. Rai and Dutta Munshi (1989) have also reported that the presence of macrophytes profoundly influences water temperature. The present study also confirms the same. According to Banerjea (1967); Jhingran (1989) in water bodies with high organic contents in bottom mud, large-scale mortality takes place in summer months especially after a shower or cold wind.

CHEMICAL ATTRIBUTES

Dissolved oxygen

The prime life-bearing gas in aquatic media was within the moderate range of 6.4 to 10.8 ppm (Table- 1). The reason for the maximum stratification of oxygen in monsoon may be attributed to the high rate of surface mixing of atmospheric oxygen due to the showering of a raindrop (Banerjea, 1967). It is interesting to mention that the higher concentration of oxygen in the surface water during monsoon was always not in confirmation with the high plankton density whereas Das and Srivastava, (1956) reported that the phytoplankton peak corresponds to the high oxygen values while zooplankton peaks are associated with low oxygen values. Oxygen content observed to be poor during the period of the high temperature such as the summer season (Bhowmik, 1968; 1988; Sugunan *et al.*, 2000) conforms with the present study. Kumar (1985) also reported similar observations. Dense aquatic vegetation, shallow water depth, and intense fishing activities can cause large fluctuations in the dissolved oxygen content of water in the beels. (Yadava *et al.*, 1987).

Water reaction pH

In the present investigation, the hydrogen-ion concentration in the surface water of the *beel*s was 8.0 and above excepting on few occasions. The observed pH as 8.0 and above has been recorded to be productive by various workers (Hutchinson, 1957; Banerjea, 1967). Michael (1969) observed that when pH ranged between 7.3 and 8.4 the water provided optimum conditions for the growth of plankton. The present study bears the agreement of alkaline pH with the study of Bhowmik (1988) where the pH value of the *beels* and *baors* of West Bengal was recorded between 6.8 and 9.1.

Alkalinity

Since total alkalinity values are the resultant of the entire biological and chemical process taking place in the water body, as such it is also taken as a rough index of productivity of the water body (Laal, 1981). In the present investigation, the alkalinity of the *beels* waters was observed to be within the product range. The high alkalinity value was recorded in *beels* infested with a high density of macrophyte-associated fauna and benthic biomass. Sugunan *et al.*, (2000) reported similar observations.

Free CO_2

Such absence of free CO_2 in water was found to be related to the presence of heavy phytoplankton populations (Michael, 1969). The pronounce absence of the free CO_2 at the subsurface level of the water was in confirmation of the observation made by Reid (1961), who reported that at pH 8 and above the free CO_2 is usually absent. Most fish species will survive waters containing up to 60 ppm (Hart, 1944).

Specific conductivity

The specific conductance of water is a measure of the resistance of a solution to electrical flow, which declines with increasing ion content (Wetzel, 2001). The specific conductivity values recorded from these lakes were in an acceptable range. It has been reported an optimum range as 250–400 µS/cm and opined that specific conductivity above 400 µS/cm does not limit or favor productivity. The total concentration of solid constituents in natural waters is measured by specific conductivity.

Nitrate-Nitrogen

In the present investigation, the values of water-soluble nitrate varied from system to system and with seasonal changes. The level of the nutrient was 0.3–1.5 ppm in Kole, while, it was comparatively higher in the range of 0.8 to 1.3 ppm in Saguna (Tables – 1). The fluctuation trend in nitrate level indicated mesotrophic to the eutrophic condition of the *beel*s (Goldman and Horne, 1983). The nitrate levels in the studied beels were within the productive range (Banerjea, 1967) and ideal for plankton growth, which is consistent with the findings of the study.

Phosphate-phosphorus

The phosphate cycle of the *beels* was in correlation with the dissolved oxygen and is known to play important role in controlling the rate of phosphorus release from the sediment to the photic zone (Munawar, 1970). A major distinguishing factor among the water bodies is the difference in frequency and length of river inputs or connectivity (Hamilton and Lewis, 1990; Amoros, 1991). The nutrient enrichment during low water was attributed by Hamilton and Lewis (1987) to turbulence from wind action and sediment resuspension. It was attributed by Boneto et al. (1984) to hypolimnetic anoxic conditions and the release of nutrients from the sediment.

Silicate

Many workers (Bhowmick, 1968) have observed a direct relationship between silicate content and diatom population in the water body. Furch (1984) found a similar phenomenon in Amazonian ‘Varzea' (flood plain) lakes and a floodplain lake in Sao Paulo, Brazil.

During the study period, water temperature, pH, Dissolved Oxygen (DO), Free Carbon Dioxide (FCO_2), Total Alkalinity were measured monthly for six months. The limnological parameters of the study site were found to be highest during October 2012. the pH of the Kole was found to be at par during the six months study period. DO and FCO2 were found to be highest during October and lowest during the winter months i.e, December 2011 – January 2013.

The water quality, nutrient level, and fish fauna of the Kole beel show change from time to time as it receives different types of water at the different parts of the year. During monsoon, the water from river Ganga enters the beel along with nutrients, fishes, and inundates the beel. Again the combined flow from the rivulet upstream along with nutrient and water from the catchment area reverts the flow to the Ganges that continues till the flood receded. Therefore, in both cases, many fishes enter the beel along with and against the water current giving a dual benefit to the beel.

SEDIMENT CHARACTERISTICS

Chemical attributes

Soil pH

In the present study, the pH values recorded in the soil (6.0–7.0) were thus indicative of high productivity in the investigated *beels*, which confirms the study. Das (2000) working on the *beel*s of West Bengal has reported a similar pH of soil.

Organic carbon

The fluctuation of organic carbon in an aquatic system with the change of places and during different seasons has been reported by various workers (Bhowmick, 1968). The seasonal fluctuation indicated a definite pattern of peaks of organic carbon as observed by Bhowmick (1968). Kumar (1985) reported a similar observation where organic carbon values ranged from 3.8 to 4.8 % in *beels* located at Kalyani.

Available nitrogen

In the present study, available nitrogen in the *beels sediment* was varying in concentrations. The nitrate and available phosphorus are considered to be limiting factors, being the primary nutrient for ecosystem functions (Carney *et al*., 1993 and Brown, 1981). The nitrogen levels in *beel*s were within the range of favorable productivity (Banerjea, 1967).

Available phosphorus

It is well documented that in shallow lakes, aquatic macrophytes act as a sink for nutrients, both nitrate (N) and Phosphorus (P), during their growth phase withdrawing up to 60% of N & P from the sediment and after their decomposition releases them back to the water as well as to the sediment (Donk *et al*., 1993). According to Sugunan et al., (2000), usable phosphorus values were lowest in closed and weed-choked beels (traces to 3.18 mg/100 g of soil), higher in closed but moderately weed-infested beels (traces to 7.6 mg /100 g of soil), and maximum in open beels (traces to 10.08 mg /100 g of soil), in comparison to other nutrient parameters. This observation is based on the study made on a large number of *beels* of West Bengal and eventually, the present observation is, by and large, in agreement with the findings and indicative of productive.

Biotic Communities

Planktonic structure

The plankton population in the *beel*s systems was diverse in respect of species and population density. From the 2 systems, 62 species of plankters belonging to 51 genera and 29 families were identified. (Table- 1). Sugunan et al., (2000) found that phyto and zooplankton populations in West Bengal flood plain wetlands were lower during the southwest monsoon, but increased after the ecosystem stabilized and the plankton population formed using inorganic nutrients and organic matter brought in by the incoming flood or run-off water. Bhowmik (1988) also found that phytoplankton dominated the maximum plankton population in the summer, while zooplankton dominated in the winter. In Bihar, Jha (1997) discovered a higher plankton population in closed flood plain lakes.

The beer's phytoplankton was low due to the use of nutrients by a thick growth of macro vegetation. (Yadava *et al*., 1987). The wetlands exhibited strong competition between the macrophytes and phytoplankton in respect to sunlight and nutrients (N: P), influencing the abundance and quality of phytoplankton from one system to another (Wetzel, 2001). Macrophytes being the dominant autotrophs might have used the available nutrients, sunlight more efficiently, as such grow rapidly, almost shadowing the proliferation of phytoplankton (Boyd, 1971).

Several researchers have documented increased phytoplankton production when dissolved oxygen levels are higher. (Alikunhi *et al*., 1955; Das and Srivastava, 1956; Moitra and Bhattacharjee, 1965; Saha *et al*., 1971). However, no such connection could be made during the ongoing investigation. According to Reid (1961), as the temperature is lowered, the solubility of oxygen in water increases.

Cairns (1965) investigated the optimum temperature range (15–30°C) as the most favorable for the growth of diatoms. Copepods were present throughout the year, but there was no discernible trend. Rotifers have a diverse ability to survive in a variety of habitats, as some feed on phytoplanktons, others on detritus and bacteria, and still others have been identified as predatory raptors (Singh, 2000). Rotifers predominate in Indian freshwaters, which is a natural occurrence. (Michael, 1969; Lahon, 1983). Singh (2000) recorded maximum production of rotifers during the summer season. Similar observations have been made by Michael (1966) and Singh (2000). Their growth seemed to be favored by a temperature range of 23.5 to 26.1°C, which is within the optimal temperature range for protozoan growth (Pennak, 1953).

During the investigation, a total of 15 taxa from three classes were discovered: 5 Cladocera taxa, 4 Copepoda taxa, and 6 Rotifera taxa. The site's highest Zooplankton abundance was in October 2012, and the lowest was in February 2013. A similar study in three different kinds of freshwater waterbodies in Penang Island, Ismail, and Zaidin, 2015 reported the highest Zooplankton abundance in November while the lowest in February. Among all the Zooplankton groups, Rotifera was reported to be dominant among other groups during the period of investigation consisting of 6 taxa of which *Filinia* sp. shows highest abundance and *Keratella* sp. shows the lowest abundance throughout the six months study. In the Cladocera group, *Moina* sp. shows highest and *Bosmina* sp. shows the lowest abundance while

Copepoda group, *Mesocyclops* sp. shows highest abundance and *Microcyclops* sp. shows the lowest abundance throughout the study period. Compared to all other taxa, *Filinia* sp. of the Rotifera group were found to dominate the population of Zooplankton. The abundance of the Rotifera group may indicate the presence of dissolved solids in the study site, as they are known to increase the growth of minor phylum of Zooplankton in the water body (Goswami and Mankodi, 2012).

Figures show the percentage composition of Zooplankton in the study during the period of investigation. Cladocera contributes the highest percentage of 43% of the total Zooplankton composition followed by 42% of Rotifera and 15% of Copepoda. The presence of the highest percentage of Cladocera again depicts the better condition of the water body and can be used for the aquacultural program. Cladocera shows the highest abundance among other groups of Zooplankton present in the study site. Cladocera was found to be abundant during October 2012 whereas Copepoda and Rotifera were also found abundantly during October 2012. The lowest abundance of Zooplankton composition was found to be during February 2013.

Limnology and plankton community of floodplain wetlands

Floodplain lakes' chemistry and biology are strongly affected by their proximity to rivers. (Amoros and Roux, 1988; Van den Brink *et al.*, 1992; Tockner *et al.*, 2000b). One of the most striking features of plankton populations is the ongoing substitution of organisms (Hutchinson, 1967; Edmondson and Litt, 1982). The stagnant floodplain waters are one-of-a-kind environments in terms of water chemistry, phytoplankton and zooplankton composition, and dynamics, with exceptional spatial and temporal heterogeneity in the ecosystem, resulting in high species and population richness (Pethart, 1995). Changes in the prevailing environment over the wetland, as well as external factors, may cause changes in the physicochemical parameters (Abbasi, 1997). The phyto- and zooplankton community composition in floodplain lakes are influenced by hydrology, relevant nutritional resources, and habitat characteristics, primarily through N and P input from eutrophic main channels during floods. The complexity of ecosystems created by the presence of aquatic plants was linked to plankton species richness (Van den Brink *et al.*, 1994). Plankton diversity in semi-isolated floodplain reservoirs, as well as natural river-floodplain systems, are known as biodiversity hotspots (Ward *et al.*, 1999), due to the variability in hydrology and disturbances of the lentic, lotic and semi-aquatic habitat types present. When connectivity is considered the most important disruption of floodplain lakes, lakes with intermediate connectivity have the most diversity, while lakes that are permanently linked (highest connectivity) and isolated (lowest connectivity) have the least diversity. (Roozen, 2005).

The highest phytoplanktonic population is observed during the rising water cycle when limnological changes are most visible as river water reaches the floodplain for the first time. Water and plankton populations from the pools and depressions are replaced by the flood. Nitrate-nitrogen is abundant in river water, which can be used as a source of nutrients and oxygen. Diatoms and green flagellates, Volvocales, are carried in by the flood, and they will spread and take over after the flood. (Pethart, 1995). The river is a highly complex entity that has a significant impact on the limnology of stagnant waters in the floodplain. Even though plankton cannot swim against currents, rivers also have an abundance of it.

(Hynes, 1970; Winner, 1975; Rzoska, 1978). Factors influencing the transport of species from the source region to the water, and factors affecting the growth and reproduction of organisms in the river, are the two types of factors that influence the abundance of plankton in rivers. (Hynes, 1970). Plankton can be supplied to the river by standing water in contact with the channel.

Many tropical rivers have a wide stretch of the natural floodplain that could be significant zooplankton sources (Saunders and William, 1988). Inundation of source areas is caused by changes in water levels, which increases zooplankton abundance.

The timing of a flood is thought to be important in assessing the effects on the water quality of flooded lakes. (Junk *et al.*, 1989; Bayley, 1991; Hein *et al.*, 1999; Tockner *et al.*, 2000b). Phytoplankton is extremely sensitive to environmental changes, and major shifts in phytoplankton species composition are often a result of substantial changes in ecosystem ambient conditions. (Devassy and Goes, 1988, 1989). Floodplain lakes with a long annual flood cycle have cyanobacteria, Chlorophyta, and filter-feeding zooplankton taxa associated with open water. Bacillariophyceae and scraping zooplankton taxa associated with aquatic macrophytes, on the other hand, are popular in floodplain lakes with short annual flood durations. (Van den Brink *et al.*, 1994). Physical properties of water, such as mixing and light availability, are two of the most important determinants of phytoplankton vertical distribution. (Reynolds, 1994). These properties are closely related to seasonal flood pulse changes in floodplain lakes. (Junk *et al.*, 1989). Sept and Reynolds (1995) discovered that a water level's phytoplanktonic production was affected by temperature, light, and nutrients. Lentic phytoplankton is washed away during the inundation, while riverine species are taken in by floodwaters. Nonetheless, river water causes phytoplankton dilution and wash-out, resulting in a drop in abundance (Talling, 1986). Under insecure environmental conditions, small flagellate forms (cryptophytes or green algae) with rapid growth rates (r-selected) often dominate. (river water inflow can be considered a disturbance factor) (Reynolds, 1984). Another significant aspect is diatom input into river water, where they are often dominant. (Moss *et al.*, 1989; Kasten, 2003). Zooplankton is an integral component of the marine ecosystem, performing a broad range of important functions. Water is purified by feeding on phytoplankton and microorganisms. The quality of water can be assessed based on the species dominance in the zooplankton population. The clay content of floodplain soils is higher than that of depressional wetland soils. (C.B. Craft, unpublished data). According to the few studies that have been conducted, open (floodplain) and closed (depressional) wetlands both sequester similar quantities of organic C and N.

The relatively high rate of soil organic C and N deposition in floodplain soils and possibly other floodplain wetlands is due to slower soil accretion and higher C and N concentrations in the subsoil. As demonstrated by higher P accumulation in floodplain wetlands, catchment size and connectivity to sources of fine-textured (clay) sediments influence P retention (Christopher and William, 2000). Wetland productivity, species diversity, and water quality are all influenced by nutrient accumulation and storage.

External nutrient loadings and accumulation are often linked to high primary and secondary productivity (Brinson *et al.*, 1981; Hopkinson *et al.*, 1992). The potential of freshwater wetlands to remediate water quality depletion by collecting sediment and sequestering nutrients is one of their advantages (C, N, and P). However, the efficacy of wetlands in nutrient and sediment retention is based on several factors, including the scale of the watershed, the land use within it, and the degree of wetland access to open water habitats. (Christopher and William, 2000). In infertile wetlands that receive little in the way of fertilizer subsidies or have low soil nutrient supplies, species diversity and the prevalence of rare species are typically higher. (Moore *et al.*, 1989; Marrs, 1993). Long-term lake studies have provided clear evidence of the impact of increased major nutrients (nitrogen and phosphorus) on lake production and biota variations. (Abd El-Karim, 2009).

Macrophyte

Living organisms and their abiotic surroundings are inextricably linked and interact with one another (Odum, 1983). Aquatic plants play an important role in the habitats of lakes, wetlands, rivers, and streams all over the world (Jamil, 1993). Sharma (1995) also recorded dominance by submerged and emergent vegetation in Kawar lake of Bihar. The high turbulence of water was perhaps the main constraint for lesser growth of macrophytes in Kole which conforms with the study of Saha *et al.* (1971); Sugunan *et al.*, (2000). Submerged macrophytes regulate plankton density and primary productivity by providing optimal light quality and quantity, temperature, and total alkalinity (Yadava, 1987). Kole beel had a lower infestation and biomass of macrophytes than the parent river, which was partly due to management action and partly due to contact with the parent river.

The results show that both free-floating and submerged macrophytes have a wide seasonal variation in biomass. Camargo and Florentino (2000) found that the biomass of aquatic macrophytes in tropical water bodies varies greatly from season to season. Junk (1986), Junk and Piedade (1993), Da Silva and Esteves (1993), and Camargo and Esteves (1993) all made similar observations (1996). Saha et al. (1990) found a significant difference in water quality parameters during the planktonic and macrophytic phases in Kulia beels (closed beels) in West Bengal. During the macrophyte process, they discovered a lot of Secchi disc visibility (from top to bottom). In the current analysis, however, no direct correlation between macrophytic dominance and transparency could be found.

Munawar (1970) claimed that a dense macrophyte population would result in increased photosynthetic activity and, as a result, an increase in pH. The absorption of phosphorus by macrophytes both from the water and sediment is well known (Bristow, 1975; Denny, 1995; Chamber *et al.*, 1989 and Gunnison and Barko, 1989). This suggests that nitrate is a more limiting nutrient for macrophyte growth in these lakes than phosphorus.

Aquatic macrophytes play an important role in the dynamics of the Beels' physicochemical and biological properties. Aquatic macrophytes provide nutrition to herbivores while also strengthening the Beel ecosystem's detritus food chain.

Marginal plants, especially Ipomoea fistulosa, were found in the Closed Beel. In the closed Beel, other aquatic plants such as Jussiaeadiffusa, Alternantheraphylloxeroides, and Paspalum scrobiculate were not present. Floating pants Eichhornia crassipes (Panimeteka) and Monochoria vaginalis (bhatmeteka) are the most common macrophytes, followed by Chara (submerged).

The open beel was devoid of floating plants such as Trapa natans var. bispinosa (cattail). Ipomoea fistulosa, Ipomoea aquatica (waterspinach), Ipomoea carnea, Alternantherasessilis, Alternantheraphylloxeroides, Jussicadiffusa, and Paspalumscorbiculatum are examples of marginal amphibious plants that can thrive on damp soil lands as well as float on the water surface. Monochoria vaginalis (water hyacinth), Eichhornia crassipes followed by Chara (submerged), and Ipomoea fistulosa (marginal) are all dominant macrophytes in the Open beel. Aquatic weeds are heavily infested in West Bengal's Beels. Eichhornia crassipes and Monochoria vaginalis (water hyacinths), Chara (submerged), Salvina, Lemna, Wolffia, Potamogeton, Hydrilla verticillate, vallisnereia, Ipomoea fistulosa, Nymphaea cristata (water lily), Eurylferox (Makhna), etc. are some of the common forms.

The primary productivity of the studied beels came from two sources: phytoplankton and macrophytes. The rate of energy transformation by phytoplankton is lower than that of macrophytes, according to Beels. It's a complicated process to transfer energy from the primary producer to fish (carnivores). The fish reflect a fraction of the energy trapped by primary producers as a secondary product of the beels. It's a complicated process to transfer energy from the primary producer to fish (carnivores). The fish reflect a fraction of the energy trapped by primary producers as a secondary product of the beels. In the Open Beel, the average Gross primary output (GPP) by phytoplankton is 1.82 g/m2 per day. The value is 1.68 g/m2 /day in the case of Closed Beel. The phytoplankton of Open Beel produced more gross primary production (GPP) than that of Closed Beel. The Open Beel's Net Primary Production (NPP) is 1 g/m2 per day, while the Closed Beel's NPP is 0.83 g/m2 per day. In the Beels, differences in phytoplankton net primary production (NPP) are 0.17g/m2/day.

Ranges of Gross Primary Production (GPP) 1206–4371 g/m2/yr. and 506 g/m2/yr. with an average value of 2655.80g/m2/yr and 2142.27 g/m2/yr in the Closed and Open Beels respectively. Lowest Gross Primary Productive (GPP) was observed in December (1456g/m2/yr.) in the Open Beel and 2160.33g/m2 /yr in the Closed Beel. In Closed Beel, the highest average value was observed in November (3174.33g/m2/yr) and in November (3174.33g/m2/yr). GPP falls during the winter and steadily rises during the summer. If water is accessible in the wetlands, Eichhorniacrassipes and Monochoria vaginalis (water hyacinth) are usually abundant throughout the year. Rainfall, high and high-temperature humidity all influence their development. During the monsoon and post-monsoon, the dominant period was observed.

Despite the drying up of some patches of the wetland beds, some weeds, such as Hydrilla verticillata, Vallisneria spiralis, and Potamageton octundrus, renew their seasonal cycle. Over the winter season, the macrophytes decompose. The availability of water in the wetlands' bed influences the seasonal variation of biomass.

Despite their immense ability, the Beels only use around 1% of the energy used by fish, and the rest is transformed into a detritus food chain at the bottom of the beels. Because of the two types of productivity sources, the primary productivity of the Beels is higher than the productivity of any other freshwater reservoir. Most of these macrophytes are not specifically grazed by herbivores, and the unused material is deposited at the bottom as detritus energy, which is generally high in both Beels. Detritus levels in the Open Beel ranged from 0.91 to 4.56 kg/m2/yr/m2, with an average of 2.55 kg/m2/yr. Detritus levels in Closed Beel ranged from 2.05 to 4.75 kg/m2/yr, with an average of 2.75 kg/m2/yr. In both the Beels, the value of detritus was higher in the winter season (4.45kg/m2/yr.) than in the summer season (1.3kg/m2/yr.). The rich growth of marginal and submerged vegetation in the Brahmaputra floodplain wetlands is a unique feature due to heavy nutrient loading from both allochthonous and autochthonous sources. These macrophytes often supplant the plankton population, hastening eutrophication by replacing the plankton community with macrophytes as the primary producer. This results in a higher rate of evapotranspiration and lake amplification. This method, however, can be reversed with good management. Open Beels, which have fewer macrophytes (on average 2142.27 g/m2/yr), are best suited for energy transformation by phytoplankton.

The productivity of West Bengal's Closed Beels (average 2655.80g/m2/yr) is hampered by floating (water hyacinth), submerged (Najas, Vallisnaria, Hydrilla, and Chara), and marginal (Typha) vegetation. As a result, both the Closed Beel (0.83 g/m2/day) and the Open Beel (1 gc/m2/day) have poor net productivity rates.

Macrobenthic community

Sugunan *et al.* (2000) opined that the *beel*s of West Bengal support rich growth of benthos, the average density ranging from 90 to 13,238 nos./m^2. Parameswaran and Vass (1995) stated benthos of the *beels* of West Bengal is generally dominated by mollusks, insect larvae, nymphs, and *Oligochaetes* which agrees with the present investigation.

Conclusion

The limnology and productivity of the two beels are different. Kole and Suguna beels are both shallow and have similar thermal characteristics. Kole beel primary production was poor, ranging from 0.273 to 0.702 g C m-2 day-l.

Rain showers in the forenoon resulted in higher development. This confirms Vcrduin's (1957) hypothesis that phytoplankton exposed to low light during the day can still photosynthesize at high rates in the late afternoon when showers occur earlier in the day. Low photosynthetic concentrations are indicated by alkalinities below 50 ppm (Pleasant, Rand, and Namcrov 1962). The comparison between Ooty Lake and Kodaikanal Lake is striking. Probiotics are recommended for water with a lower tropical temperature. Performance was strong in water with a lower tropical temperature, reaching 8.16 g C m-2 per day. The lake had been highly active, as shown by improvements in oxygen and alkalinity, except in April 1963, when primary production was poor due to persistent cloudy weather. Output was higher when rain showers occurred, according to the carbon dioxide change process.

It can be inferred that the nutrients in water and soil in an aquatic environment play a significant role in aquatic production under various temperature regimes. The productivity of relatively regulated water bodies, such as the Suguna beel (closed), is primarily determined by allochthonous nutrient input and management practices. The sources of nutrients in natural open water bodies like the Kole beel, on the other hand, are both allochthonous and autochthonous. Apart from other hydrobiological parameters, the productivity of natural water bodies is affected by several factors such as aquatic vegetation, eutrophication, pollution, and various anthropogenic activities. The abundance of nitrogen and phosphorus in water and soil has a positive association with productivity. However, there was no connection between potassium content and productivity. In contrast to nitrogen and phosphorus, potassium tends to play a smaller role in aquatic production.

In conclusion, phosphorus was released because of repeated drying and wetting. This effect was greater when the drying time was 200 hours rather than 100 hours, suggesting that the degree of drying is a key factor in regulating phosphorus after rewetting.

It is also recognized by the study that human activity remains one of the major ecological elements in the floodplain wetlands and its catchments in both the cases of open and closed floodplain wetlands.

The presence of a good abundance of Cladocera is very much appreciable as they are known to be the staple food of larvae of various culturable fishes. But the increasing abundance of Rotifera may be an indication of the increase of pollutants to the water body.

Just like the other wetlands of the state the Kole Beel experience the most dramatic changes in their trophic status and biota. There is a gradual shrinkage in the size of the wetland due to encroachment, agricultural activities, and human settlement within the wetland causing an imbalance in the wetland eco-system.

Although the Millennium Ecosystem Assessment estimates that wetlands cover seven percent of the earth's surface and deliver 45% of the world's natural productivity and ecosystem services.

The existence of these unique resources in this region of the country is under threat due to differential developmental activities and population pressure. This calls for a long-term

planning for the preservation and conservation of these resources.

The water quality of Kole Beel is deteriorating as years are passing by resulting in prolific weed growth, thereby, affecting sustainable food production and potable water for humans and livestock. A large number of people residing in or on the fringe areas of wetlands are partially or entirely dependent upon the aquatic resources of the Beel. The Beel is a habitat of diverse groups of organisms and harbors a vast array of aquatic resources. Therefore, restoration of the Beel is

very much important for maintaining bio-diversity.

Fish is an important component in people's diets, providing about 2.9 billion people with almost 20 percent of their average intake of animal protein. Fishery sectors are particularly important in developing countries, for providing both food and livelihoods. The Beel offers immense potential for increasing fish production, employment generation, and several other additional sources of income for the rural population of this area of West Bengal.

Therefore, if we can attract the attention of all the regulating bodies for better scientific management and maintenance along with the introduction of culture-based fishery then the fish

production of the beel can be increased 3 fold i.e. up to 668 tonnes of fishes per year.

It is our considered opinion that the fish production of the beel can be augmented if the beel is taken under culture-based fishery using proper scientific management framework. This will require support from the Government especially in i. regulating the flow of floodwater from river Ganges, ii. leasing the beel to the co-operative society with traditional (*Koiborta, Mahimal*) and trained fisher, iii. strict enforcement of regulations (Indian Fisheries Act, 1897) regarding fishing

access, period, time, type, mesh size, gears, encroachment, and free riders, iv. training the fisher about the recent scientific technique.

Table 1
Descriptive statistics of Water quality parameters data of Saguna

Parameters	Mean	SE	SD
Transparency (m)	1.9	0.06	0.27
Water coverage(%)	68.1	3.26	13.81
Macrophyte coverage (%)	5.0	0.67	2.85
Depth(m)	2.8	0.07	0.28
Temp (Air) °C	26.1	0.64	2.70
Temp (Water) °C	25.1	0.61	2.60
Water reaction(pH)	8.0	0.07	0.28
Specific conductivity (μS/cm)	263.7	8.35	35.41
Dissolved oxygen (ppm)	7.5	0.13	0.53
Free Carbon di Oxide (ppm)	1.1	0.21	0.90
Total Alkalinity (ppm)	1.3	0.97	4.12
Total Hardness (ppm)	105.3	3.20	13.57
Calcium (ppm)	39.7	0.93	3.93
Magnesium(ppm)	1.9	0.39	1.64
Chloride (ppm)	20.0	1.03	4.37
Nitrate – N (ppm)	98.4	11.95	50.71
Phosphate-phosphorus (ppm)	143.0	23.21	98.45
Silicate-silica (ppm)	7.1	0.52	2.19

Table 2
Descriptive statistics of water quality parameters of Kole

Parameters	**Mean**	**SE**	**SD**
Transparency (m)	1.2	0.1	0.3
Water coverage(%)	0.6	0.04	0.2
Macrophyte coverage (%)	0.4	0.03	0.1
Depth(m)	60.9	2.3	9.8
Temp (Air) °C	34.9	2.6	11.0
Temp (Water) °C	0.02	0.001	0.004
Water reaction(pH)	67.8	3.2	13.7
Specific conductivity (µS/cm)	16.2	1.2	5.0
Dissolved oxygen (ppm)	2.2	0.1	0.5
Free Carbon di Oxide (ppm)	27.5	1.1	4.6
Total Alkalinity (ppm)	26.6	1.0	4.4
Total Hardness (ppm)	7.9	0.1	0.2
Calcium (ppm)	472.3	11.0	46.5
Magnesium(ppm)	7.7	0.1	0.5
Chloride (ppm)	1.3	0.3	1.3
Nitrate – N (ppm)	145.2	2.5	10.5
Phosphate-phophorus (ppm)	149.6	2.4	10.3
Silicate-silica (ppm)	34.8	1.1	4.7

Table 3
Diversity of phytoplankton in selected beels (floodplain wetlands) of west Bengal

Myxophyceae	***Pandorina morum* (S,K)**
Anabaena spiroides (S,K)	*Pediastrum duplex* (S,K)
Aphanocapsa roeseana (S,K)	*Scenedesmus obliqumus* (S,K)
Aphanothece pallida (S,K)	*Spirogyra maxima* (S,K)
Chroococcus minutus (S,K)	*Staurasterum orbiculare (S)*
Cylindrospermum sp (S,K)	*Stigoclonium sp* (S,K)
Gleocapsa sp (S,K)	*Tetraedon sp (SK)*
Gloeotrichia echinulat (S,K)	*Tetraspora gelatinosa (S)*
Lyngbya birgei (S,K)	*Ulothrix zonata* (S,K)
Merismopedia minima (S,K)	*Westella botryoides (K)*
Microcystis aeruginosa (S,K)	*Volvox areus* (S,K)
Nostoc linckia (S,K)	Bacillariophyceae
Oscillatoria rubescens (S,K)	*Amphora coffeaeformis* (S,K)
Phormidium inundatum (S,K)	Cyclotella *meneginiyana* (S,K)
Rivullaria aquatica (K)	*Cymbella lanceolata (S)*
Spirulina princeps (S,K)	*Eunotia pectinalis (S)*
Actinasrtum gracillinum (S,K)	*Fragillaria brevistriata (S)*
Eudorina elegans (S,K)	*Gomphonema lanceolatum* (S,K)
Ankistrodesmus falcatus (S,K)	*Gyrosigma acuminatum* (S,K)
Asterococcus limneticus (S,K)	*Melosira granulate* (S,K)
Characium augustum (K)	*Navicula radiosa* (S,K)
Chlorella vulgaris (S,K)	*Nitzschia sigmoidia* (S,K)
Chlorococcum infusionum (S)	*Pinnularia major* (S,K)
Cladophora sp (S,K)	*Rhopalodia gibba* (S,K)
Closterium parvulum (S,K)	*Surirella sp* (S,K)
Cosmerium bengalicum (S,K)	*Synedra capitata* (S,K)

S = Saguna Floodplain wetland, K = Kole Floodplain wetland

Myxophyceae	***Pandorina morum* (S,K)**
Crucigenia quadrata (S,K)	Euglenophyceae
Dictyosphaerium pulchellum (S)	*Euglena viridis (S)*
Euastrum spinulosum (S,K)	*Phacus caudate* (S,K)
Hydrodiction idium (S,K)	*Dinophyceae*
Micrasterius agardh (S,K)	*Ceratium macroceros (S)*
Mougeotia genuflexa (S,K)	Xanthophyceae
Oedogonium australe (S,K)	*Botrydium granulatum* (S,K)
Oocystis crassa (S)	*Tribonema vulgare (K)*
S = Saguna Floodplain wetland, K = Kole Floodplain wetland	

Table 4
Descriptive statistics of Phytoplankton data of Saguna

Sl. No.	Parameters	Mean	SE	SD
1.	Total Plankton NO	1849.6	92.36	391.85
2.	Phytoplankton No	1543.2	75.90	322.01
3.	Myxophyceae No	404.5	28.23	119.75
4.	Chlorophyceae No	355.1	44.29	187.89
5.	Bacillariophyceae No	529.8	20.22	85.80
6.	Euglenoida No	131.4	12.91	54.78
7.	Dinophyceae No	83.6	9.64	40.88
8.	Xanthophyceae No	38.8	5.67	24.04

Table 5
Descriptive statistics of Phytoplankton data of Kole

Sl. No.	Parameters	Mean	SE	SD
1.	Total Plankton NO	1111.8	56.4	239.3
2.	Phytoplankton No	1052.0	60.4	256.1
3.	Myxophyceae No	295.7	23.5	99.8
4.	Chlorophyceae No	243.7	28.2	119.6
5.	Bacillariophyceae No	316.5	26.0	110.3
6.	Euglenoida No	93.6	9.7	41.3
7.	Dinophyceae No	78.6	9.9	42.1
8.	Xanthophyceae No	23.9	4.3	18.1

Table 6
Diversity of zooplankton in selected beels (floodplain wetlands) of west Bengal

Zooplankton		
Copepod	Rotifer	Protozoa
Nauplii larvae (S,K)	*Asplanchna intaonedia* (S,K)	*Arcella discoides* (S,K)
Cyclops larvae (S,K)	*Brachionus caudatus* (S,K)	*Centropyxis aculeata* (S,K)
Cladocera	*Filinia longiseta* (S,K)	*Difflugia rubsence (S)*
Daphnia pulex (S,K)	*Keratella tropica* (S,K)	*Vorticella sp (S)*
Ceriodaphnia rigaudi (S,K)	*Lecane paxiana* (S,K)	
Moina brachiata (S,K)	*Monostylla closterocera* (S,K)	
Bosmina longirostris (S,K)	*Nathalca sp* (S,K)	
	Polyarthra sp (S,K)	
	Platysis sp (S,K)	
S = Saguna Floodplain wetland, K = Kole Floodplain wetland		

Table 7
Descriptive statistics of Zooplankton data of Saguna

Parameters	Mean	SE	SD
ZPNO	310.4	30.78	130.59
COPNO	103.6	11.83	50.17
ROTNO	105.2	12.27	52.04
CLADONO	53.3	6.97	29.59
PROTONO	32.8	4.56	29.00
MISCNO	15.8	1.95	8.29

Table 8
Descriptive statistics of Zooplankton data of Kole

Parameters	Mean	SE	SD
ZPNO	82.8	4.8	20.4
COPNO	31.9	3.3	14.2
ROTNO	19.7	1.1	4.9
CLADONO	17.1	1.6	7.0
PROTONO	9.1	0.9	3.7
MISCNO	5.0	0.6	2.4

Table 9
Diversity of periphyton in selected beels (floodplain lakes) of West Bengal, (2011-13)

Sl. No.	Myxophyceae	Sl. No.	Bacillariophyceae
1	*Anabaena spiroides* (S,K)	24	*Amphora coffeaeformis* (S,K)
2	*Aphanocapsa crassa* (S,K)	25	*Closterum parvulum* (S,K)
3	*Chroococcus minutus* (S,K)	26	*Cosmarium bengalicum* (S,K)
4	*Cylindrospermum muscicola* (S,K)	27	*Cyclotella meneginiyana* (S,K)
5	*Gleocapsa sp* (S,K)	28	*Cymbella lanceolata* (S,K)
6	*Gleotrichia echinulat* (S,K)	29	*Diatoma sp* (S,K)
7	*Lyngbya birgei* (S,K)	30	*Diploneis ovalis* (S,K)
8	*Merismopedia minima* (S,K)	31	*Gomphonema lanceolatum* (S,K)
9	*Nostoc linckia* (S,K)	32	*Gyrosigma acuminatum* (S,K)
10	*Oscillatoria rubescens* (S,K)	33	*Melosira granulate(SK)*
11	*Phormidium inundatum* (S,K)	34	*Navicula radiosa* (S,K)
	Chlorophyceae	35	*Nitzschia sigmoidia* (S,K)
12	*Chlorella vulgaris* (S,K)	36	*Pinnularia major* (S,K)
13	*Closteridium difficile* (S,K)	37	*Rhopalodia gibba* (S,K)
14	*Crucigenia quadrata* (S,K)	38	*Synedra capitata* (S,K)
15	*Mougeotia genuflexa* (S,K)	39	*Euglena viridis* (S,K)
16	*Oedogonium australe* (S,K)	40	*Phacus caudate* (S,K)
17	*Pediastrum duplex* (S,K)	41	*Tribonema vulgare* (S,K)
18	*Scenedesmus obliqumus* (S,K)	42	*Dinobryon divergens* (S,K)
19	*Spirogyra maxima* (S,K)		Animalcules
20	*Staurastrum orbiculare (S)*	43	*Difflugia humilis* (S,K)
21	*Tetraedon sp* (S,K)	44	*Actinospherium sp* (S,K)
22	*Ulothrix zonata* (S,K)	45	*Conochilus unicornis* (S,K)
23	*Zygnema sp* (S,K)	46	*Brachionus falcatus* (S,K)
		47	*Keratella tropica* (S,K)

S = Saguna Floodplain wetland, K = Kole Floodplain wetland

Table 10

Descriptive statistics of Periphyton data of Saguna

Parameters	Mean	SE	SD
PERITOT	434.4	37.88	160.70
PMYXONo	99.0	8.10	34.38
PCHLORONo	87.6	5.78	24.54
BACILNo1	139.1	14.61	61.98
PMISCNO	108.9	13.52	57.37

Table 11

Descriptive statistics of Periphyton data of Kole

Parameters	Mean	SE	SD
PERITOT	550.5	51.2	217.2
PMYXONo	189.4	23.3	98.8
PCHLORONo	106.5	6.3	26.7
BACILNo1	158.2	18.9	80.3
PMISCNO	96.4	5.7	24.0

Table 12
Diversity of macrophytes in selected beels (floodplain wetlands) of West Bengal

Macrophyte	Family	Occurance	%
Floating			50–60
Eichhornia crasipes (S,K)	Pontederiaceae	Floating	
Azolla pinnata(S,K)	Azollaceae	Floating	
Pistia stratiotes(S,K)	Araceae	Floating	
Lemna minor(S,K)	Lemnaceae	Floating	
Lemna perpusilla (S)	Lemnaceae	Floating	
Spirodella polyrhiza (S)	Lemnaceae	Floating	
Wolfia arhiza (S,K)	Lemnaceae	Floating	
Trapa natans (S,K)	Trapaceae	Floating	
Rooted floating		Floating	
Nymphoides indicum (S,K)	Gentianaceae	Floating	
Nelumbo nucifera (S,K)	Brassicaceae (Cruciferae)	Floating	
Nymphaea stellate (S,K)	Nymphaeaceae	Floating	
Nymphaea nauchali (S,K)	Nymphaeaceae	Floating	
Euryale ferox (S,K)	Nymphaeaceae	Floating	
Potamogeton nodosus (S,K)	Potamogetonaceae	Floating	
Myriophylum tuberculatum (S,K)	Haloragaceae	Floating	
Aponogeton natans (S,K)	Aponogetonaceae	Floating	
Submerged			15–20
Hydrilla verticillata (S,K)	Hydrocharitaceae	Submerged	
Ceratophyllum demersum (S,K)	Ceratophyllaceae	Submerged	
Vallisneria spiralis (S,K)	Hydrocharitaceae	Submerged	
Potamogeton pectinatus (S,K)	Potamogetonaceae	Submerged	
Najas minor (S,K)	Hydrocharitaceae	Submerged	
S = Saguna Floodplain wetland, K = Kole Floodplain wetland			

Macrophyte	Family	Occurance	%
Chara vulgaris (S)	Characeae	Submerged	
Chara zeylanica (S,K)	Characeae	Submerged	
Chara nuda (S,K)	Characeae	Submerged	
Marginal (prostrate emergent)			10–15
Marselia quadrifolia (S,K)	Marseliaceae	Marginal(prostrate emergent)	
Marselia minuta (S)	Marseliaceae	Marginal(prostrate emergent)	
Ipomoea aquatic (S,K)	Convolvulaceae	Marginal(prostrate emergent)	
Enhydra fuctuans(S)	Compositae	Marginal(prostrate emergent)	
Marginal (erect element)			1–5
Acorus calamus (S)	Acoraceae	Marginal (erect element)	
Colocasia esculenta (S,K)	Araceae	Marginal (erect element)	
Cyperus difformis (S,K)	Cyperaceae	Marginal (erect element)	
Cyperus procerus (S,K)	Cyperaceae	Marginal (erect element)	
Limnophyla indica(S,K)	Scrophulariaceae	Marginal (erect element)	
S = Saguna Floodplain wetland, K = Kole Floodplain wetland			

Table 13
Diversity of Macrobenthic Invertebrate in selected floodplain wetlands of west Bengal

Sl. No.	Gastropods	Sl. No.	Bivalve
1.	*Planorbis compressus (S,K)*	16	*Aelosoma bengalensis(S,K)*
2.	*Vivipora bengalenis (S,K)*	17	*Nais simplex(S,K)*
3.	*Pila globosa (S,K)*	18.	*Nais pectinata (S)*
4.	*Bellamya bengalensis(S,K)*	19	*Limnodrilus hoffmeisteri(S,K)*
5.	*Digniostemma pulchella (S,K)*	20	*Tubifex tubifex (S,K)*
6.	*Lymnea acuminate (S,K)*	21	*Chaetogastor orientalis (S,K)*
7.	*Indoplanorbis exustus (S,K)*		Chironomid
8.	*Gobia orcula(S,K)*	22	*Chironomus sp (S,K)*
9.	*Orbicular striatella(S,K)*		Miscellaneous organism
10.	*Gyraulus convexiusculus(S,K)*	23	*Hellobdella triserialis (S)*
11.	*Thiara acuminate(S)*	24	*Nymphs of dragon fly(S,K)*
	Bivalve	25	*Damsel fly (S,K)*
12.	*Lamellidens marginalis (S)*	26	*Stone fly (S,K)*
13	*Unio tumidus (S,K)*	27	*May fly (S,K)*
14.	*Parreysia fevidens-plagiasoma (S,K)*	28	*Eeucypris affinis (S,K)*
15.	*Parreysia radiatula caerulea (S,K)*	29	*Stenocypris sp. (S,K)*
S = Saguna Floodplain wetland, K = Kole Floodplain wetland			

Table 14
Descriptive statistics of Benthos data of Saguna

Parameters	Mean	SE	SD
Benthos (Total No)	336.9	26.17	111.01
Gastropod No	290.3	27.43	116.39
Bivalve No	12.9	2.25	9.53
Oligochaete No	17.6	4.13	17.52
Chironomids No	10.2	2.69	11.40
Other No	5.9	0.86	3.67

Table 15
Descriptive statistics of Benthos data of Kole

Parameters	Mean	SE	SD
Benthos (Total No)	383.6	29.2	124.1
Gastropod No	317.1	28.9	122.8
Bivalve No	16.5	2.3	9.6
Oligochaete No	21.2	4.5	19.2
Chironomids No	15.3	3.8	16.1
Other No	13.5	1.2	4.9

Table 16
Descriptive statistics of Productivity data of Saguna

Parameters	Mean	SE	SD
Gross Primary Productivity	0.5	0.04	0.15
Net Primary Productivity	0.3	0.03	0.12
Assimilation efficiency	57.8	1.74	7.37
Respiration	28.1	1.52	6.43
Photosynthesis Respiration Ratio	0.0	0.00	0.00

Table 17
Descriptive statistics of Productivity data of Kole

Parameters	Mean	SE	SD
Gross Primary Productivity	0.6	0.0	0.2
Net Primary Productivity	0.4	0.0	0.1
Assimilation efficiency	60.9	2.3	9.8
Respiration	34.9	2.6	11.0
Photosynthesis Respiration Ratio	0.0	0.0	0.0

Declarations

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Tables

Table 1: Descriptive statistics of Water quality parameters data of Saguna

Parameters	Mean	SE	SD
Transparency (m)	1.9	0.06	0.27
Water coverage(%)	68.1	3.26	13.81
Macrophyte coverage (%)	5.0	0.67	2.85
Depth(m)	2.8	0.07	0.28
Temp (Air) °C	26.1	0.64	2.70
Temp (Water) °C	25.1	0.61	2.60
Water reaction(pH)	8.0	0.07	0.28
Specific conductivity (µS/cm)	263.7	8.35	35.41
Dissolved oxygen (ppm)	7.5	0.13	0.53
Free Carbon di Oxide (ppm)	1.1	0.21	0.90
Total Alkalinity (ppm)	1.3	0.97	4.12
Total Hardness (ppm)	105.3	3.20	13.57
Calcium (ppm)	39.7	0.93	3.93
Magnesium(ppm)	1.9	0.39	1.64
Chloride (ppm)	20.0	1.03	4.37
Nitrate – N (ppm)	98.4	11.95	50.71
Phosphate-phosphorus (ppm)	143.0	23.21	98.45
Silicate-silica (ppm)	7.1	0.52	2.19

Table 2: Descriptive statistics of water quality parameters of Kole

Parameters	Mean	SE	SD
Transparency (m)	1.2	0.1	0.3
Water coverage(%)	0.6	0.04	0.2
Macrophyte coverage (%)	0.4	0.03	0.1
Depth(m)	60.9	2.3	9.8
Temp (Air) °C	34.9	2.6	11.0
Temp (Water) °C	0.02	0.001	0.004
Water reaction(pH)	67.8	3.2	13.7
Specific conductivity (μS/cm)	16.2	1.2	5.0
Dissolved oxygen (ppm)	2.2	0.1	0.5
Free Carbon di Oxide (ppm)	27.5	1.1	4.6
Total Alkalinity (ppm)	26.6	1.0	4.4
Total Hardness (ppm)	7.9	0.1	0.2
Calcium (ppm)	472.3	11.0	46.5
Magnesium(ppm)	7.7	0.1	0.5
Chloride (ppm)	1.3	0.3	1.3
Nitrate – N (ppm)	145.2	2.5	10.5
Phosphate-phophorus (ppm)	149.6	2.4	10.3
Silicate-silica (ppm)	34.8	1.1	4.7

Table 3: Diversity of phytoplankton in selected beels (floodplain wetlands) of west Bengal

Myxophyceae	*Pandorina morum* (S,K)
Anabaena spiroides (S,K)	*Pediastrum duplex* (S,K)
Aphanocapsa roeseana (S,K)	*Scenedesmus obliqumus* (S,K)
Aphanothece pallida (S,K)	*Spirogyra maxima* (S,K)
Chroococcus minutus (S,K)	*Staurasterum orbiculare (S)*
Cylindrospermum sp (S,K)	*Stigoclonium sp* (S,K)
Gleocapsa sp (S,K)	*Tetraedon sp (SK)*
Gloeotrichia echinulat (S,K)	*Tetraspora gelatinosa (S)*
Lyngbya birgei (S,K)	*Ulothrix zonata* (S,K)
Merismopedia minima (S,K)	*Westella botryoides (K)*
Microcystis aeruginosa (S,K)	*Volvox areus* (S,K)
Nostoc linckia (S,K)	Bacillariophyceae
Oscillatoria rubescens (S,K)	*Amphora coffeaeformis* (S,K)
Phormidium inundatum (S,K)	Cyclotella *meneginiyana* (S,K)
Rivullaria aquatica (K)	*Cymbella lanceolata (S)*
Spirulina princeps (S,K)	*Eunotia pectinalis (S)*
Actinasrtum gracillinum (S,K)	*Fragillaria brevistriata (S)*
Eudorina elegans (S,K)	*Gomphonema lanceolatum* (S,K)
Ankistrodesmus falcatus (S,K)	*Gyrosigma acuminatum* (S,K)
Asterococcus limneticus (S,K)	*Melosira granulate* (S,K)
Characium augustum (K)	*Navicula radiosa* (S,K)
Chlorella vulgaris (S,K)	*Nitzschia sigmoidia* (S,K)
Chlorococcum infusionum (S)	*Pinnularia major* (S,K)
Cladophora sp (S,K)	*Rhopalodia gibba* (S,K)
Closterium parvulum (S,K)	*Surirella sp* (S,K)
Cosmerium bengalicum (S,K)	*Synedra capitata* (S,K)
Crucigenia quadrata (S,K)	Euglenophyceae
Dictyosphaerium pulchellum (S)	*Euglena viridis (S)*
Euastrum spinulosum (S,K)	*Phacus caudate* (S,K)

Hydrodiction idium (S,K)	*Dinophyceae*
Micrasterius agardh (S,K)	*Ceratium macroceros (S)*
Mougeotia genuflexa (S,K)	Xanthophyceae
Oedogonium australe (S,K)	*Botrydium granulatum* (S,K)
Oocystis crassa (S)	*Tribonema vulgare (K)*

S=Saguna Floodplain wetland, K= Kole Floodplain wetland

Table 4: Descriptive statistics of Phytoplankton data of Saguna

Sl. No.	Parameters	Mean	SE	SD
1.	Total Plankton NO	1849.6	92.36	391.85
2.	Phytoplankton No	1543.2	75.90	322.01
3.	Myxophyceae No	404.5	28.23	119.75
4.	Chlorophyceae No	355.1	44.29	187.89
5.	Bacillariophyceae No	529.8	20.22	85.80
6.	Euglenoida No	131.4	12.91	54.78
7.	Dinophyceae No	83.6	9.64	40.88
8.	Xanthophyceae No	38.8	5.67	24.04

Table 5: Descriptive statistics of Phytoplankton data of Kole

Sl. No.	Parameters	Mean	SE	SD
1.	Total Plankton NO	1111.8	56.4	239.3
2.	Phytoplankton No	1052.0	60.4	256.1
3.	Myxophyceae No	295.7	23.5	99.8
4.	Chlorophyceae No	243.7	28.2	119.6
5.	Bacillariophyceae No	316.5	26.0	110.3
6.	Euglenoida No	93.6	9.7	41.3
7.	Dinophyceae No	78.6	9.9	42.1
8.	Xanthophyceae No	23.9	4.3	18.1

Table 6: Diversity of zooplankton in selected beels (floodplain wetlands) of west Bengal

Zooplankton		
Copepod	Rotifer	Protozoa
Nauplii larvae (S,K)	*Asplanchna intaonedia* (S,K)	*Arcella discoides* (S,K)
Cyclops larvae (S,K)	*Brachionus caudatus* (S,K)	*Centropyxis aculeata* (S,K)
Cladocera	*Filinia longiseta* (S,K)	*Difflugia rubsence (S)*
Daphnia pulex (S,K)	*Keratella tropica* (S,K)	*Vorticella sp (S)*
Ceriodaphnia rigaudi (S,K)	*Lecane paxiana* (S,K)	
Moina brachiata (S,K)	*Monostylla closterocera* (S,K)	
Bosmina longirostris (S,K)	*Nathalca sp* (S,K)	
	Polyarthra sp (S,K)	
	Platysis sp (S,K)	

S=Saguna Floodplain wetland, K= Kole Floodplain wetland

Table 7: Descriptive statistics of Zooplankton data of Saguna

Parameters	Mean	SE	SD
ZPNO	310.4	30.78	130.59
COPNO	103.6	11.83	50.17
ROTNO	105.2	12.27	52.04
CLADONO	53.3	6.97	29.59
PROTONO	32.8	4.56	29.00
MISCNO	15.8	1.95	8.29

Table 8: Descriptive statistics of Zooplankton data of Kole

Parameters	Mean	SE	SD
ZPNO	82.8	4.8	20.4
COPNO	31.9	3.3	14.2
ROTNO	19.7	1.1	4.9
CLADONO	17.1	1.6	7.0
PROTONO	9.1	0.9	3.7
MISCNO	5.0	0.6	2.4

Table 9: Diversity of periphyton in selected beels (floodplain lakes) of West Bengal, (2011-13)

Sl. No.	Myxophyceae	Sl. No.	*Bacillariophyceae*
1	*Anabaena spiroides* (S,K)	24	*Amphora coffeaeformis* (S,K)
2	*Aphanocapsa crassa* (S,K)	25	*Closterum parvulum* (S,K)
3	*Chroococcus minutus* (S,K)	26	*Cosmarium bengalicum* (S,K)
4	*Cylindrospermum muscicola* (S,K)	27	*Cyclotella meneginiyana* (S,K)
5	*Gleocapsa sp* (S,K)	28	*Cymbella lanceolata* (S,K)
6	*Gleotrichia echinulat* (S,K)	29	*Diatoma sp* (S,K)
7	*Lyngbya birgei* (S,K)	30	*Diploneis ovalis* (S,K)
8	*Merismopedia minima* (S,K)	31	*Gomphonema lanceolatum* (S,K)
9	*Nostoc linckia* (S,K)	32	*Gyrosigma acuminatum* (S,K)
10	*Oscillatoria rubescens* (S,K)	33	*Melosira granulate(SK)*
11	*Phormidium inundatum* (S,K)	34	*Navicula radiosa* (S,K)
	Chlorophyceae	35	*Nitzschia sigmoidia* (S,K)
12	*Chlorella vulgaris* (S,K)	36	*Pinnularia major* (S,K)
13	*Closteridium difficile* (S,K)	37	*Rhopalodia gibba* (S,K)
14	*Crucigenia quadrata* (S,K)	38	*Synedra capitata* (S,K)
15	*Mougeotia genuflexa* (S,K)	39	*Euglena viridis* (S,K)
16	*Oedogonium australe* (S,K)	40	*Phacus caudate* (S,K)
17	*Pediastrum duplex* (S,K)	41	*Tribonema vulgare* (S,K)
18	*Scenedesmus obliqumus* (S,K)	42	*Dinobryon divergens* (S,K)
19	*Spirogyra maxima* (S,K)		Animalcules
20	*Staurastrum orbiculare (S)*	43	*Difflugia humilis* (S,K)
21	*Tetraedon sp* (S,K)	44	*Actinospherium sp* (S,K)
22	*Ulothrix zonata* (S,K)	45	*Conochilus unicornis* (S,K)
23	*Zygnema sp* (S,K)	46	*Brachionus falcatus* (S,K)
		47	*Keratella tropica* (S,K)

S=Saguna Floodplain wetland, K= Kole Floodplain wetland

Table 10: Descriptive statistics of Periphyton data of Saguna

Parameters	Mean	SE	SD
PERITOT	434.4	37.88	160.70
PMYXONo	99.0	8.10	34.38
PCHLORONo	87.6	5.78	24.54
BACILNo1	139.1	14.61	61.98
PMISCNO	108.9	13.52	57.37

Table 11: Descriptive statistics of Periphyton data of Kole

Parameters	Mean	SE	SD
PERITOT	550.5	51.2	217.2
PMYXONo	189.4	23.3	98.8
PCHLORONo	106.5	6.3	26.7
BACILNo1	158.2	18.9	80.3
PMISCNO	96.4	5.7	24.0

Table 12: Diversity of macrophytes in selected beels (floodplain wetlands) of West Bengal

Macrophyte	Family	Occurance	%
Floating			50-60
Eichhornia crasipes (S,K)	Pontederiaceae	Floating	
Azolla pinnata(S,K)	Azollaceae	Floating	
Pistia stratiotes(S,K)	Araceae	Floating	
Lemna minor(S,K)	Lemnaceae	Floating	
Lemna perpusilla (S)	Lemnaceae	Floating	
Spirodella polyrhiza (S)	Lemnaceae	Floating	
Wolfia arhiza (S,K)	Lemnaceae	Floating	
Trapa natans (S,K)	Trapaceae	Floating	
Rooted floating		Floating	
Nymphoides indicum (S,K)	Gentianaceae	Floating	
Nelumbo nucifera (S,K)	Brassicaceae (Cruciferae)	Floating	
Nymphaea stellate (S,K)	Nymphaeaceae	Floating	
Nymphaea nauchali (S,K)	Nymphaeaceae	Floating	
Euryale ferox (S,K)	Nymphaeaceae	Floating	
Potamogeton nodosus (S,K)	Potamogetonaceae	Floating	
Myriophylum tuberculatum (S,K)	Haloragaceae	Floating	
Aponogeton natans (S,K)	Aponogetonaceae	Floating	
Submerged			15-20
Hydrilla verticillata (S,K)	Hydrocharitaceae	Submerged	
Ceratophyllum demersum (S,K)	Ceratophyllaceae	Submerged	
Vallisneria spiralis (S,K)	Hydrocharitaceae	Submerged	
Potamogeton pectinatus (S,K)	Potamogetonaceae	Submerged	
Najas minor (S,K)	Hydrocharitaceae	Submerged	
Chara vulgaris (S)	Characeae	Submerged	
Chara zeylanica (S,K)	Characeae	Submerged	
Chara nuda (S,K)	Characeae	Submerged	

Marginal (prostrate emergent)			10-15
Marselia quadrifolia (S,K)	Marseliaceae	Marginal(prostrate emergent)	
Marselia minuta (S)	Marseliaceae	Marginal(prostrate emergent)	
Ipomoea aquatic (S,K)	Convolvulaceae –	Marginal(prostrate emergent)	
Enhydra fuctuans(S)	Compositae	Marginal(prostrate emergent)	
Marginal (erect element)			1-5
Acorus calamus (S)	Acoraceae	Marginal (erect element)	
Colocasia esculenta (S,K)	Araceae	Marginal (erect element)	
Cyperus difformis (S,K)	Cyperaceae	Marginal (erect element)	
Cyperus procerus (S,K)	Cyperaceae	Marginal (erect element)	
Limnophyla indica(S,K)	Scrophulariaceae	Marginal (erect element)	

S=Saguna Floodplain wetland,   K= Kole Floodplain wetland

Table 13: Diversity of Macrobenthic Invertebrate in selected floodplain wetlands of west Bengal

Sl. No.	Gastropods	Sl. No.	Bivalve
1.	*Planorbis compressus (S,K)*	16	*Aelosoma bengalensis(S,K)*
2.	*Vivipora bengalenis (S,K)*	17	*Nais simplex(S,K)*
3.	*Pila globosa (S,K)*	18.	*Nais pectinata (S)*
4.	*Bellamya bengalensis(S,K)*	19	*Limnodrilus hoffmeisteri(S,K)*
5.	*Digniostemma pulchella (S,K)*	20	*Tubifex tubifex (S,K)*
6.	*Lymnea acuminate (S,K)*	21	*Chaetogastor orientalis (S,K)*
7.	*Indoplanorbis exustus (S,K)*		Chironomid
8.	*Gobia orcula(S,K)*	22	*Chironomus sp (S,K)*
9.	*Orbicular striatella(S,K)*		Miscellaneous organism
10.	*Gyraulus convexiusculus(S,K)*	23	*Hellobdella triserialis (S)*
11.	*Thiara acuminate(S)*	24	*Nymphs of dragon fly(S,K)*
	Bivalve	25	*Damsel fly (S,K)*
12.	*Lamellidens marginalis (S)*	26	*Stone fly (S,K)*
13	*Unio tumidus (S,K)*	27	*May fly (S,K)*
14.	*Parreysia fevidens-plagiasoma (S,K)*	28	*Eeucypris affinis (S,K)*
15.	*Parreysia radiatula caerulea (S,K)*	29	*Stenocypris sp. (S,K)*

S=Saguna Floodplain wetland, K= Kole Floodplain wetland

Table 14: Descriptive statistics of Benthos data of Saguna

Parameters	Mean	SE	SD
Benthos (Total No)	336.9	26.17	111.01
Gastropod No	290.3	27.43	116.39
Bivalve No	12.9	2.25	9.53
Oligochaete No	17.6	4.13	17.52
Chironomids No	10.2	2.69	11.40
Other No	5.9	0.86	3.67

Table 15: Descriptive statistics of Benthos data of Kole

Parameters	Mean	SE	SD
Benthos (Total No)	383.6	29.2	124.1
Gastropod No	317.1	28.9	122.8
Bivalve No	16.5	2.3	9.6
Oligochaete No	21.2	4.5	19.2
Chironomids No	15.3	3.8	16.1
Other No	13.5	1.2	4.9

Table 16: Descriptive statistics of Productivity data of Saguna

Parameters	Mean	SE	SD
Gross Primary Productivity	0.5	0.04	0.15
Net Primary Productivity	0.3	0.03	0.12
Assimilation efficiency	57.8	1.74	7.37
Respiration	28.1	1.52	6.43
Photosynthesis Respiration Ratio	0.0	0.00	0.00

Table 17: Descriptive statistics of Productivity data of Kole

Parameters	Mean	SE	SD
Gross Primary Productivity	0.6	0.0	0.2
Net Primary Productivity	0.4	0.0	0.1
Assimilation efficiency	60.9	2.3	9.8
Respiration	34.9	2.6	11.0
Photosynthesis Respiration Ratio	0.0	0.0	0.0

Figures

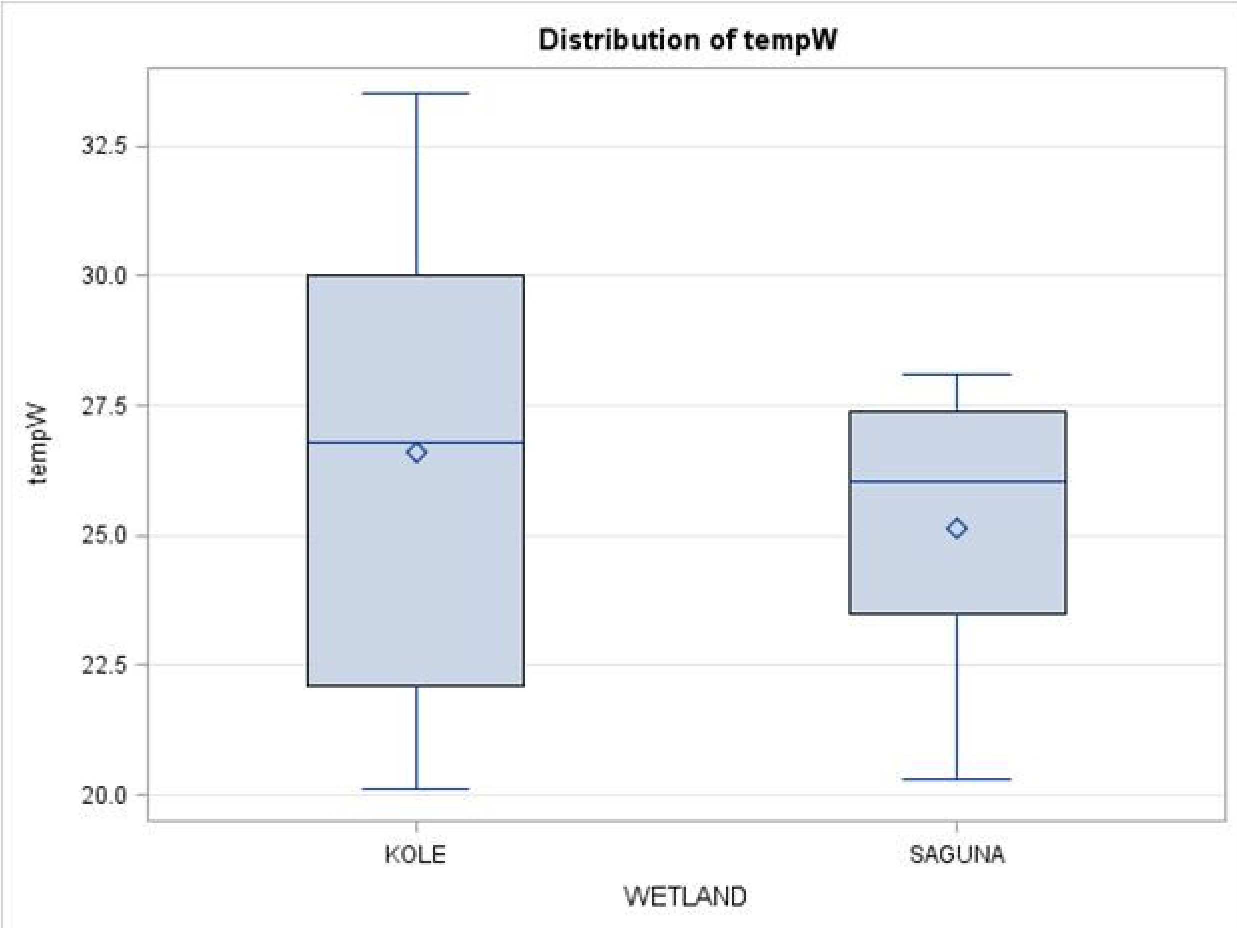
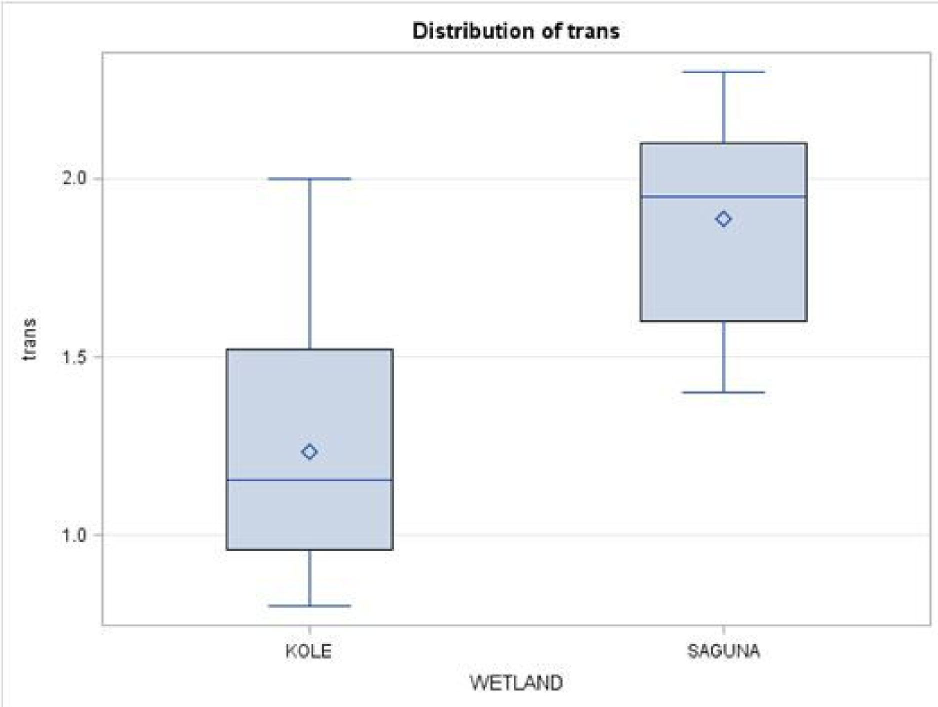


Figure 1

Boxplot for water temp of the selected floodplain wetlands



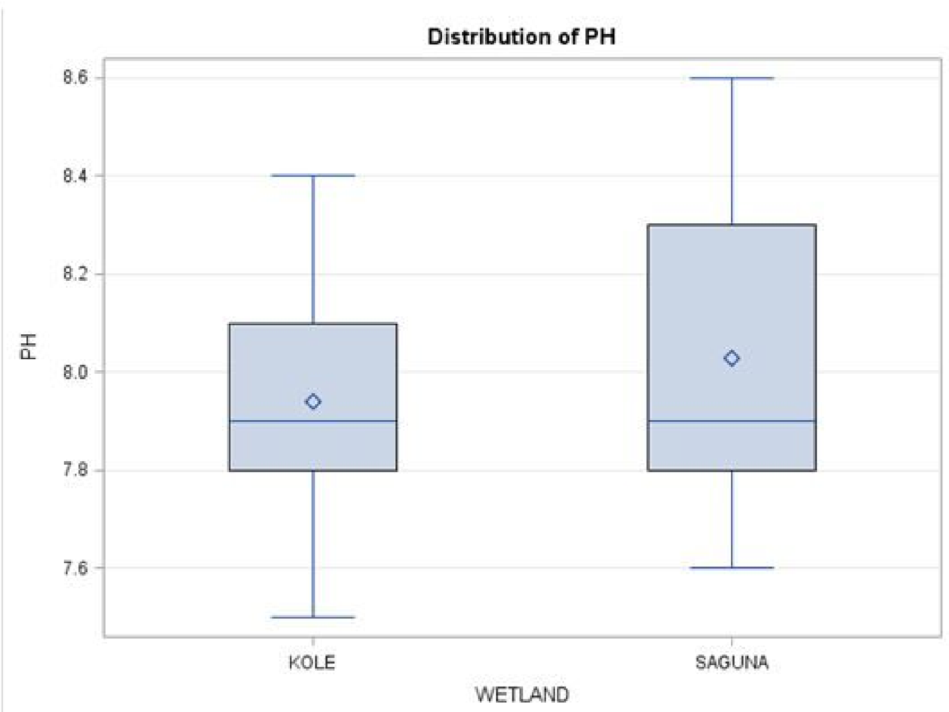
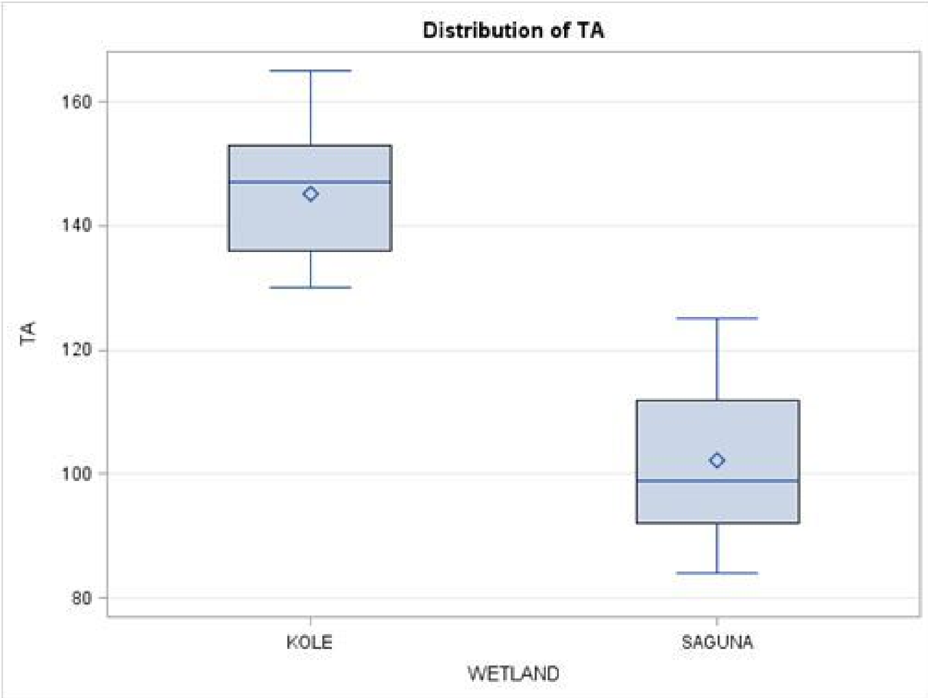


Figure 2

2a: Boxplot for transparency of the selected floodplain wetlands 2b: Boxplot for pH of the selected floodplain wetlands



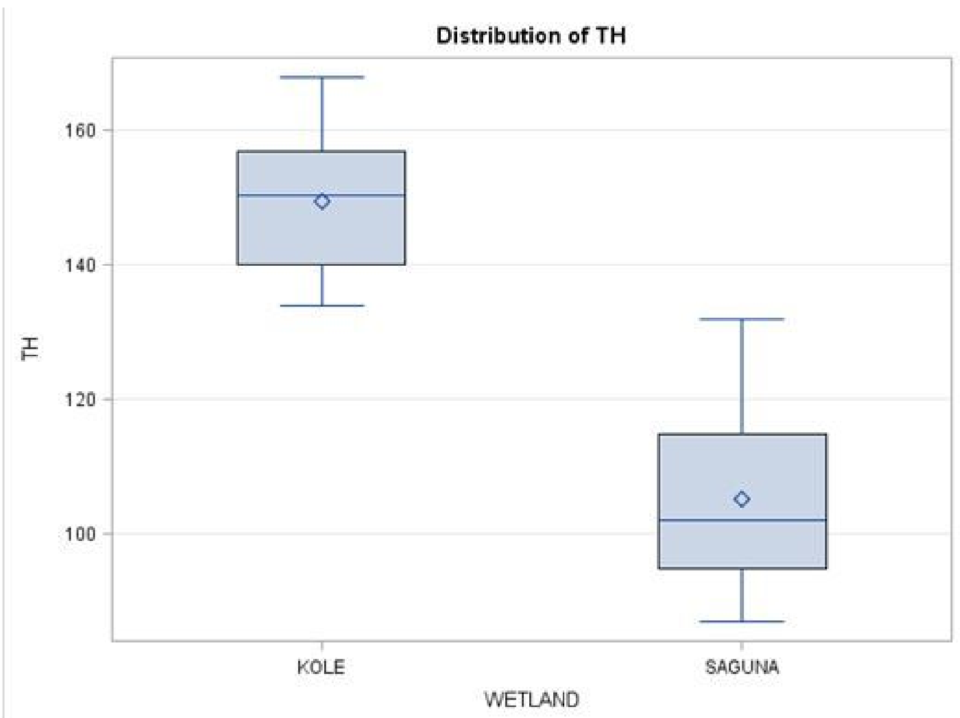
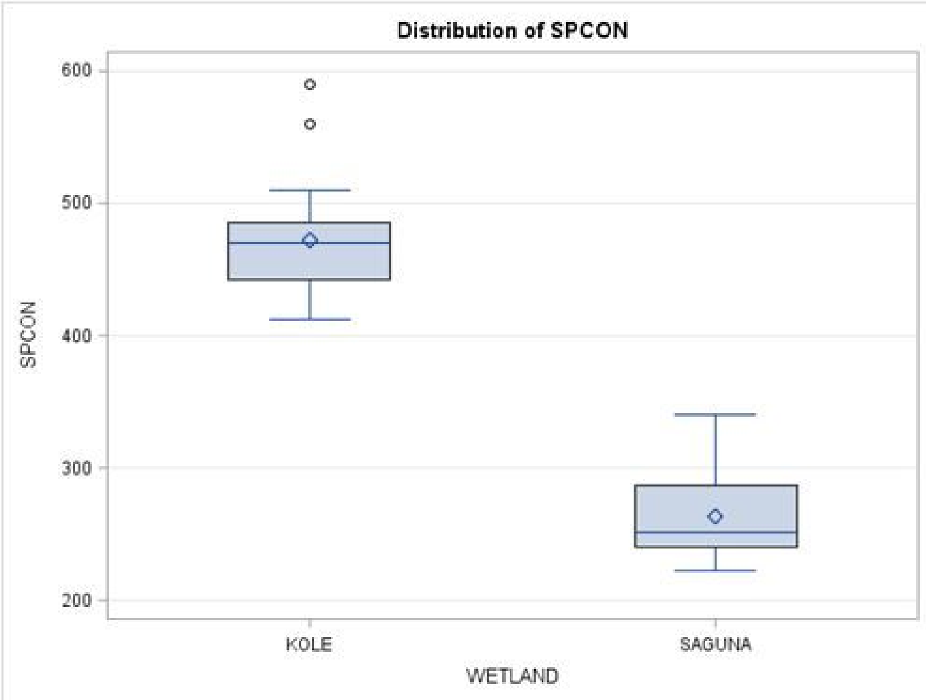


Figure 3

3a: Boxplot for Total alkalinity of the selected floodplain wetlands 3b: Boxplot for total hardness of the selected floodplain wetlands



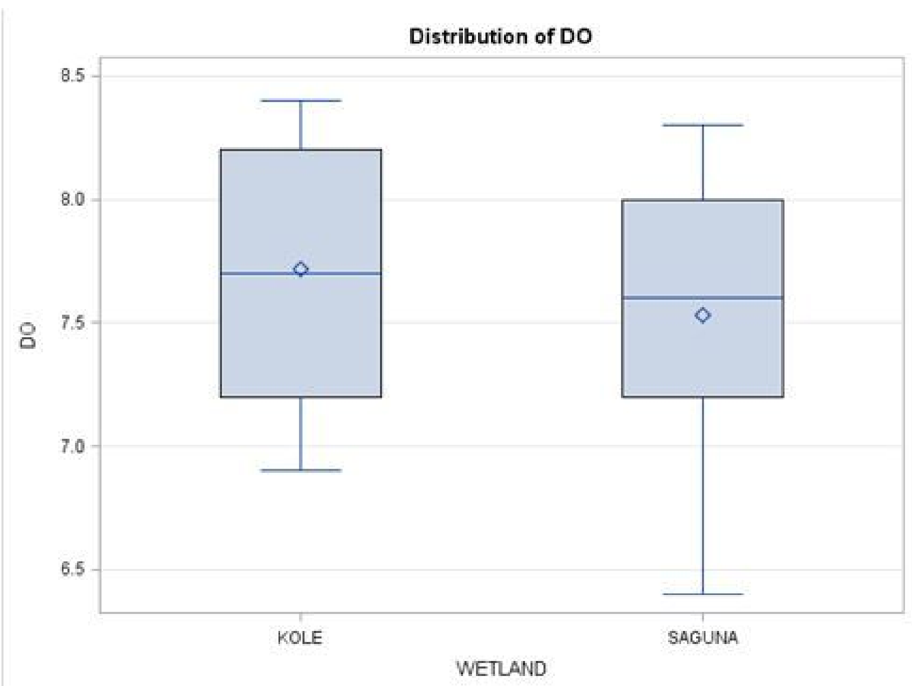
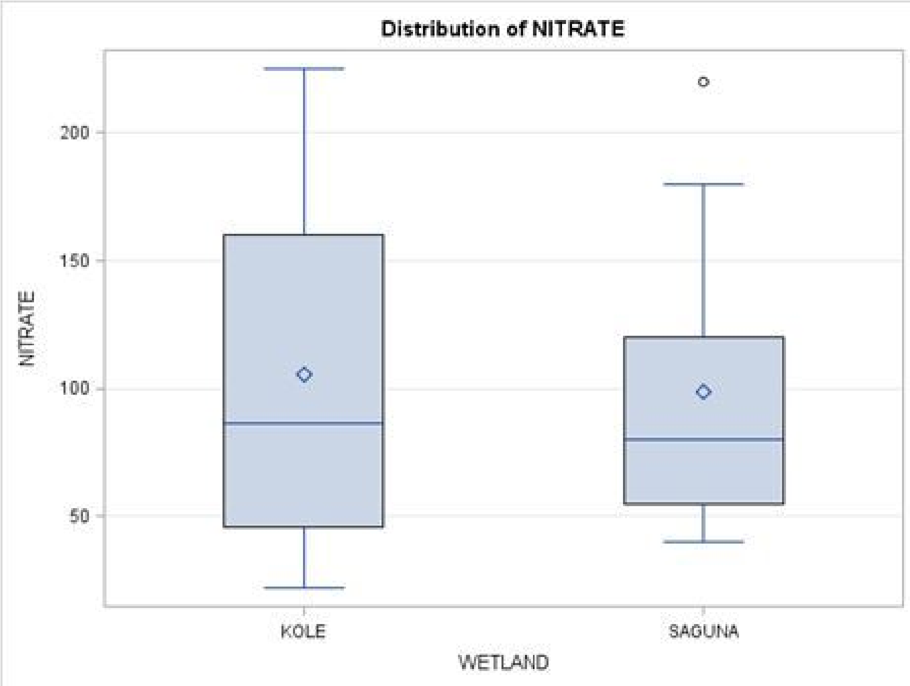


Figure 4

4a: Boxplot for Specific conductivity of the selected floodplain wetlands 4b: Boxplot for Dissolved oxygen of the selected floodplain wetlands



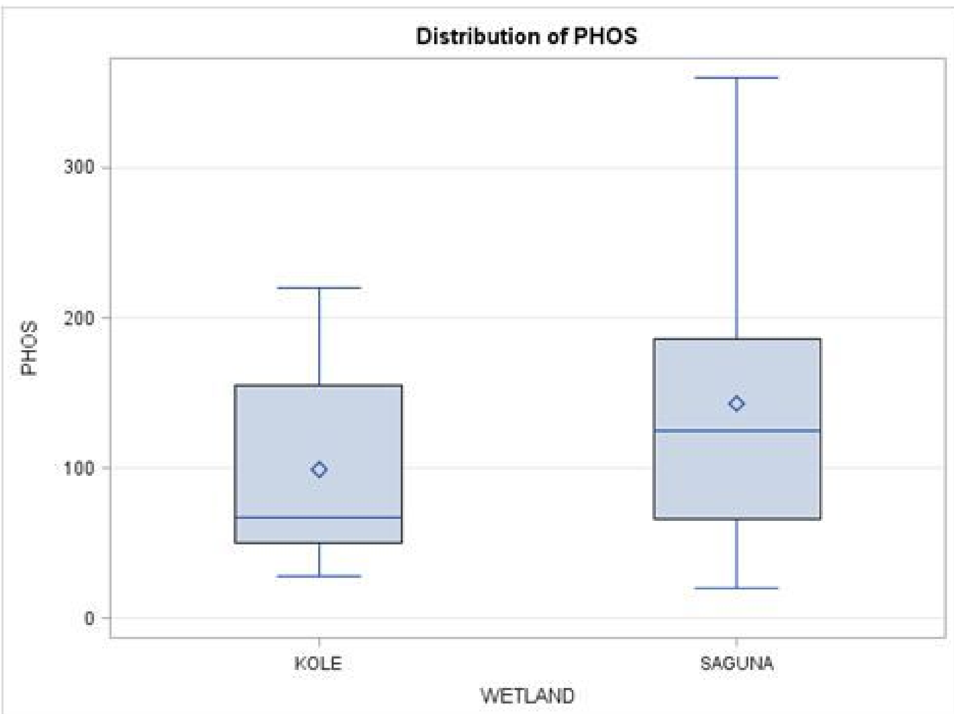
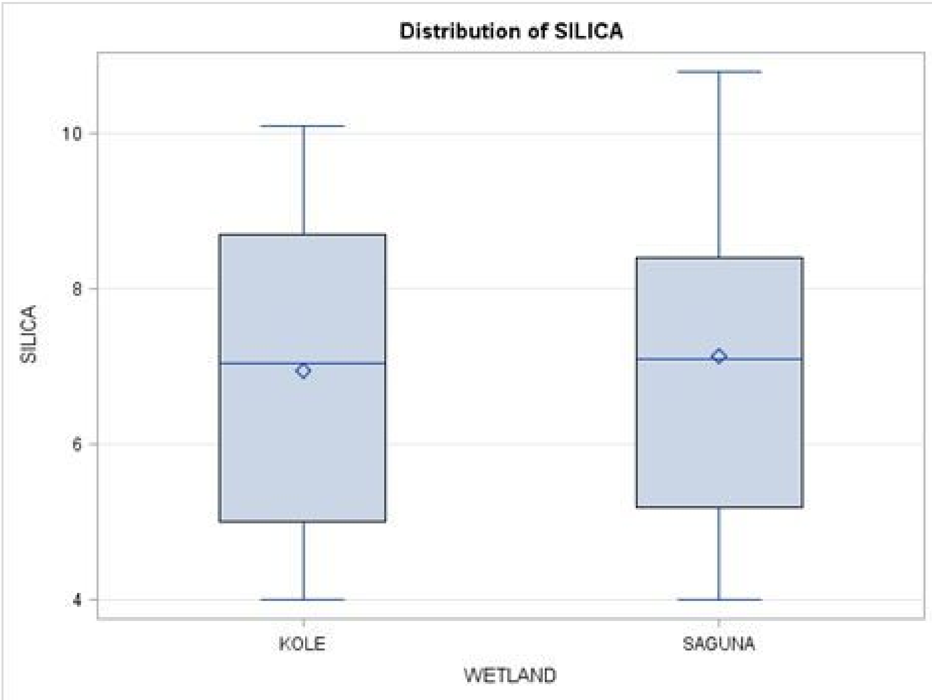


Figure 5

5a: Boxplot for Nitrate-Nitrogen of the selected floodplain wetlands 5b: Boxplot for phosphate-phosphorous of the selected floodplain wetlands



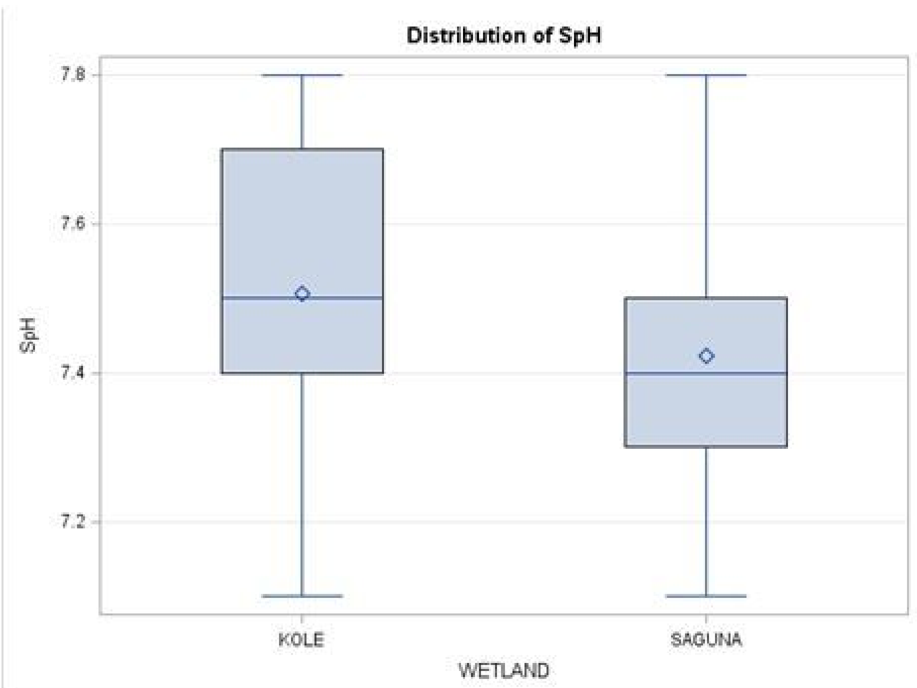
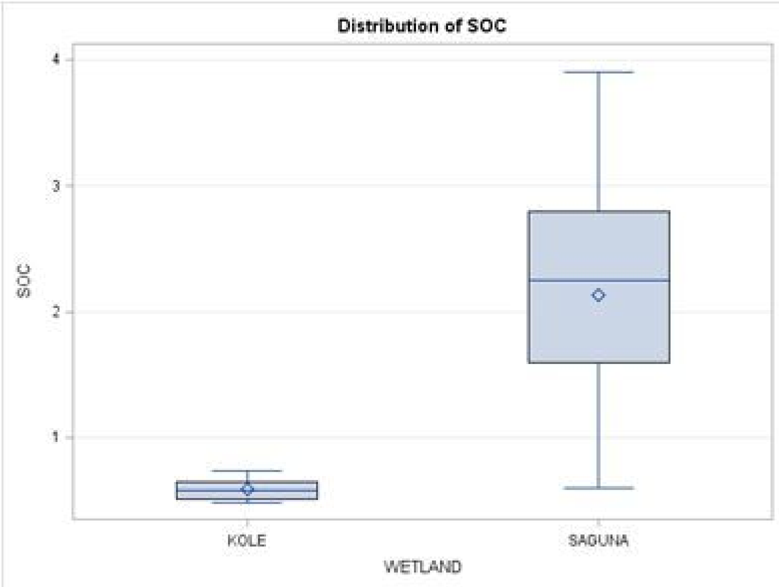


Figure 6

6a: Boxplot for silicate-Silica of the selected floodplain wetlands 6b: Boxplot for soil pH of the selected floodplain wetlands



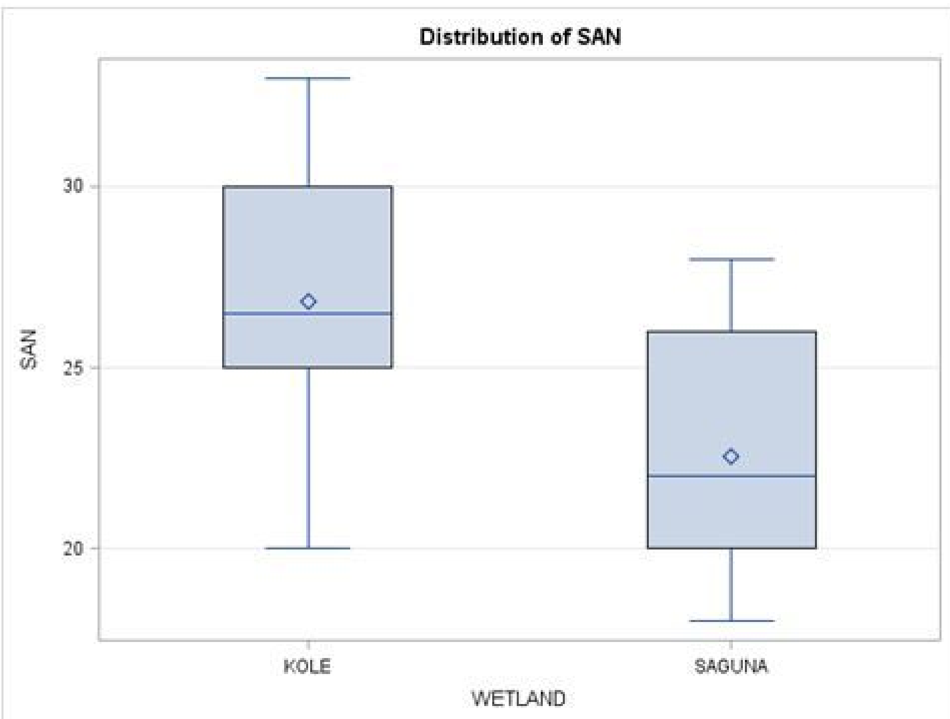
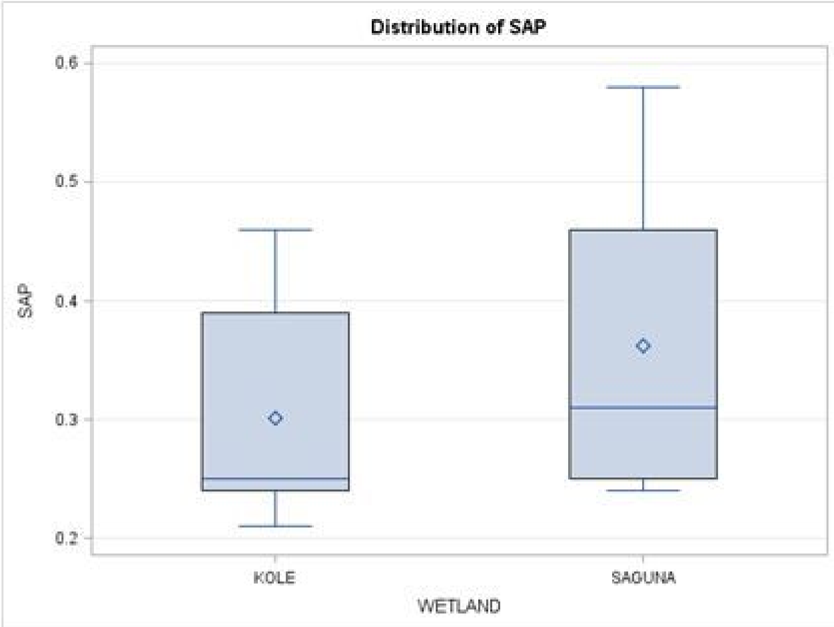


Figure 7

7a: Boxplot for organic carbon of soil of the selected floodplain wetlands 7b: Boxplot for Available nitrogen of the selected floodplain wetlands



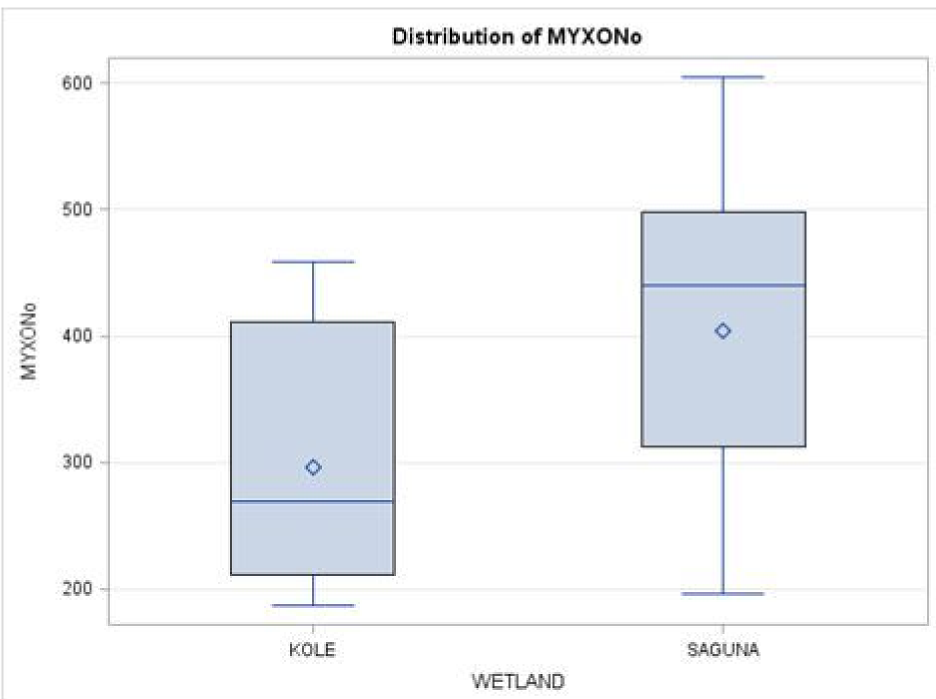
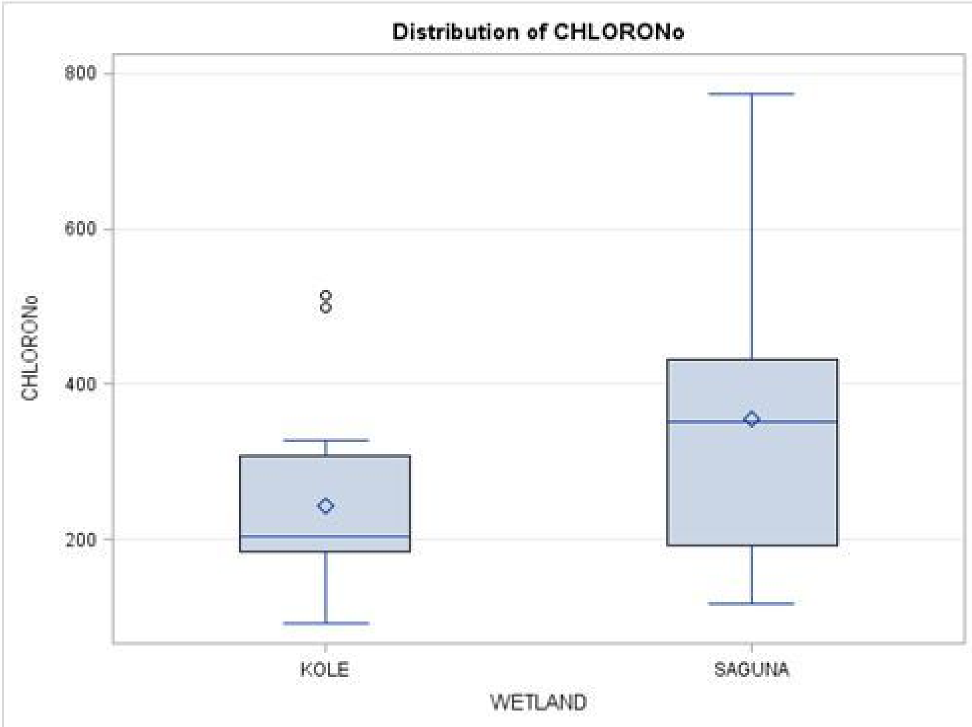


Figure 8

8a: Boxplot for available phosphorous of soil of the selected floodplain wetlands 8b: Boxplot for Myxophyceae of the selected floodplain wetlands



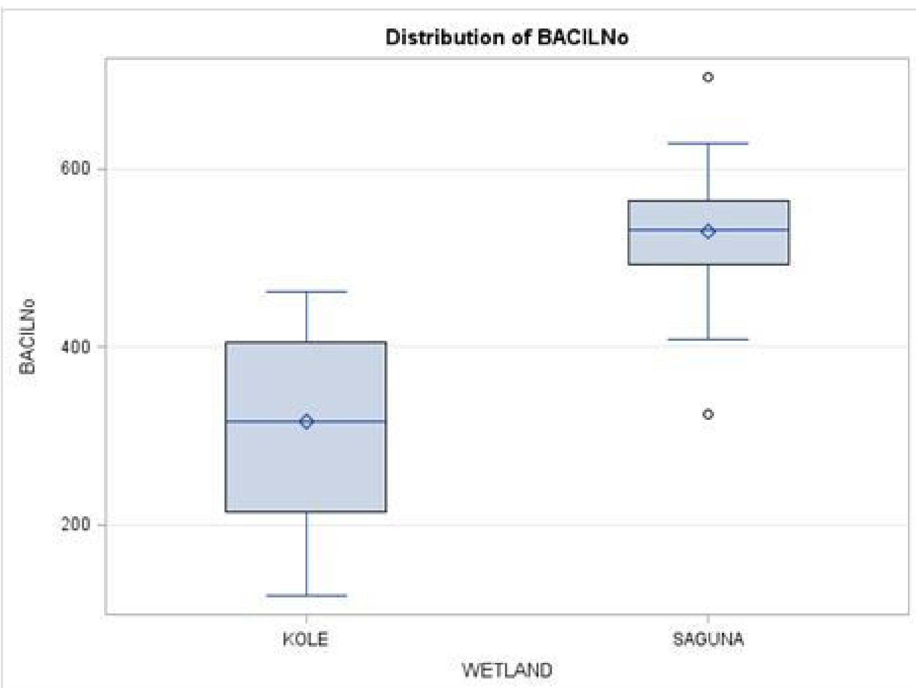
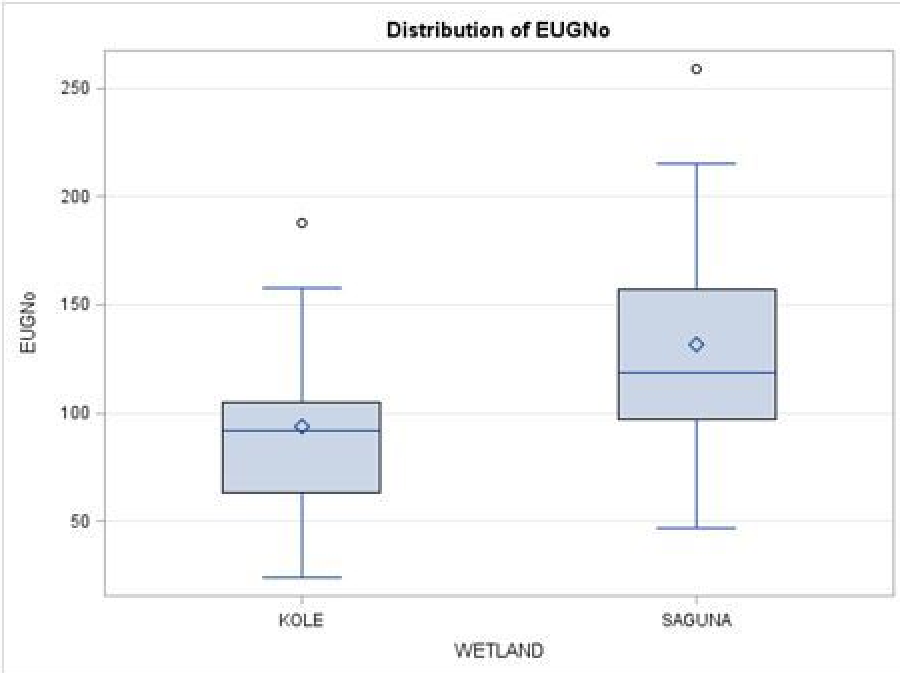


Figure 9

9a: Boxplot for Chlorophyceae of the selected floodplain wetlands 9b: Boxplot for Bacillariophyceae of the selected floodplain wetlands



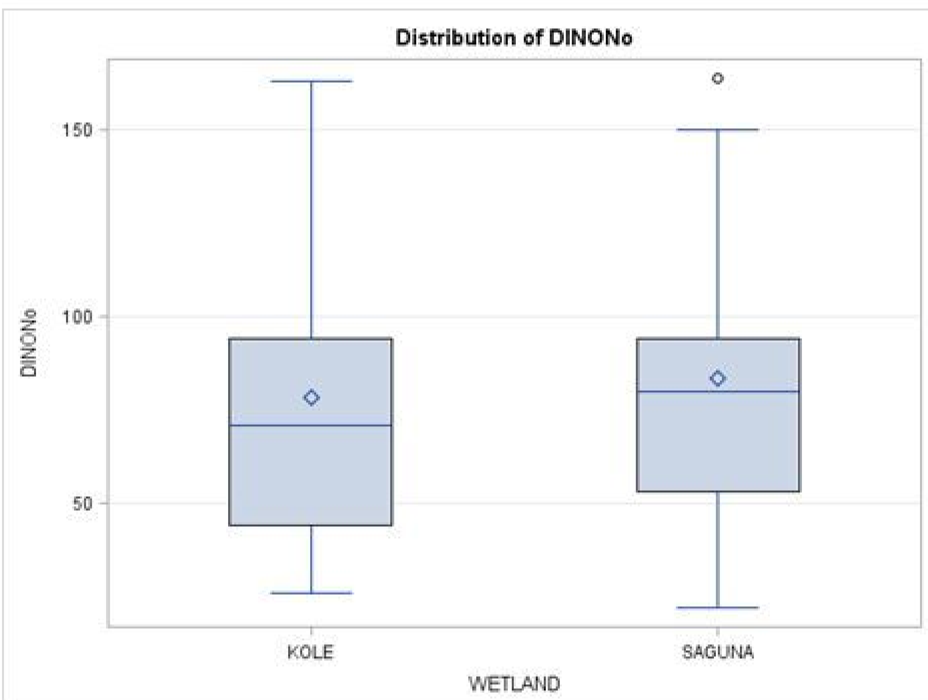


Figure 10

10a: Boxplot for Euglenoida of the selected floodplain wetlands 10b: Boxplot for Dinophyceae of the selected floodplain wetlands

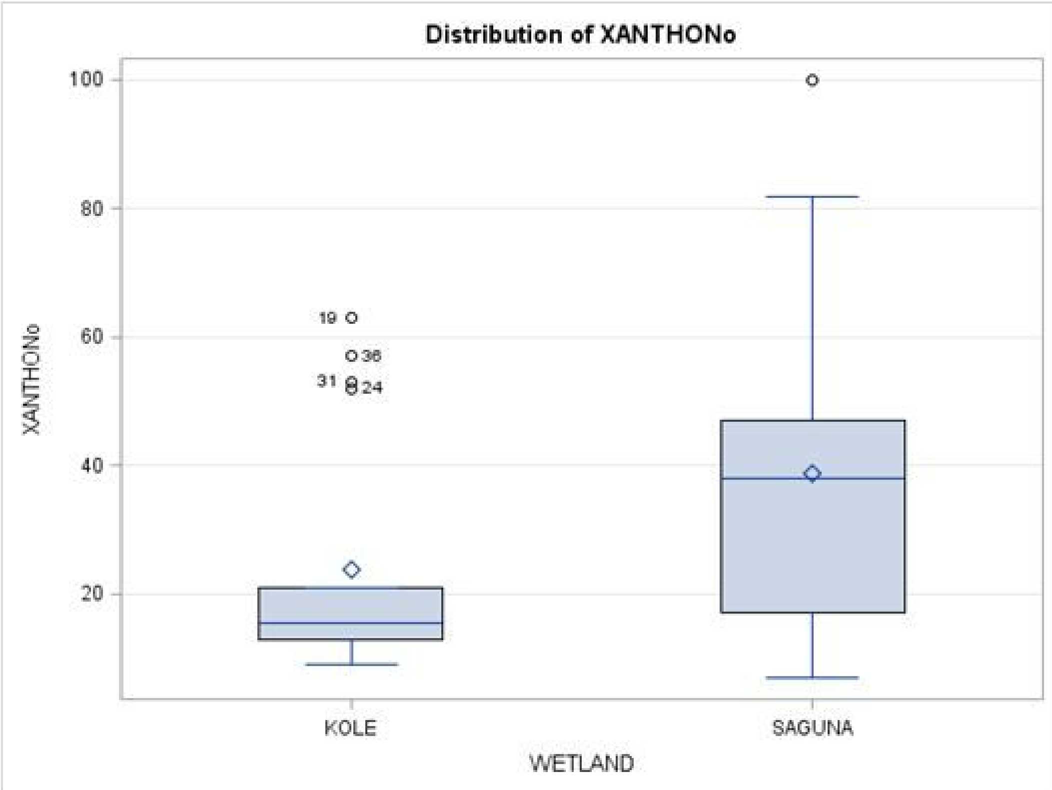
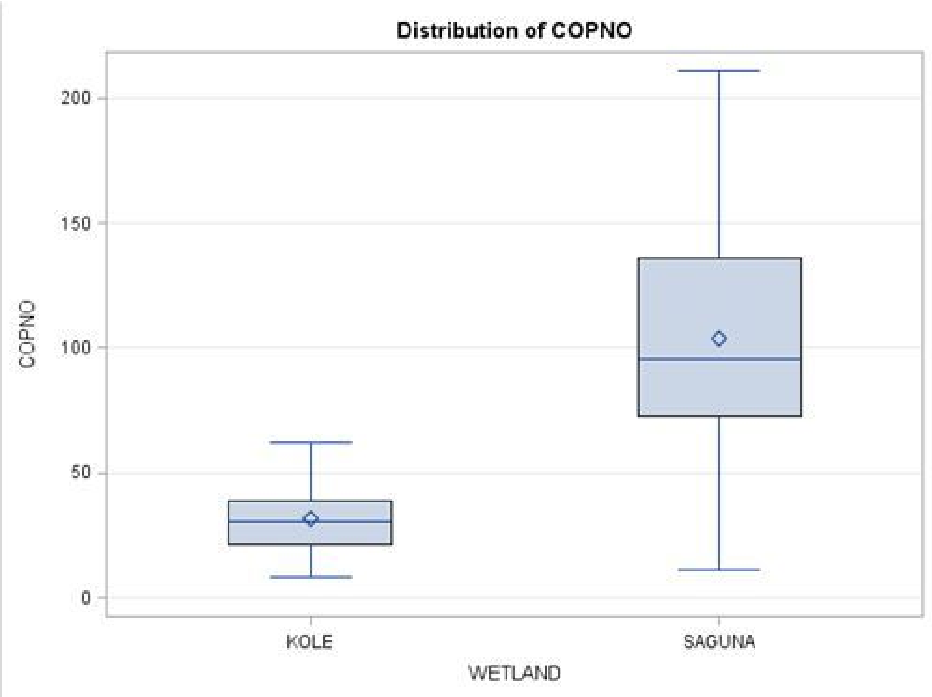


Figure 11

11a: Boxplot for Xanthophyceae of the selected floodplain wetlands



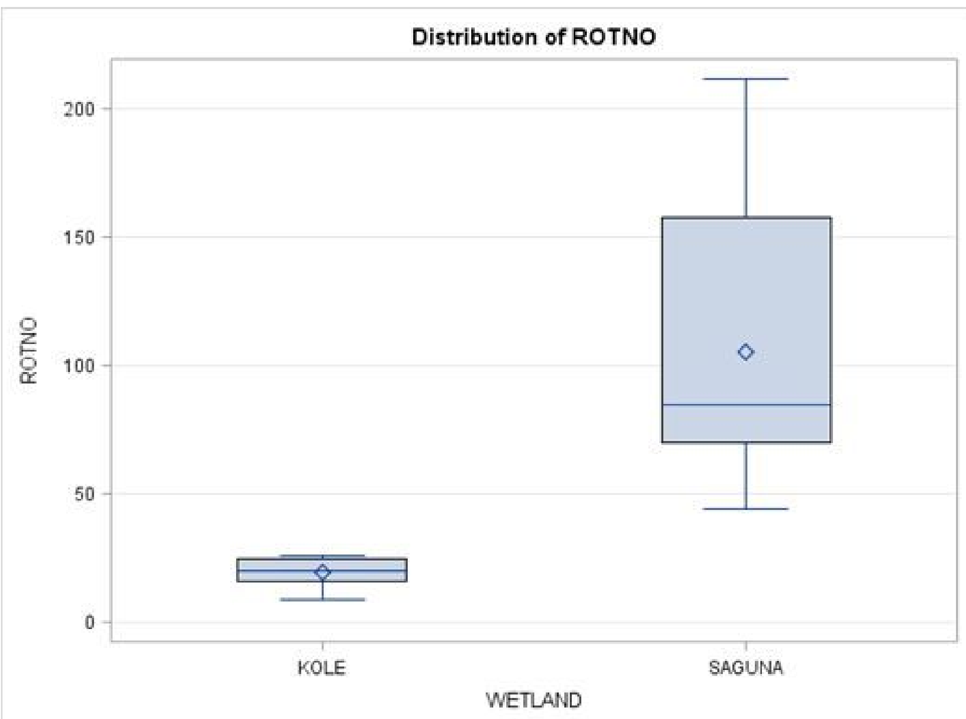
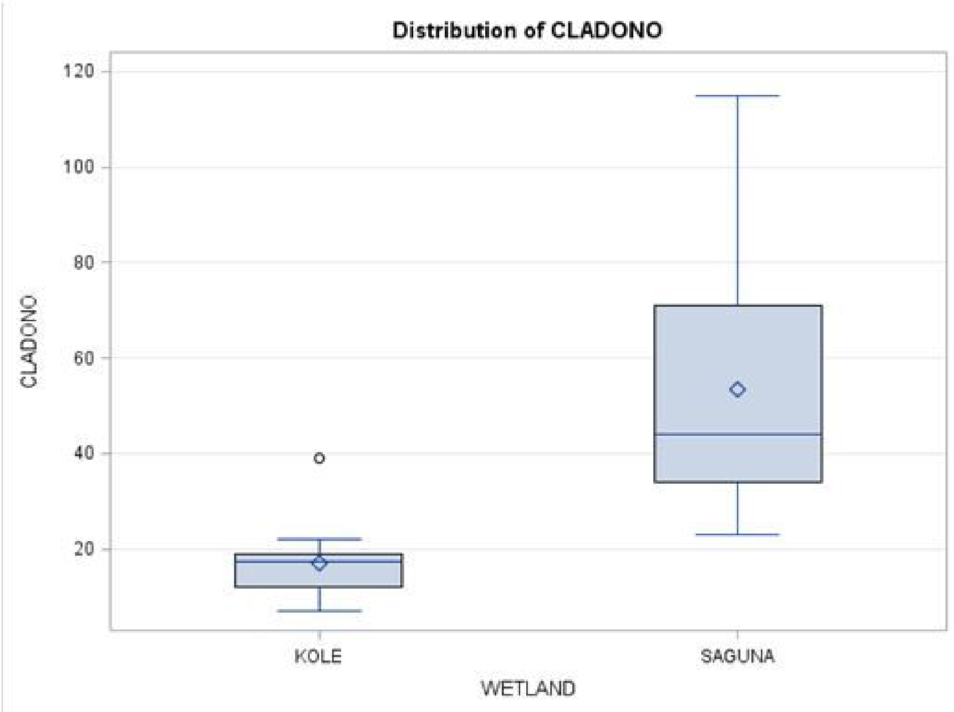


Figure 12

12a: Boxplot for copepoda of the selected floodplain wetlands 12b: Boxplot for Rotifers in the selected floodplain wetlands



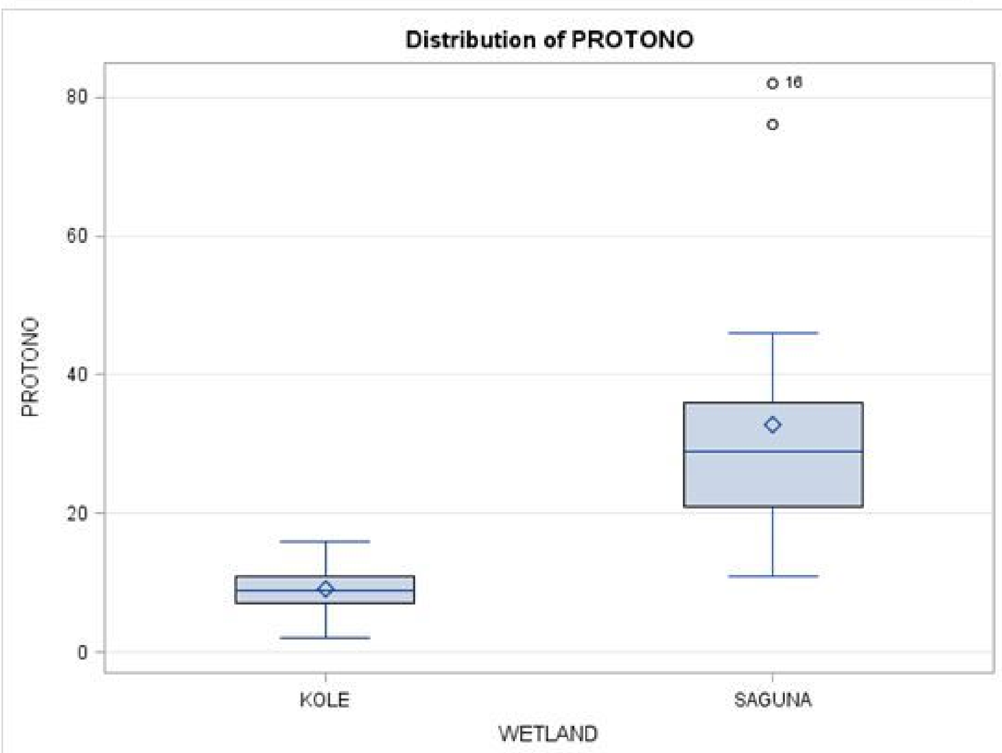


Figure 13

13a: Boxplot for Cladoceron of the selected floodplain wetlands 13b: Boxplot for protozoa of the selected floodplain wetlands

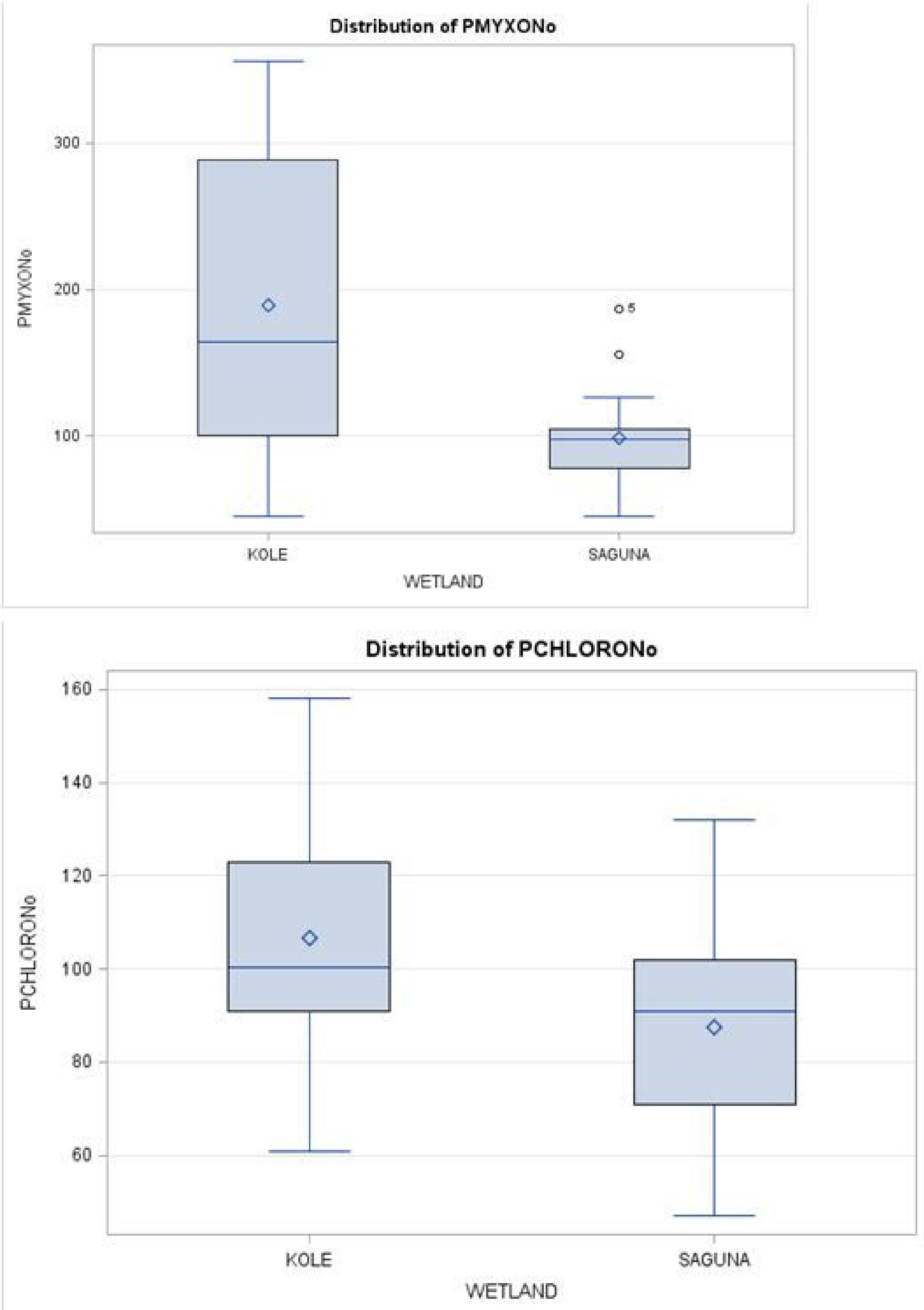


Figure 14

14a: Boxplot for Myxophyceae (Periphyton) of the selected floodplain wetlands 14b: Boxplot for Chlorophyceae (Periphyton) of the selected floodplain wetlands

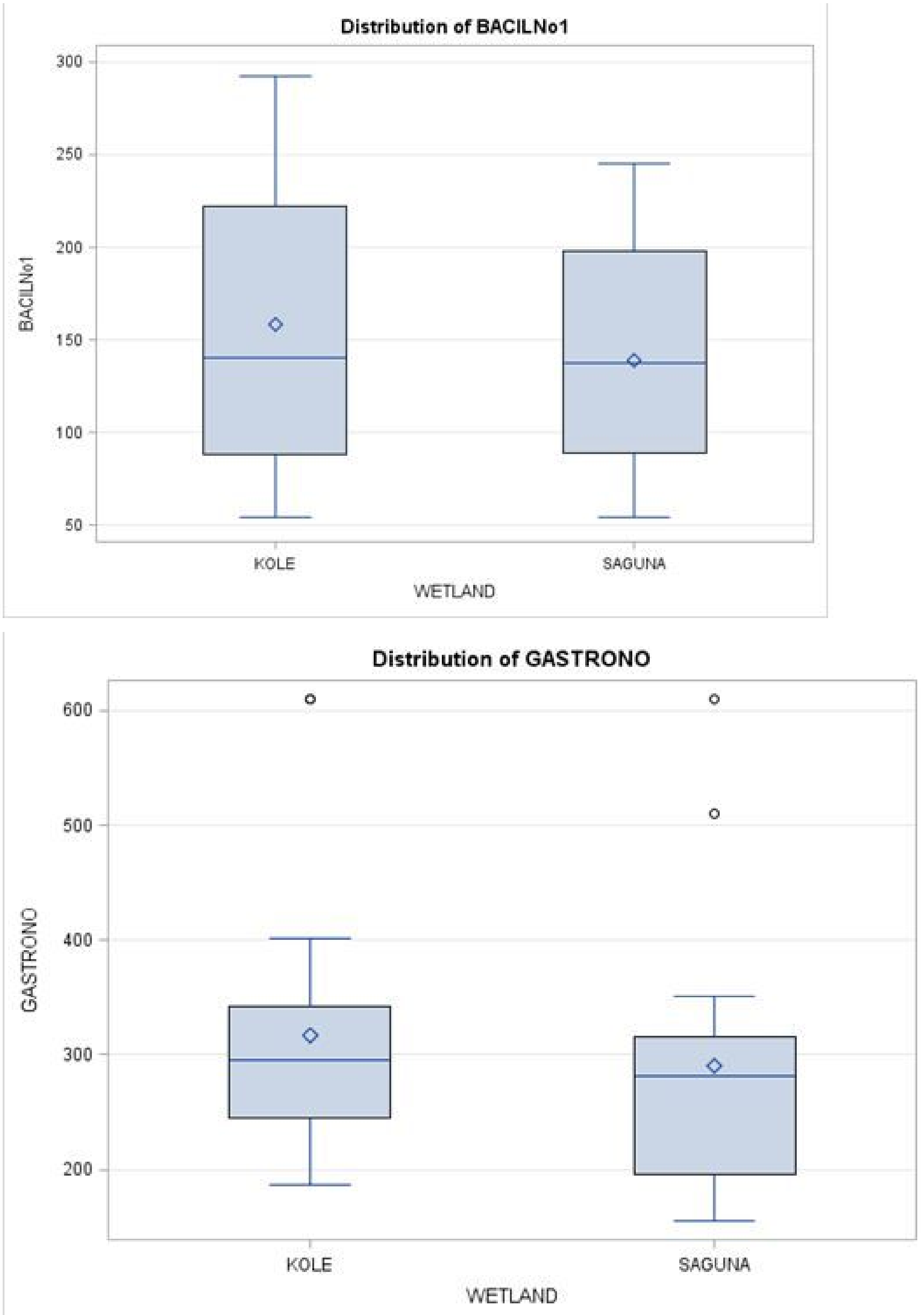
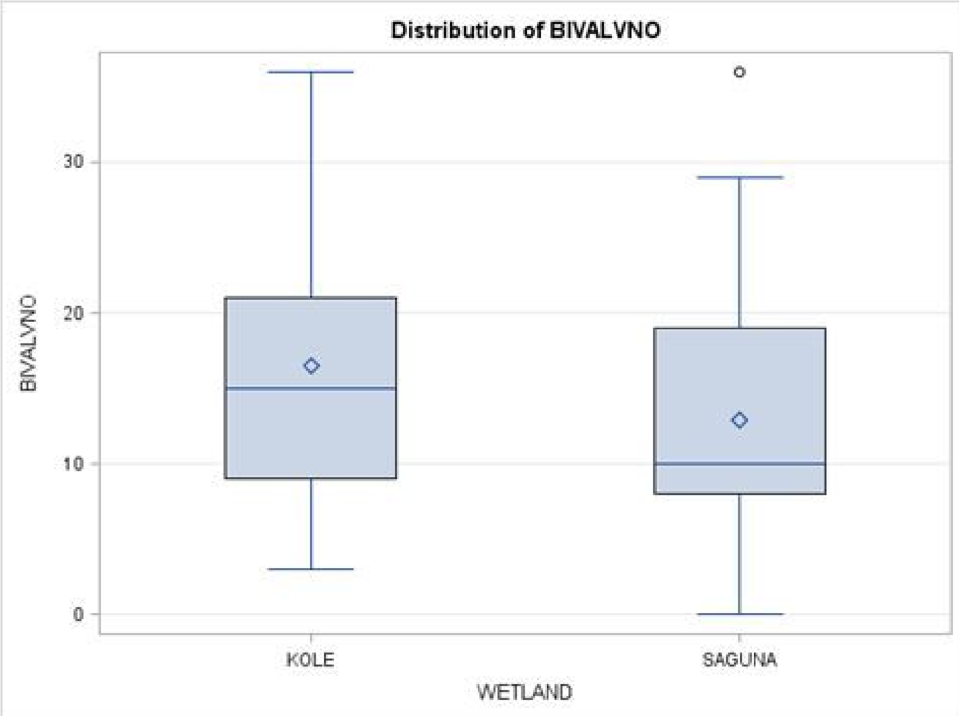


Figure 15

15a: Boxplot for Bacillariophyceae (Periphyton) of the selected floodplain wetlands 15b: Boxplot for Gastropod of the selected floodplain wetlands



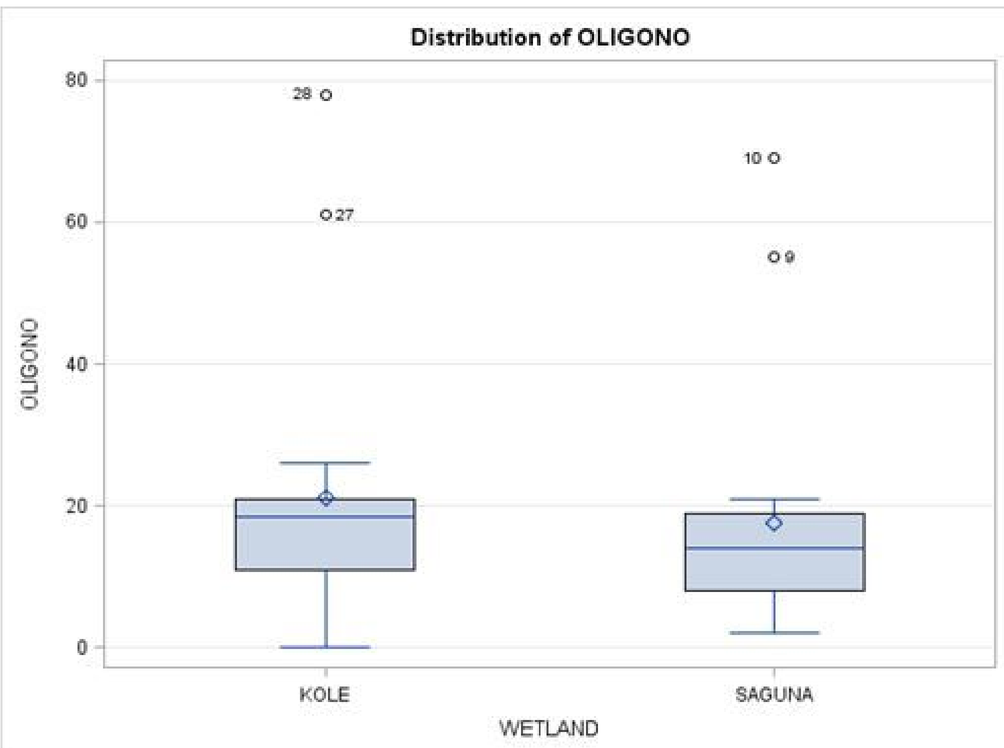
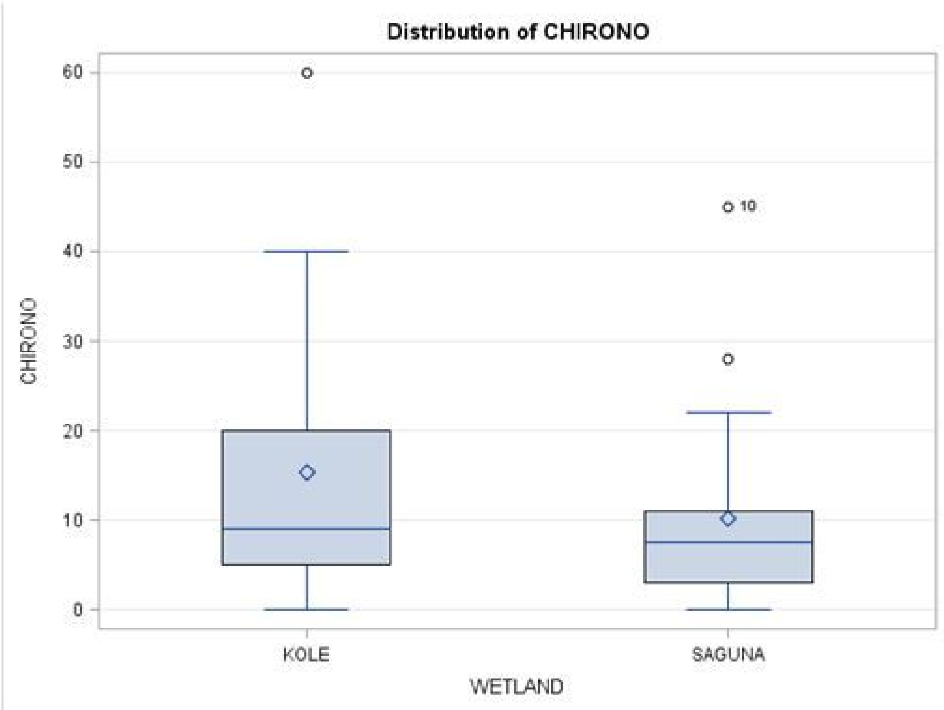


Figure 16

16ac: Boxplot for Bivalve of the selected floodplain wetlands 16b: Boxplot for Oligochaete (Benthos) of the selected floodplain wetlands



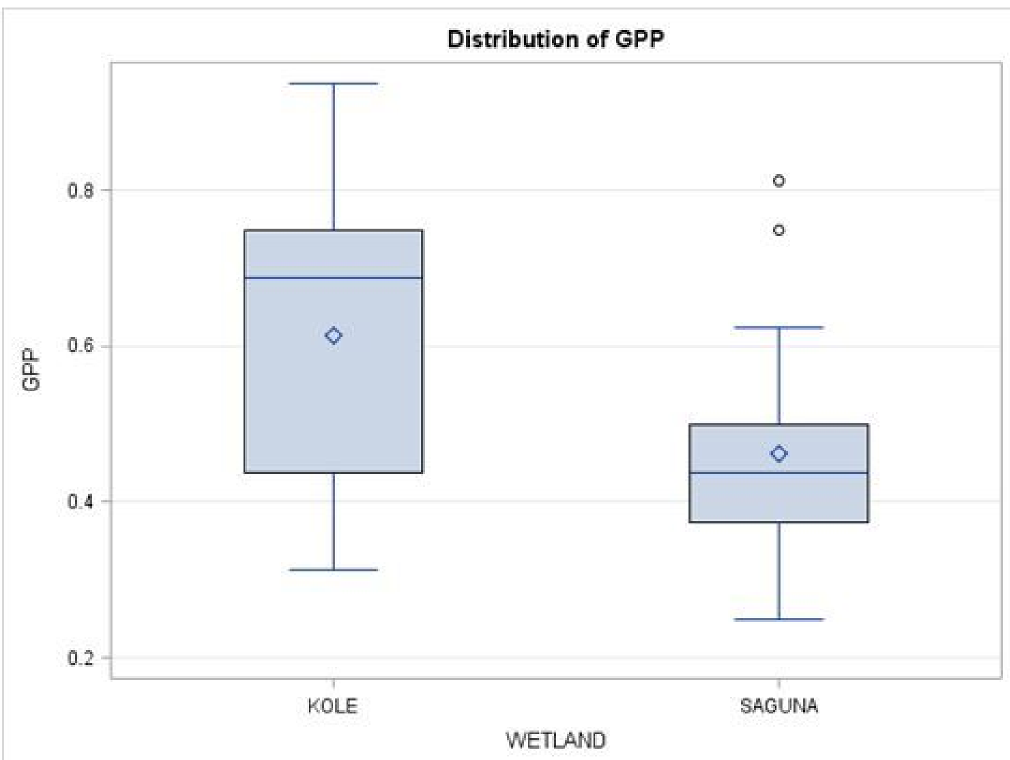


Figure 17

17a: Boxplot for Chironomids (Benthos) of the selected floodplain wetlands 17b: Boxplot for Gross Primary Productivity of the selected floodplain wetlands

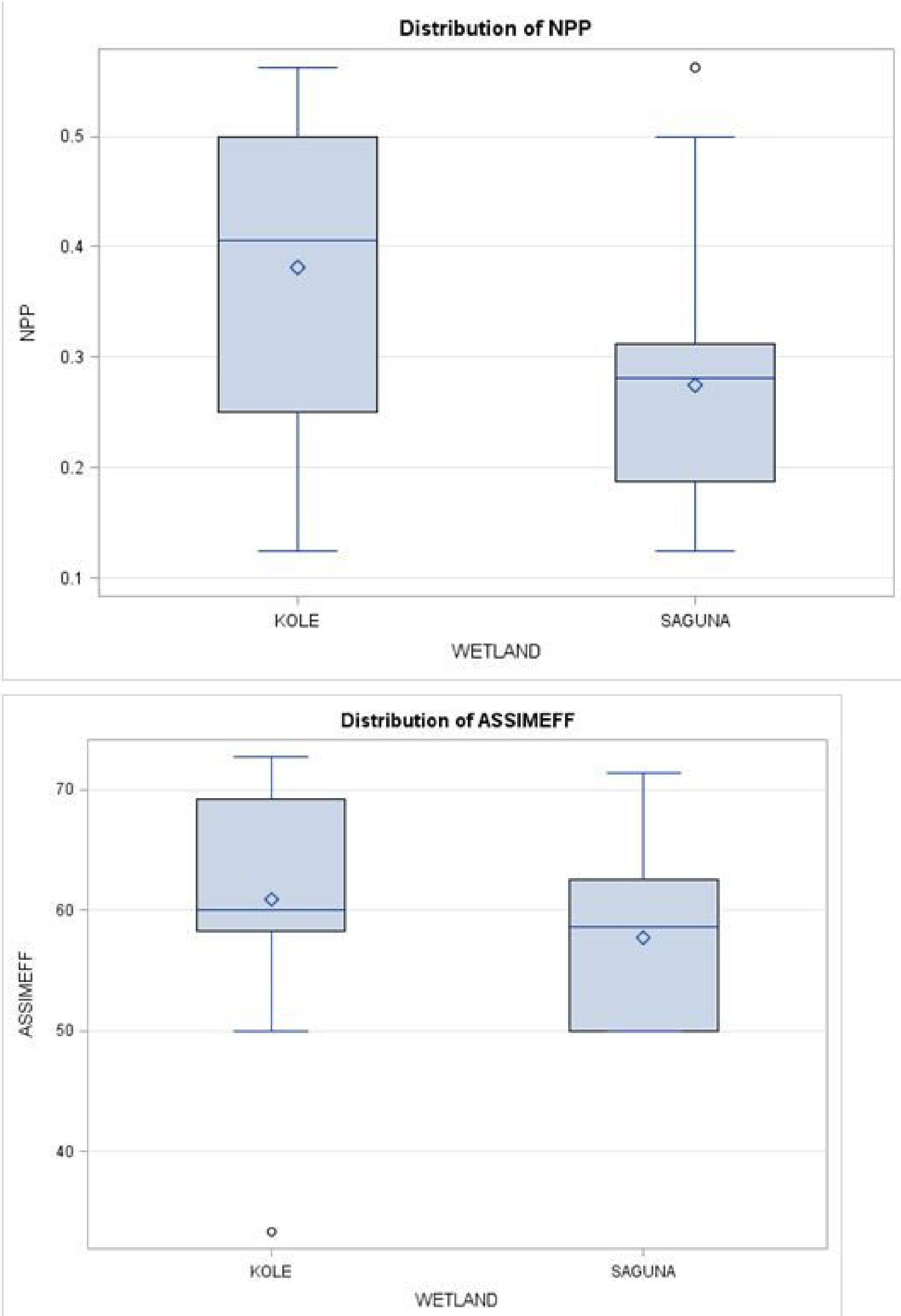


Figure 18

19a: Boxplot for NPP of the selected floodplain wetlands 19b: Boxplot for Assimilaion efficiency of the selected floodplain wetlands

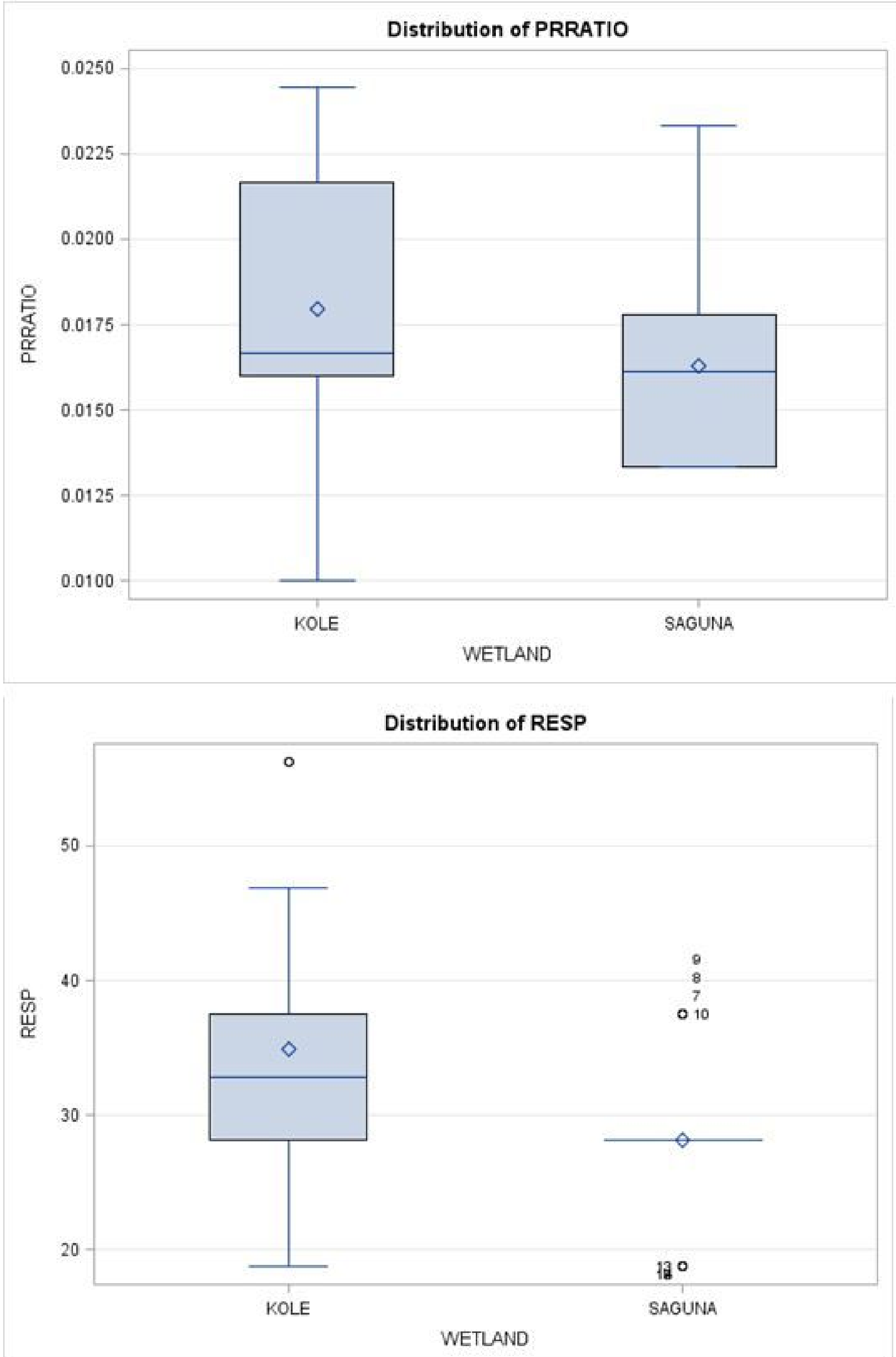


Figure 19

20a: Boxplot for prratio of the selected floodplain wetlands 20b: Boxplot for respiration of the selected floodplain wetlands