# Diversity, Abundance and Interspecific Correlation in Water-Birds at Anasagar Lake, Ajmer

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**Abstract:** *Anasagar Lake, situated in the north west of the Ajmer city is an important habitat for many resident and migratory birds. Various anthropogenic activities in most of its catchment area have turned the lake into severely polluted water body. The perceived beautification of the lake has further added to the decline of avifaunal diversity around the lake. Water-birds play a very significant role in ecosystems. During this study seasonal variation in the diversity and abundance of water-birds and the correlation between their occurrences and numbers of individuals were determined. Transect walk, point transect and direct observation methods were deployed for water birds' survey from April 2016 to March 2017. During the total 92 visits made at the study site, forty species of water-birds belonging to 16 families and 9 orders were recorded. Diversity variables selected for the study were Shannon-Weiner diversity index, species richness, Shannon's equitability/evenness, effective number of species, mean frequency of occurrence and mean abundance of water-bird species. For relationship between occurrences and between numbers of individuals of different species, Karl Pearson's coefficient of correlation and coefficient of determination i.e. R-squared was used. Seasonal Variation in the various diversity variables at Anasagar Lake shows that during winter season species richness and mean abundance of species were highest but values of Shannon Weiner diversity index, Shannon's equitability and effective number of species for winter season were the least. Exactly opposite happened during autumn. This suggests indirect relationship in these variables. Mean frequency of occurrence of species was highest during monsoon and lowest in summer. This indicates that during monsoons water-birds frequently come out in search of new foraging opportunities for their old foraging and resting platforms are submerged. Correlation analysis between numbers of individuals of water-bird species revealed that there were significant positive correlations among 9 pairs of water-bird species including birds like Black headed gull, Little grebe, Great white pelican, Great cormorant, Indian cormorant, Little cormorant, Eurasian coot, Eurasian spoonbill and Lesser flamingo. Highest correlation was observed between Cormorant species and between Black headed gull and Great white pelican. These observations can be attributed to the fact that these species prefer similar habitat variables. Significant correlations were found between occurrences of four pairs of water-bird species i.e. between Common teal, Black headed gull, Great white pelican and Pied kingfisher. The results with the taxonomic families corroborated with the correlations in individual species. Order wise correlation analysis brought out that orders Suliformes and Pelicaniformes are correlated in terms of numbers of individuals throughout the year. Presence of one species indicates the potential of habitat for other correlated species, which can be explored further. For conserving the avifaunal diversity at the scenic Anasagar Lake, it is also necessary to monitor the water quality and encourage the growth of favourable emergent vegetation around the lake. For this study, CSIR New Delhi must be thanked for their indispensable support in the form of Senior Research Fellowship.*

**Keywords:** Anasagar Lake, Water-birds, Correlation, Diversity, Abundance, Frequency of occurrence, Species richness.

## 1. Introduction

The tranquil Anasagar Lake, which is situated in the north west of the city (Latitude 26°47' N & Longitude 74°62' E) has been an important touristic and religious spot for people. While it was primarily created for the domestic water supply, it has now turned into a severely polluted water body. It is an important habitat for many resident and migratory birds. In most of its catchment area, various anthropogenic activities like washing, farming and religious activities take place. According to Pandey et al.(2013) disposal of raw sewage and municipal wastewater is one of factors contributing to deterioration of water quality of Anasagar Lake. Yet, no proper attention is being paid to biodiversity and ecology of this treasured and aesthetic lake. The perceived beautification of the lake which has been taking place recently has further added to the decline of avifaunal diversity around the lake. Attempts have been made from time to time to study the population of wetland birds but there is no systematic record of avifauna of Anasagar Lake to refer. The local bird watchers are very much discouraged by the increasing pollution around and inside the lake which is the cause of awful stinking of the lake. Limnological studies related to primary productivity by

Ranga and Koli (2011) have clearly indicated that the lake has been in eutrophic condition and is highly under pressure of city encroachment and urbanization.

Water-birds and their natural habitats play a very significant role in ecosystems. A systematic knowledge of their diversity and abundance can help in their conservation. Avifaunal diversity has been continually reducing because of ongoing habitat destruction and the anthropogenic activities (Grewal B, 2000). During this study seasonal variation in the diversity and abundance of water-birds and the correlation between their occurrences and numbers of individuals were determined. This information will be crucial in the ecological management and sustainable development of the lake.

## 2. Methods

The geographical area under study is Anasagar Lake, Ajmer which is almost 8 miles (13 km) in circumference. The water-spread area of lake varies between 97 and 182 ha, and the depth ranges from 1.9 m to 4.4 m. Its catchment area including Nagpahar hills and Taragarh hills covers 70.6 km$^2$. Capacity of lake is 2052 million liters (13 feet). The climate

of the region is semi-arid with strong seasonality of rainfall. The summer season (April - June) experiences high temperature (max. 44.0°C) and during winters (December - January) it goes down to as low as 5.0°C. Most of the annual precipitation (784.0 mm) is received from July to September (Sharma et al., 2008).

Transect walk, point transect and direct observation methods were deployed for water birds' survey which were regularly done from April 2016 to March 2017. The observations started at 6AM and lasted till 10 AM except winters when birds were observed till 11 AM. Water-birds were identified at their first detection using Nikon 7x35 CF binoculars and Nikon camera (26X zooming capacity). Identification of water-birds was done using field guides (Ali, 2012; Grimmett et al., 2011).

Diversity variables selected for monitoring the seasonal variation in diversity at the lake were Shannon-Weiner diversity index (H), species richness (S), Shannon's equitability/evenness (EH= H/lnS), effective number of species {EXP(H)}, mean frequency of occurrence, mean abundance of water-bird species.

For the study of seasonal patterns in diversity variables, four climatological seasons of three months each were followed based on the climate of Ajmer according to the city wise data of Indian Meteorological Department. These are Winter, occurring from January to March, Summer or pre-monsoon season, lasting from April to June, Monsoon or rainy season, lasting from June to September and Post-monsoon or autumn season, lasting from October to November. In Ajmer, October and November are usually cloudless.

For relationship between occurrences and numbers of individuals of different species Karl Pearson's coefficient of correlation and coefficient of determination i.e. R-squared was used as a statistical measure of how close the data are to the fitted regression line (Steel, R. G. D.; Torrie, J. H., 1960; Frost, 2013). Calculations were done using Data Analysis ToolPak of Microsoft Excel 2016.

## 3. Results and Discussion

Total 92 visits were made at the study site. Forty species of water-birds belonging to 16 families and 9 orders were recorded at the Lake during the period. Table 1 shows the taxonomic families, scientific and common names of the recorded water-bird species and their residing status in India.

Fourteen of the 40 species belonged to the order Charadriiformes and 12 belonged to the order Pelicaniformes. Family wise distribution of water-birds is shown in Table 2, which indicates that most species (9) belonged to the heron family Ardeidae. This family was previously kept under the order Cinconiformes but recent phylogenomic studies show that herons and ibises (Threskiornithidae) are more closely related to pelicans than storks (Hackett et al., 2008). Family Scolopacidae is represented by 8 species at Anasagar Lake.

At Anasagar lake, waterhen family Rallidae is represented by 4 species, Phalacrocoracidae by 3 species; and Anatidae, Recurvirostridae, Charadridae and Threskiornithidae by 2 species each while Laridae, Sternidae, Podicipedae, Pelicanidae, Cinconiidae, Phoenicopteridae, Alcedinidae and Cerylidae are represented by one species per family.

Seasonal Variation in the various diversity variables at Anasagar Lake shows that during winter season species richness and mean abundance of species were highest but value of Shannon Weiner diversity index, Shannon's equitability and effective number of species for winter season were least as compared with those for the other three seasons. For autumn season values of Shannon Weiner diversity index, Shannon's equitability and effective number of species were highest while species richness and mean abundance of species were lowest (values depicted in Table 3 and figures 1.1 to 1.6). This suggests indirect relationship in these variables. Mean frequency of occurrence of species was highest during monsoon and lowest in summer. This indicates that during monsoons water-birds frequently come out in search of new foraging opportunities for their old foraging and resting platforms are submerged.

Correlation analysis between numbers of individuals of water-bird species revealed that there were significant positive correlations among 9 pairs of species out of the total 40 water-bird species observed during the period. Karl Pearson's coefficient of correlation (r) for Black headed gull and Little grebe; Black headed gull and Great white pelican; Great cormorant and Indian cormorant; Great cormorant and Little cormorant; Indian cormorant and Little cormorant; Indian cormorant and Great white pelican; Indian cormorant and Eurasian coot; Great white pelican and Eurasian coot; and Eurasian spoonbill and Lesser flamingo are given in Table 4. Correlations are also depicted in Figure 2 with the respective values of coefficient of determination. Highest correlation was observed between different Cormorant species and between Black headed gull and Great white pelican. These observations can be attributed to the fact that these species prefer similar habitat variables.

Significant correlations were found between occurrences of four pairs of water-bird species i.e. between Common teal and Black headed gull; Common teal and Great white pelican; Black headed gull and Great white pelican; and Great white pelican and Pied kingfisher. Values of Karl Pearson's 'r' and R-squared are depicted in the Table 5 and Figure 3 for each of these pairs.

When correlation analysis was done between the taxonomic families of water-birds it was found that the numbers of individuals of family Laridae and Podicipedae; Laridae and Pelicanidae; and Phalacrocoracidae and Pelicanidae are significantly correlated (Table 6 and figure 4). Similar correlations were found between occurrences of species of family Laridae and Pelicanidae; Recurvirostridae and Charadriidae; and Pelicanidae and Cerylidae. These results with the families corroborated with the correlations in individual species. Order wise correlation analysis brought out that order Suliformes and Pelicaniformes are correlated in terms of numbers of individuals throughout the year.

These correlations hint towards the overlapping niches which are related to the morphology and food of water-birds. Yet, variation in abundance of every species is different and this requires a customised approach for their conservation and management. Presence of one species indicates the potential of habitat for other correlated species, which can be explored further. For conserving the avifaunal diversity at the scenic Anasagar Lake, it is also necessary to monitor the water quality and encourage the growth of favourable emergent vegetation around the lake.

## 4. Acknowledgements

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## Tables & Figures:

**Table 1:** Water-birds observed at Anasagar Lake during the study year

| Family | Scientific Name | Common Name | *Residing Status |
|---|---|---|---|
| **Anatidae** | *Anas poecilorhyncha* Forster, JR, 1781 | Spot billed duck | R |
| | *Anas crecca* Linnaeus, 1758 | Common teal | W |
| | | | |
| **Scolopacidae** | *Calidris minuta* (Leisler, 1812) | Little stint | W |
| | *Calidris pugnax* (Linnaeus, 1758) | Ruff (Reeve for female) | W |
| | *Gallinago gallinago* (Linnaeus, 1758) | Common snipe | W |
| | *Calidris temminckii* (Leisler, 1812) | Temmnick's stint | W |
| | *Limnodromus semipalmatus* (Blyth 1848) | Asian dowitcher | W |
| | *Tringa ochropus* Linnaeus, 1758 | Green sandpiper | W |
| | *Tringa stagnatilis* (Bechstein, 1803) | Marsh sandpiper | W |
| | *Tringa totanus* (Linnaeus, 1758) | Common redshank | W |
| | | | |
| **Laridae** | *Chroicocephalus ridibundus* (Linnaeus, 1766) | Black headed gull | W |
| | | | |
| **Sternidae** | *Sterna aurantia* Gray, JE, 1831 | Indian river tern | R |
| | | | |
| **Recurvirostridae** | *Himantopus himantopus* (Linnaeus, 1758) | Black winged stilt | R |
| | *Recurvirostra avosetta* Linnaeus, 1758 | Pied avocet | W |
| | | | |
| **Charadriidae** | *Charadrius dubius* Scopoli, 1786 | Little ringed plover | RW |
| | *Vanellus indicus (*Boddaert, 1783) | Red wattled lapwing | R |
| | | | |
| **Podicipedidae** | *Tachybaptus ruficollis* (Pallas, 1764) | Little grebe (Dabchick) | R |
| | | | |
| **Phalacrocoracidae** | *Phalacrocorax carbo* (Linnaeus, 1758) | Great cormorant | R |
| | *Phalacrocorax fuscicollis* Stephens, 1826 | Indian Cormorant | R |
| | *Microcarbo niger* (Vieillot, 1817) | Little cormorant | R |

| | | | |
|---|---|---|---|
| **Pelicanidae** | *Pelecanus onocrotalus* Linnaeus, 1758 | Great white pelican | RW |
| | | | |
| **Ardeidae** | *Ardea alba* Linnaeus, 1758 | Great white egret | R |
| | *Ardea cinerea* Linnaeus, 1758 | Grey heron | RW |
| | *Ardea pupurea* Linnaeus, 1766 | Purple heron | R |
| | *Ardeola grayii* (Sykes, 1832) | Indian pond heron | R |
| | *Bubulcus ibis* (Linnaeus, 1758) | Cattle egret | R |
| | *Egretta garzetta* (Linnaeus, 1766) | Little egret | R |
| | *Ixobrychus sinensis* (Gmelin, 1789) | Yellow bittern | R |
| | *Mesophoyx intermedia* (Wagler, 1829) | Intermediate egret | R |
| | *Nycticorax nycticorax* (Linnaeus, 1758) | Black crowned night heron | R |
| | | | |
| **Threskiornithidae** | *Platalea leucorodia* Linnaeus, 1758 | Eurasian spoonbill | R |
| | *Threskiornis melanocephalus* (Latham, 1790) | Black headed ibis | R |
| | | | |
| **Cinconiidae** | *Mycteria leucocephala* (Pennant, 1769) | Painted stork | R |
| | | | |
| **Phoenicopteridae** | *Phoenicopterus minor* (Geoffroy Saint-Hilaire, E, 1798) | Lesser flamingo | RW |
| | | | |
| **Rallidae** | *Amaurornis phoenicurus* (Pennant, 1769) | White-breasted waterhen | R |
| | *Fulica atra* Linnaeus, 1758 | Eurasian coot | R |
| | *Gallinula chloropus* (Linnaeus, 1758) | Common moorhen | R |
| | *Porphyrio porphyrio* (Linnaeus, 1758) | Purple swamphen | R |
| | | | |
| **Alcedinidae** | *Alcedo atthis* (Linnaeus, 1758) | Common kingfisher | R |
| | | | |
| **Cerilidae** | *Ceryle rudis* (Linnaeus, 1758) | Pied kingfisher | R |

*Grimmett

**Table 2:** Family-wise distribution of water-bird species

| Order Family | Sum of No. of Species |
|---|---|
| **Anseriformes** | **2** |
| Anatidae | 2 |
| **Charadriiformes** | **14** |
| Charadriidae | 2 |
| Laridae | 1 |
| Recurvirostridae | 2 |
| Scolopacidae | 8 |
| Sternidae | 1 |
| **Cinconiiformes** | **1** |
| Cinconiidae | 1 |
| **Coraciiformes** | **2** |
| Alcedinidae | 1 |
| Cerylidae | 1 |
| **Gruiformes** | **4** |
| Rallidae | 4 |
| **Pelicaniformes** | **12** |
| Ardeidae | 9 |
| Pelicanidae | 1 |
| Threskiornithidae | 2 |
| **Phoenicopteriformes** | **1** |
| Phoenicopteridae | 1 |
| **Podicipediformes** | **1** |
| Podicipedae | 1 |
| **Suliformes** | **3** |
| Phalacrocoracidae | 3 |
| **Grand Total** | **40** |

**Table 3:** Seasonal Variation in diversity and abundance of water-birds

| *Diversity Variables* | *Summer* | *Monsoon* | *Autumn* | *Winter* |
|---|---|---|---|---|
| **Shannon-Weiner Diversity Index (H)** | 3.218 | 3.258 | 3.301 | 3.084 |
| **Species Richness (S)** | 34 | 33 | 29 | 36 |
| **Shannon's Equitability/ Evenness (EH= H/lnS)** | 0.913 | 0.932 | 0.980 | 0.861 |
| **Effective Number of Species {EXP(H)}** | 24.976 | 26.010 | 27.135 | 21.854 |
| **Mean Frequency of Occurrence** | 0.329 | 0.498 | 0.466 | 0.443 |
| **Mean Abundance** | 2.983 | 2.601 | 1.837 | 4.442 |



**Figure 1.1**

**Species Richness (S)**

Winter 36
Autumn 29
Monsoon 33
Summer 34

**Figure 1.2**



**Shannon's Equitability/Evenness(EH= H/lnS)**

Winter 0.861
Autumn 0.980
Monsoon 0.932
Summer 0.913

**Figure 1.3**



**Effective Number of Species {EXP(H)}**

Winter 21.854
Autumn 27.135
Monsoon 26.010
Summer 24.976

**Figure 1.4**



**Mean Frequency of Occurrence**

Summer 32.92%
Monsoon 49.77%
Autumn 46.63%
Winter 44.33%
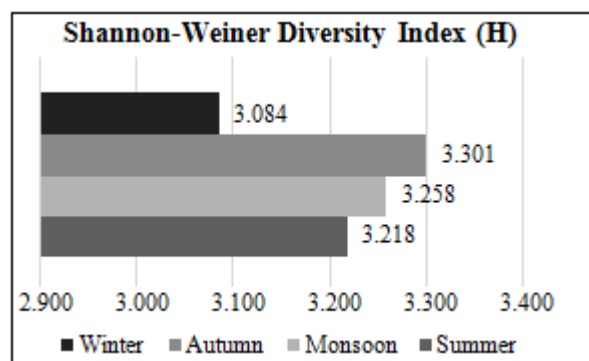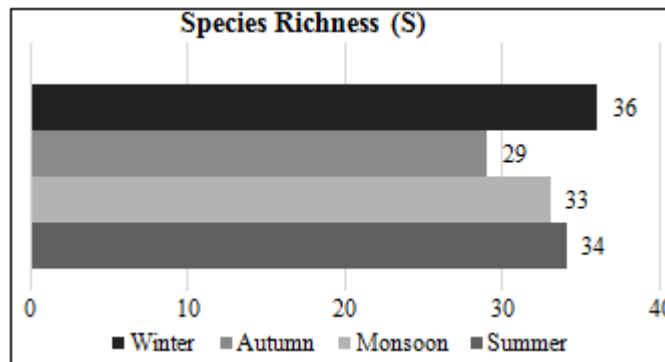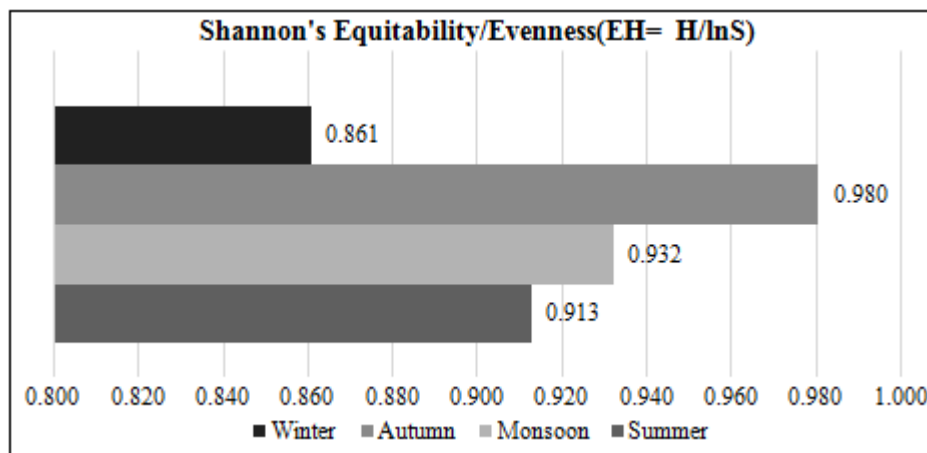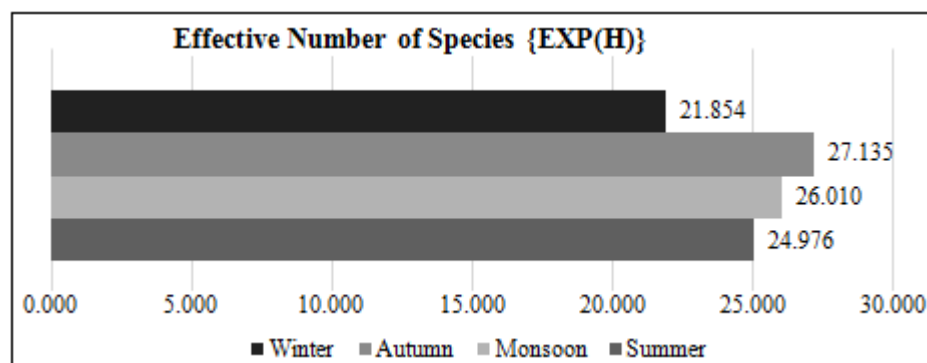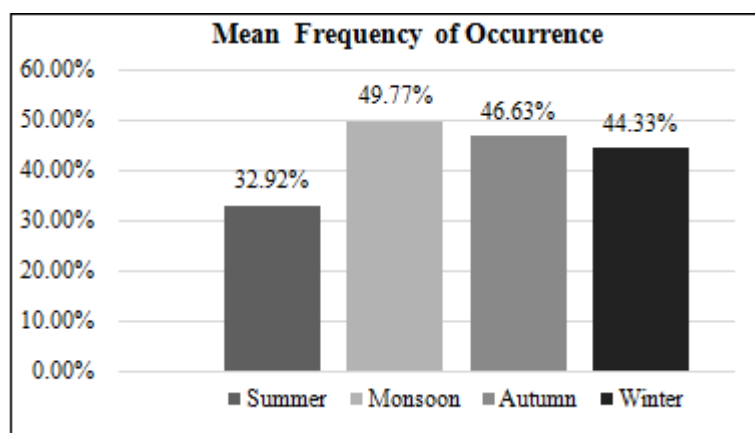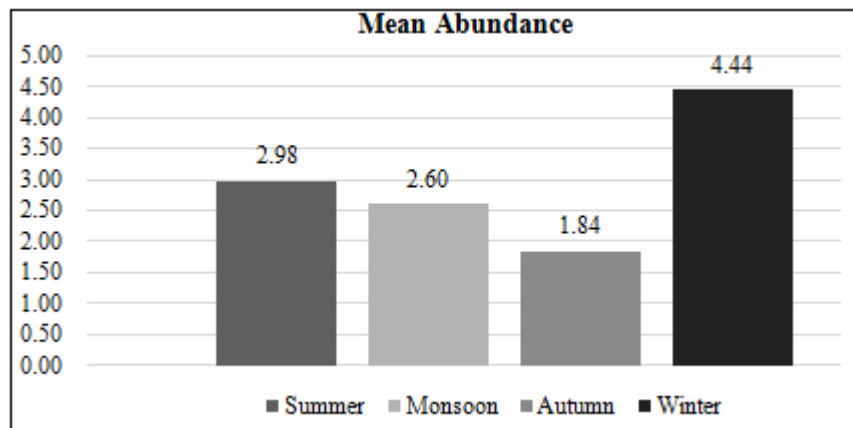
**Figure 1.5**

**Figure 1.6**
**Figure 1:** Seasonal Variation in Diversity Variables:

**Table 4:** Significant values of coefficient of correlation (r) between numbers of individuals of different water-bird species

| Species | Black headed gull | Great cormorant | Indian cormorant | Great white pelican | Eurasian spoonbill |
|---|---|---|---|---|---|
| Little grebe (Dabchick) | 0.6815 | | | | |
| Great white pelican | 0.7715 | | | | |
| Indian cormorant | | 0.8487 | | | |
| Little cormorant | | 0.7944 | 0.8357 | | |
| Great white pelican | | | 0.7150 | | |
| Eurasian coot | | | 0.7057 | 0.6671 | |
| Lesser flamingo | | | | | 0.6709 |



**Figure 2.1**



**Figure 2.2**

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**Figure 2.3**

$y = 0.581x + 1.166$
$R^2 = 0.720$



**Figure 2.4**

$y = 0.547x + 1.613$
$R^2 = 0.631$



**Figure 2.5**

$y = 0.841x + 1.223$
$R^2 = 0.698$



**Figure 2.6**

$y = 2.112x - 6.716$
$R^2 = 0.511$
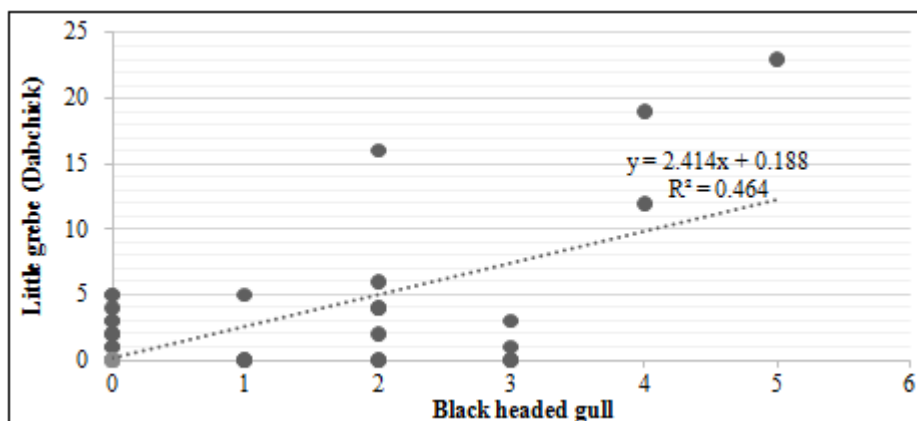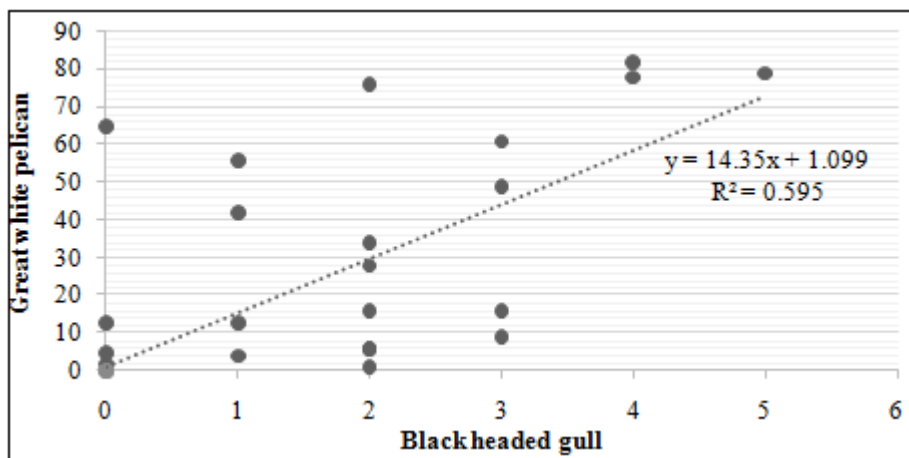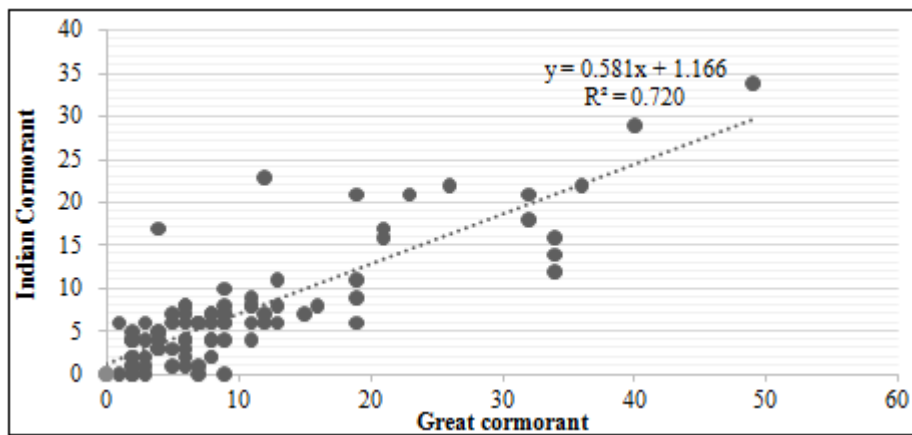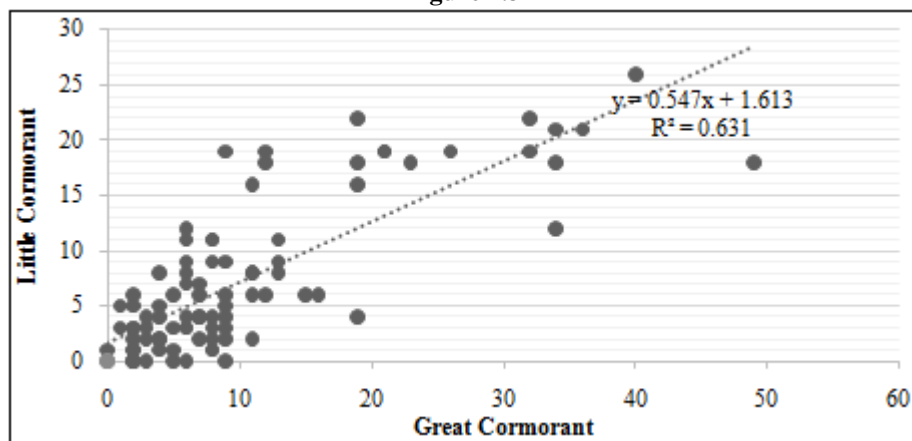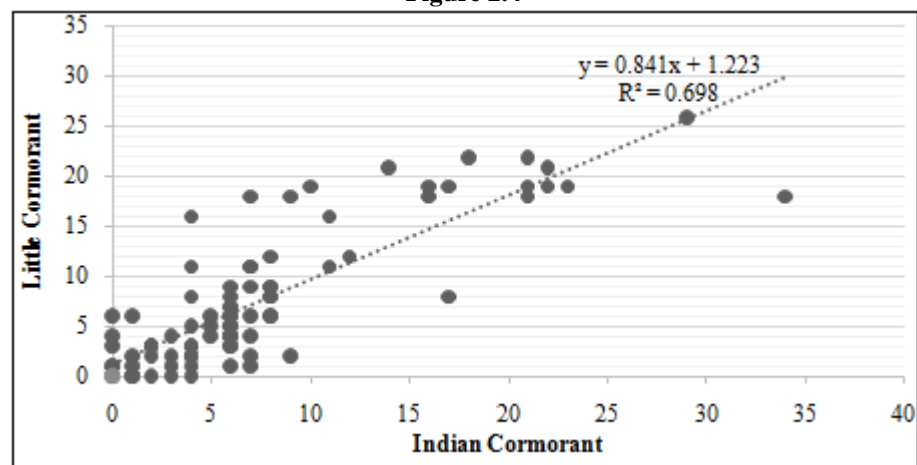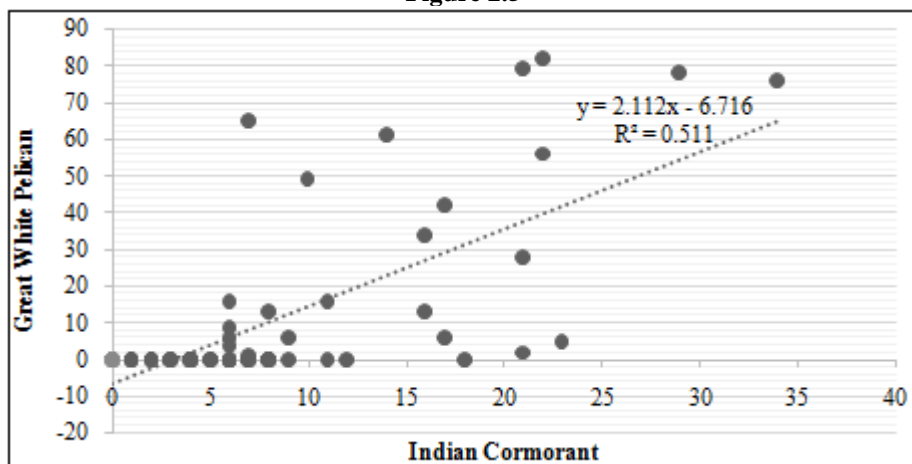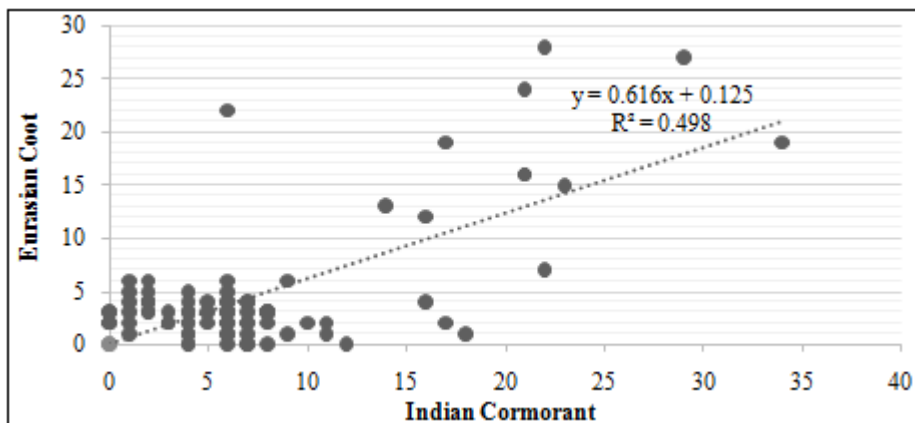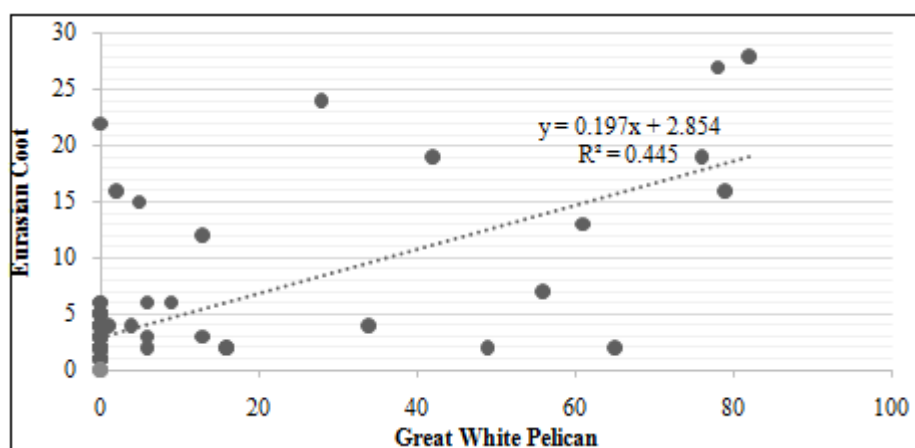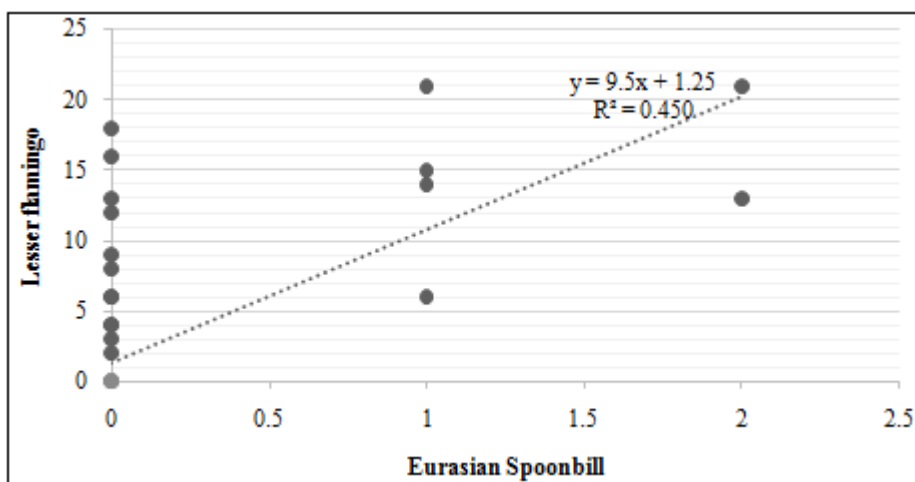
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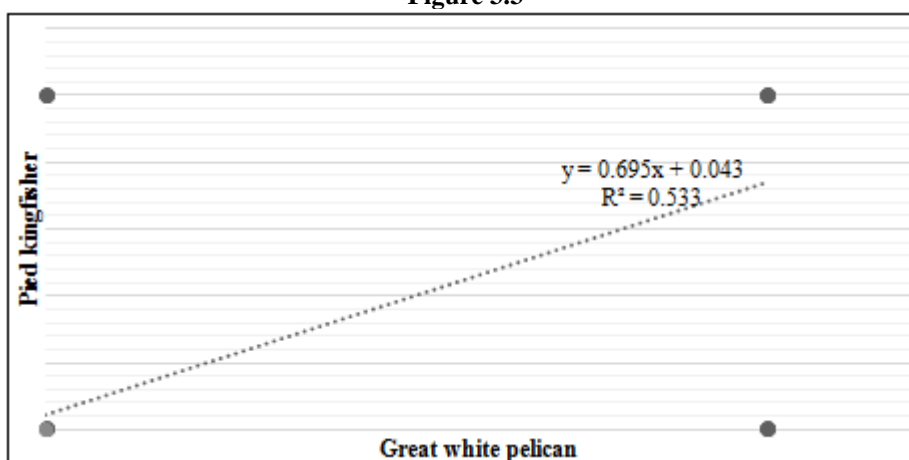

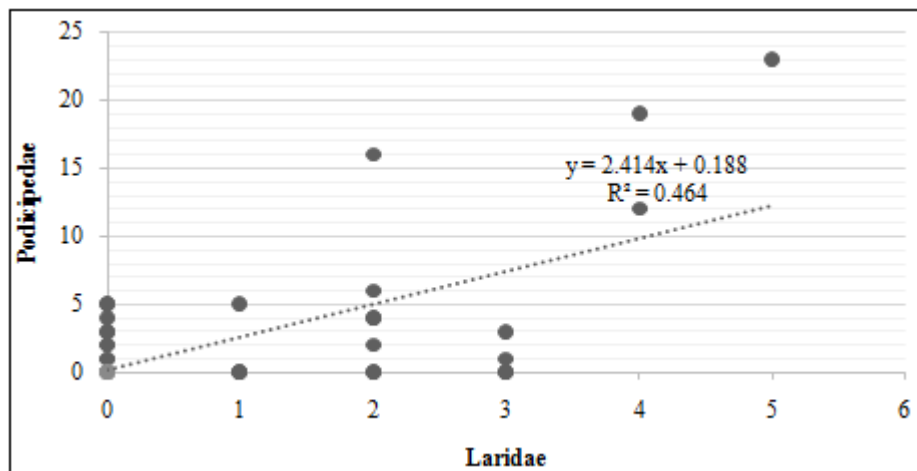
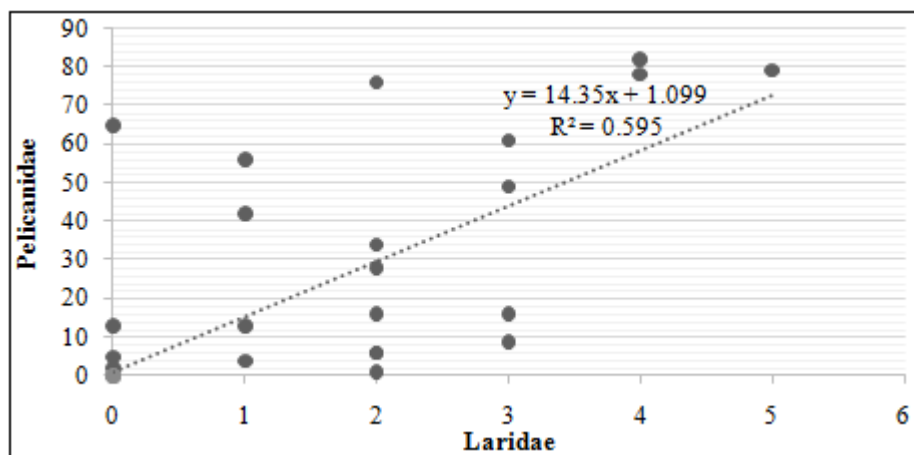**Figure 2.8**



**Figure 2.9**
**Figure 2:** Correlation between numbers of individuals of different water-bird species and coefficient of determination

**Table 5:** Significant values of coefficient of correlation (r) between occurrences of different water-bird species

| Species | Common teal | Black headed gull | Great white pelican |
|---|---|---|---|
| Black headed gull | 0.8741 | | |
| Great white pelican | 0.8224 | 0.8836 | |
| Pied kingfisher | | | 0.7303 |
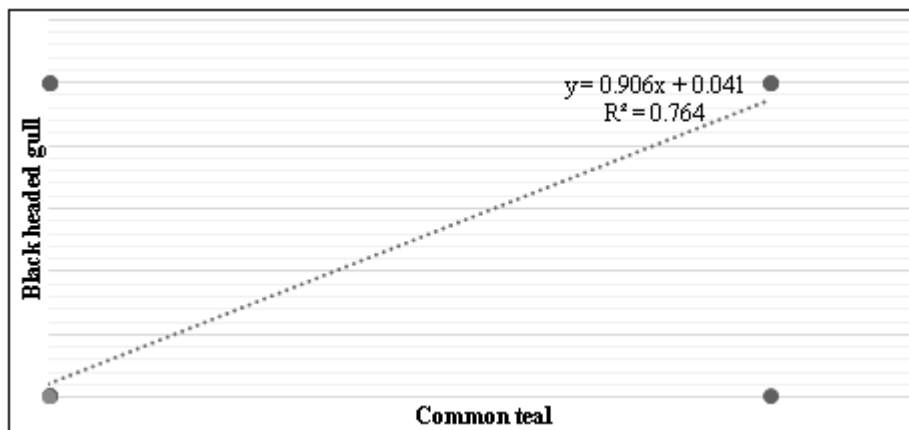
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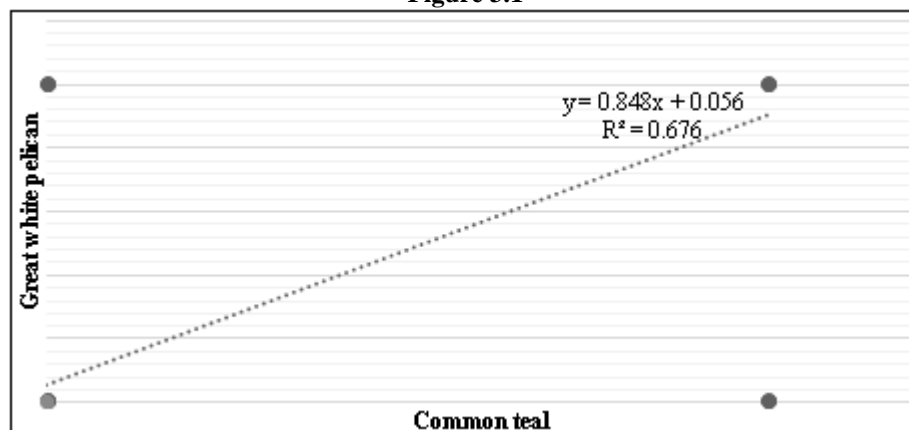


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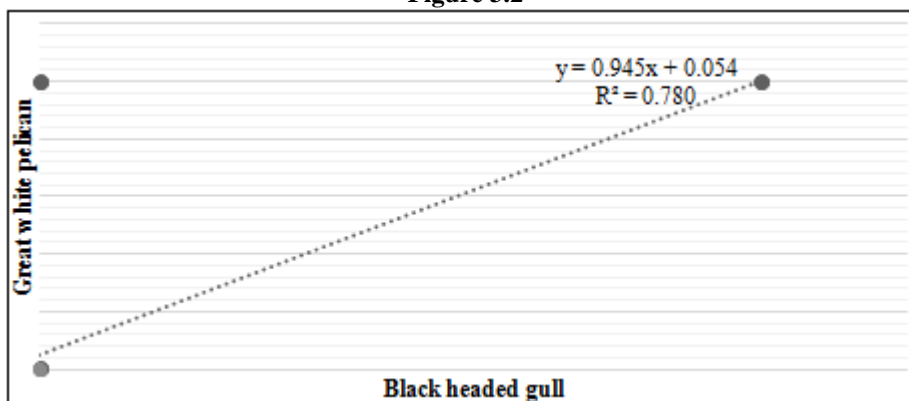


**Figure 3.3**



**Figure 3.4**

**Figure 3:** Correlation between occurrences of different water-bird species and coefficient of determination

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**Table 6:** Significant values of coefficient of correlation (r) between numbers of individuals of different taxonomic families
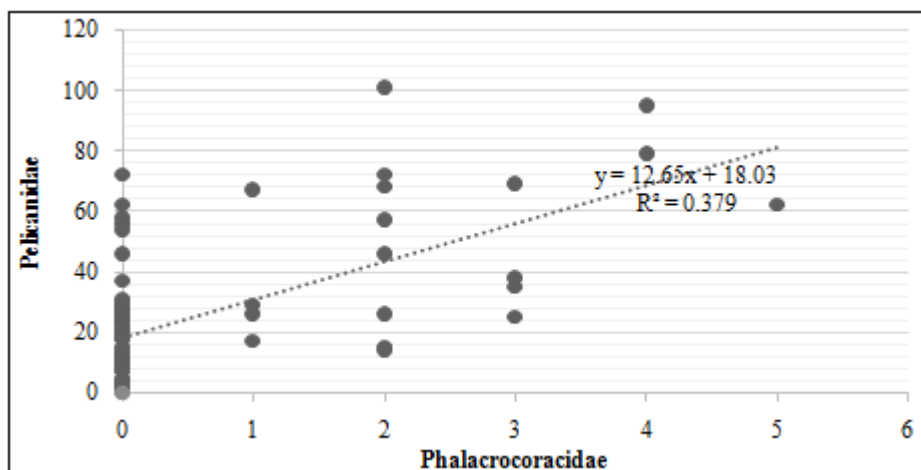
| Family | Laridae | Phalacrocoracidae |
|---|---|---|
| Podicipedae | 0.6815 | |
| Pelicanidae | 0.7715 | 0.6989 |



**Figure 4.1**



**Figure 4.2**



**Figure 4.3**

**Figure 4:** Correlation between numbers of individuals of different taxonomic families and coefficient of determination

**Table 7:** Significant values of coefficient of correlation (r) between occurrences of individuals of different taxonomic families

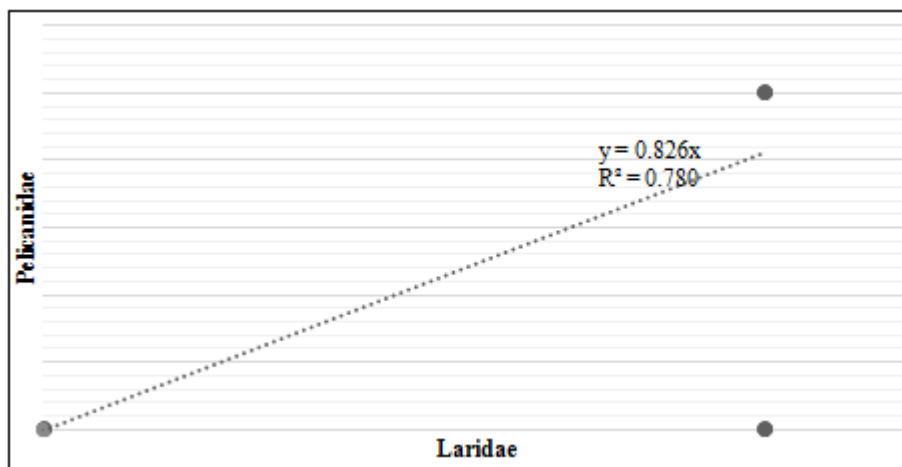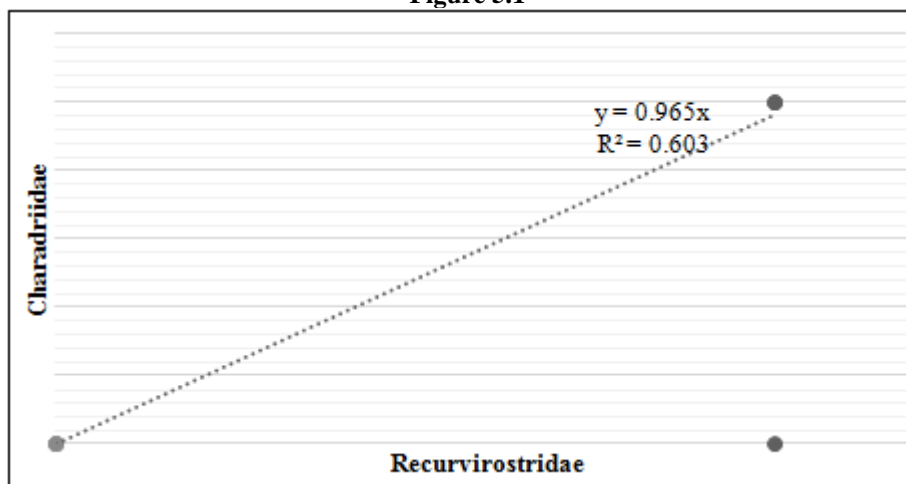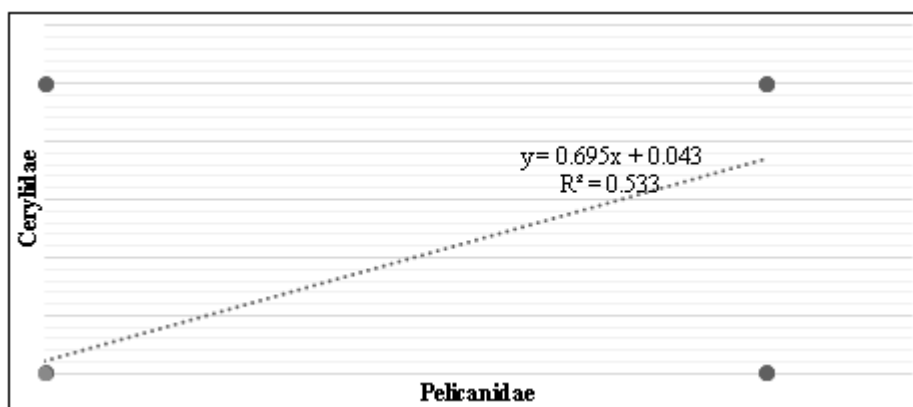| Family | Laridae | Recurvirostridae | Pelicanidae |
|---|---|---|---|
| Charadriidae | | 0.7768 | |
| Pelicanidae | 0.8836 | | |
| Cerylidae | | | 0.7303 |

**Figure 5.1**



**Figure 5.2**



**Figure 5.3**
**Figure 5:** Correlation between occurrences of individuals of different taxonomic families and coefficient of determination

**Table 8:** Significant value of coefficient of correlation (r) between numbers of individuals of different taxonomic orders

| Order | Suliformes |
|---|---|
| Pelicaniformes | 0.6674 |
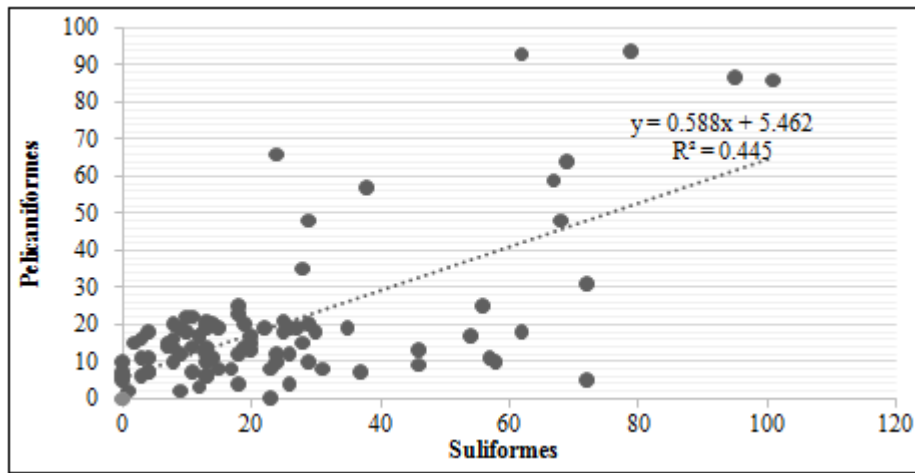
**Figure 6:** Correlation between occurrences of individuals of different taxonomic orders and coefficient of determination