Identifying the Birds Diversity Hot Spots in Teeb Protected Area South-eastern Iraq by Using Kernel Density Estimation

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Abstract

The area of Teeb and the surrounding areas located at Southeastern Iraq is well known of its ecosystem diversity that includes series of heights and cliffs, shrubby and bushy plains, flat alluvial areas, seasonal marshes and waterbodies; in addition to two large seasonal rivers: Teeb and Dweireej. Such a rich topographical diversity has created the richness in plant diversity and subsequently fauna diversity. Nevertheless, no report was conducted on Teeb area particularly on the birds diversity and its associated hot spots analysis. The objectives of this study are to determine the bird count observed in Teeb surveyed area and to estimate the avifauna habitat selection using Kernel Density Estimation.. It The study has been visited in various occasions during 2016-2020 where seven sampling sites were surveyed regularly in different seasons targeting the birds diversity and their habitats. The fieldwork targeted both: aquatic and terrestrial species, and general description for their habitats over the seven sampling sites. Kernel Density Estimation Modelling in ArcGIS was used to determine important hotspot for birds in Teeb protected area. Geostatistical analysis was also carried out using hot spot (Gi*de Getis-Ord) analysis and Nearest Neighbour analysis. One hundred and forty-nine bird species were recorded during the current study. The main goal of the current work, besides presenting the results of the fieldwork, is to demonstrate the importance of the area as a priority for conservation on the national level, and addressing conservation issues as a tool for treating the threats that threaten the Biodiversity in general and birds in particular in this key biodiversity area in Iraq. Highlighting the birds hotspots in Teeb would assist in addressing the management effort property. demonstrating the importance of the area as a priority for conservation on the national level, and addressing set of recommendations as a tool for treating the threats that threaten the biodiversity in general and birds in particular in this key biodiversity area in Iraq.

Keywords: Avifauna, biodiversity hotspot, KDE, KBAs, IBAs, Iraq, Teeb

Introduction

Teeb area is located at the southeastern of Iraq, in Missan Governorate, to the northeast of Amara city. The study area is kind of triangle shape, restricted between the Iraqi-Iranian borders
from the east, Teeb River from the west, and Dweireej River from the south. It consists of noticeable diversity in the topography of the surface and landscapes. This was due to its being located at the edges of the Low Folded Zone geological belt that includes the upper parts of Teeb area and caused this kind of diversity in the elevation and the shape of the surface of the area (Yacoub, 2011).

![Figure 1](image)

**Figure 1:** Teeb area, including the study area limits (in black), hills range (brown), seasonal marshes (green), and the two rivers: Teeb and Dweireej

Environmentally, and due to the morphological and topographical diversity, Teeb area is considered one of the richest areas on the national level (MoE, 2013; Salim, 2020). In comparison with the surrounding areas inside Iraq, plant cover is considered rich, which makes it an attractive wildlife hotspot. It seems that this area is important for migrant birds, in particular passerines, as well as resident species. The permanent water and the diverse plant cover create an attractive habitat for desert birds as well as migratory birds (Salim, 2016).

In addition to the importance of the plant cover and the topography of Teeb area, the area also includes Important wildlife that’s including globally threatened species such as the Houbara Bustard *Chlamydotis undulata*, Striped Hyena *Hyaena hyaena* and the Spiny-tailed Lizard *Uromastyx aegyptia* in addition to a great number of Passerine and Waterfowl bird species typical of the desert and wetlands biomes (MoE, 2013).

The seasonal wetland within the area consists of patches of water that either remains on an annual bases in some areas, or disappears from many areas during the summer season. The most important wetland area is the Teeb marshes that receive quite large numbers of Waterfowl each winter where the majority of the bird species remains at these areas foraging in the shallow waters and mud, or using the vast reedbeds as a shelter. Some of the regularly visiting bird species to these wetlands is the Vulnerable Lesser White-fronted Goose *Anser erythropus* (MoE, 2013).
Besides presenting the results of the fieldwork, the main goal of the current work, is to demonstrate the importance of the area as a priority for conservation on the national level, and support the management plan of Teeb protected area. It is also to addressing conservation issues related to key bird species and their habitats as a tool for treating the threats that threaten the Biodiversity in general and birds in particular in this key biodiversity area in Iraq.

Materials and Methods

Study Area

The study area of the current research is located at southeastern Iraq. It includes the geographical areas: Teeb, Dweireej, Fekka, Zubeidaat, and Abu Ghrab, that are adjacent to the Iraqi-Iranian borders (Figure 1-the combined one as I suggested previously). Teeb area consists of the hills range that goes northwest-southeast at the eastern part of the study area paralleling the Iraq-Iranian borders the western and southern parts consist of open areas of desert habitats of which some of these areas includes arid lands and sand-dunes. The middle parts of the study area consists of large seasonal wetlands (marshes) that runs towards the southwestern corner of the study area. The study area also includes two large seasonal rivers: Teeb and Dweireej rivers that includes different stripe of flora and fauna life and contribute in feeding the lowlands with quite large amounts of water especially during the raining seasons. Both rivers are originated from the Iranian highlands (Yacoub, 2011) Seven observation sites were selected and visited during the fieldwork that was carried on in various visits during four seasons over the period 2016-2020. The selection of the suitable were chosen on the basis to represent various habitat types of the area.

Surveys were based on different visits that targeted the study area within the period 2016-2020 These surveys have covered different seasons (winter, spring, summer. And autumn).

Surveyed sites:

The following sampling site were visited by the survey team (Table 1 and Figure 2). In addition to surveying the central coordinates of the survey sites, and in order to have wider coverage of the habitats in the study area, the team has surveyed the areas around the central coordinates by vehicles to include more information to the survey areas. Additionally, the team has also surveyed some sites that were not listed in the table below but it was to have better idea on the habitats of the rest of the areas within the study area. It was also due to the incapability to reach some areas in addition to the presence of the unexploded objects and mine-fields within the study area. The purpose was to complete the extrapolation of the extension of the habitats in Teeb.
Figure 2: Teeb study area delineated in black line, and the seven observation locations over the different habitats within the study area.

Table 1: Coordinates, habitat characteristics and site description of the survey area.

| Site Code | Coordinates       | Habitat Characteristics | Description                                                                                     |
|-----------|-------------------|------------------------|-------------------------------------------------------------------------------------------------|
| T-1       | 32° 25' 32" N    | River                  | Teeb River is located at the upper part, at the immediate eastern bank of Teeb River few kilometres after its first entrance to the Iraqi grounds. Teeb river is a deep and wide watercourse, about 200m width. Plant cover at both sides is dense and consists of trees (mainly *Populus euphratica*) and intensive shrubs |
| T-2       | 32° 23' 36" N    | Hills and undulated lands | It is located Upper eastern parts. Continuous chains of hills of medium height with relatively deep valleys and watercourses, covered by grass and scattered shrub plants |
| T-3       | 32° 18' 8" N     | Open, arid, and desert areas | Open plain consists of shallow but relatively separated network of watercourses. Covered by the grass with scattered, low shrubs that concentrate at the depressions. |
T-4  32° 5' 3" N  47° 35' 0.4" E  Hills and undulated lands  An open area that is close to the foothills and the highlands at the eastern side. Higher elevation than T-3. Represent the end of the hills chain to the southern edge. Plant cover consists of the seasonal grass and the low shrubs.

T-5  32°1' 23" N  47° 21' 3" E  Seasonal marshes  Seasonal wetland habitat that gets flooded during the rainy seasons and winter, and lost considerable amounts of water during summer season. Some aquatic plants were observed in this location like the Reed Phragmites australis and Typha. Some dry lands’ plant species found at the margins of the wetlands.

T-6  32° 1' 40" N  47° 30' 13" E  River  Located at the Dweireej River. General habitat is very similar to that of the site T-1 (Teeb River), however, the width of this river is less than Teeb River at this point. Consists of trees (mainly Populus euphratica) with dense shrubs.

T-7  32° 3' 10" N  47° 36' 54" E  Lake and open-water habitat  An open lake of relatively small size that was found at Dweireej River after constructing new dam on the trunk of the river. Represents the lake or the permanent water habitat. Being artificial, newly-constructed lake, no trees or large shrubs were found at the edges of the lake, however, such plant growth might be developed at the near future.

Bird Observation Methods

The recording of individual birds or flocks was conducted using Point Counts within each survey area, which includes stopping at the selected site for a given amount of time, then noting birds seen from this stationary location. Eight point count sites were made in each area of the seven areas. The bird lists were made based on direct observation of each individual bird or group of birds, or by noting down a detailed description of the unidentified birds, then checking it with references later. The second methodology utilized for larger sites containing higher density and variety of plant cover and faunal diversity was Whole Area Counts. This included
searching within the entire proposed polygon of the ecological survey site and recording all of the observed birds.

The team have used 12x50 binoculars to conduct the bird surveys in the area. The counts were conducted by direct observation from a 4X4 vehicle or by walking through the site in different directions by focusing on the bushes and plants, where the birds can perch or hide. It should be noted that the minefields hindered the birdwatcher to wander around the site freely. So, in general, the bird counts in this area do not represent the “actual” status of the birds in each site due to the restrictions of the movement of the ornithologist.

The following field guides were used during the fieldwork: Porter, Christensen, & Hansen (1996), and Salim et al (2006). Allouse (1953 & 1962) was used to review the status of the bird species over the area as a whole.

The observed birds were recorded in a field notebook that included the bird name and count in addition to any other related notes. This also included detailed descriptions of the site and any related observations.

**Hotspot analysis**

The hotspot analysis seeks to identify groupings within an area. These groupings may either represent high or low values of a given variable, which correspond to hot and cold spots, respectively. In order to identify these spots, a hot spot analysis (Getis-Ord Gi*) has been carried out, which can be implemented through the Mapping Clusters tool—available in the Spatial Statistics Tools suite of ArcGIS. In order to calculate and analyze the hotspots, the data have been fed into the program, and the equation below was sued for this purpose:

$$G_i = \frac{\sum_{j=1}^{n} w_{ij} x_j}{\sum_{j=1}^{n} x_j}$$

$$z \text{ score } = \frac{x - \mu}{\sigma}$$

Equation (1,2)

$G_i$ _Bin_ = Statistically significant hot and cold spots.

$x_j$ = Attribute value for feature.

$w_{ij}$ = Spatial weight between feature (i) and (j).

$n$ = Total number of features.

$x$ = score.

$\mu$ = mean.

$\sigma$ = Standard Deviation (SD).

Modeling Kernel Density Estimation (KDE) by ArcGIS a polygon was created to cover the Teeb zone. After acquiring the data area in the survey, the data shapefile was generated in ArcGIS 10.8.
\[ \hat{f}_{\text{kernel}}(x) = \frac{1}{Nh} \sum_{i=1}^{N} k \left( \frac{x-x_i}{h} \right) \text{ formula (3)} \]

b: bandwidth

\[ x_i = (x_1, x_2, x_3, ..., x_n) \text{ independent and identically distributed samples (point) drawn from some univariate distribution} \]

\( k = \text{Scale kernel} \)

### Results and Discussion

The surveys were conducted at seven sites that represent different habitat and natural landscape as follows:

**Teeb-1:** This site is located at the upper parts of the study area. It represents the river habitat where Teeb River in this point is included.

**Teeb-2:** This observation point is located at the northern parts of the study area. It represents that undulated and hilly habitats. It consists of The plant cover of the area consists in general of where the later concentrate at the bottoms of the valleys and the depressions.

**Teeb-3:** This site consists of part of the open plain that represents desert habitat. The general height of the area is lower than the previous one. It. The general plant cover of the area is

**Teeb-4:** This site consists of an open area that is close to the foothills and the highlands at the eastern side. The elevation of this area is relatively higher than the previous point.

**Teeb-5:** This site is located within the wetlands parts of Teeb area (Teeb marshes). These marshes are seasonal wetland habitat that gets flooded during the raining seasons and winter.

**Teeb-6:** This site is located at the Dweireej River. The habitat in general resembles the site T-1 (Teeb River).

**Teeb-7:** This site consists of an open lake of relatively small size that was found at Dweireej River after constructing new dam on the trunk of the river.

### Birds Observations

Due to the diversity of the habitats one hundred and forty-nine bird were observed. The mudflats of these wetlands are of high importance for the Waders is characterized by patches of water that remain throughout the year in scattered depressions. Historically, the area received water from the Iranian uplands mainly through the Dwerege River, and from other small drainages from highlands in Iraq and Iran, and deep pools stretched over many kilometers. Teeb wetlands provides very good habitat for large numbers of geese and ducks, especially in the western, more remote part of the site. This site is subject to intensive oil exploration activities. The natural features for which this area is noteworthy are the presence of the globally threatened
Lesser White-fronted Goose (*Anser erythropus*), Houbara Bustard (*Chlamydotis undulata*), Eastern Imperial Eagle (*Aquila heliaca*) and Greater Spotted Eagle (*Aquila clanga*).

**Table 2:** The counts of the bird species observed in each sampling site

| Observation Point | The highest count of the bird species |
|-------------------|-------------------------------------|
| Teeb-5            | 76                                  |
| Teeb-7            | 64                                  |
| Teeb-1            | 61                                  |
| Teeb-6            | 60                                  |
| Teeb-4            | 59                                  |
| Teeb-2            | 49                                  |
| Teeb-3            | 41                                  |

Each sampling site was harboring relatively considerable numbers of bird species of which some of these species were occurring in large populations. The table in the annex of this paper details the status of each bird species that were observed in the study area.

**Modeling Kernel Density Estimation (KDE) by ArcGIS**

KDE modeling was used to predict avifauna habitat selections. As a result, we will be used to build. As a consequence, the maximum core habitat of birds equals 110.7 km² and is situated along the Iraq-Iranian boundary at site T4, T6, and T7. Although the maximum minor bird habitat in the Teeb region is (24 km², 26 km², 49 km², 61 km², 73 km², 86 km², 98 km²). We concluded that there is a high biodiversity of birds in Teeb, especially along the Iraq-Iran border, due to habitat located in the line migration of birds and land rich in natural resources.
Figure 3: Modeling KDE with Clip Raster of Satellite Image explain Habitat selection by avifauna in Teeb regional, Label Site.
**Figure 4:** Modeling KDE with Clip Raster of Satellite Image (RGB) explain Habitat selection by avifauna of Teeb regional, label coordination per each site.
Figure 5: Modeling KDE with Clip Raster of Satellite Image explain Habitat selection by avifauna of Teeb regional, label Total number species per each site

Modeling Hot spot analysis by ArcGIS

After collecting 35 points, analyzing them in ArcGIS, and designing a shapefile as a layer feature class, the authors got one Hotspot with a confidence level of 90%, a $P$-value of 0.051, a $Z$ score of 1.943, and an N-neighbor of 2. All Teeb zone is considered a stopping point for thousands of migrating birds, according to the Hotspot point found in the middle polygon and a raster image from the satellite Landsat 8. The table below (Table 3) lists the Analysis statically of modeling Hot-cold spot.
Table 3: Analysis statically of modeling Hot-cold spot.

| OID | Species | Gi-Z Score | Gi-P Value | N-Neighbors | Gi-Bin | Confidence level |
|-----|---------|------------|------------|-------------|--------|------------------|
| 1   | 19      | 0.188909468 | 0.850163773 | 5            | 0      | Not confidence   |
| 2   | 12      | 0.188909468 | 0.850163773 | 5            | 0      | Not confidence   |
| 3   | 13      | 0.188909468 | 0.850163773 | 5            | 0      | Not confidence   |
| 4   | 6       | 0.188909468 | 0.850163773 | 5            | 0      | Not confidence   |
| 5   | 11      | 0.051587658 | 0.958857254 | 6            | 0      | Not confidence   |
| 6   | 13      | -0.744525552 | 0.456558595 | 5            | 0      | Not confidence   |
| 7   | 7       | -0.67220584  | 0.501452668 | 4            | 0      | Not confidence   |
| 8   | 15      | -0.15885017  | 0.873759466 | 4            | 0      | Not confidence   |
| 9   | 4       | -1.083451363 | 0.27860145  | 3            | 0      | Not confidence   |
| 10  | 10      | 0.183328865  | 0.854539987 | 4            | 0      | Not confidence   |
| 11  | 8       | -1.366815565 | 0.171683123 | 5            | 0      | Not confidence   |
| 12  | 4       | -1.366815565 | 0.171683123 | 5            | 0      | Not confidence   |
| 13  | 7       | -1.366815565 | 0.171683123 | 5            | 0      | Not confidence   |
| 14  | 9       | -1.366815565 | 0.171683123 | 5            | 0      | Not confidence   |
| 15  | 13      | -1.366815565 | 0.171683123 | 5            | 0      | Not confidence   |
| 16  | 23      | 0.774681062  | 0.438528151 | 10           | 0      | Not confidence   |
| 17  | 16      | -0.026690933 | 0.978706245 | 9            | 0      | Not confidence   |
| 18  | 12      | 0.352910261  | 0.724155718 | 10           | 0      | Not confidence   |
| 19  | 3       | 0.360177788  | 0.718714185 | 11           | 0      | Not confidence   |
| 20  | 5       | 0.097866755  | 0.920308099 | 9            | 0      | Not confidence   |
| 21  | 6       | 0.611096218  | 0.541135887 | 4            | 0      | Not confidence   |
| 22  | 22      | 1.943284808  | 0.051981756 | 2            | 1      | Hotspot 90% confidence |
| 23  | 18      | 0.354435806  | 0.723012305 | 4            | 0      | Not confidence   |
| 24  | 25      | 0.083342413  | 0.933572777 | 3            | 0      | Not confidence   |
| 25  | 5       | 0.61106218   | 0.541135887 | 4            | 0      | Not confidence   |
| 26  | 8       | 0.412701266  | 0.679825498 | 6            | 0      | Not confidence   |
| 27  | 17      | 0.11112317   | 0.911581639 | 5            | 0      | Not confidence   |
| 28  | 9       | 0.412701266  | 0.679825498 | 6            | 0      | Not confidence   |
| 29  | 14      | 0.11112317   | 0.911581639 | 5            | 0      | Not confidence   |
| 30  | 12      | 0.71442809   | 0.474962513 | 10           | 0      | Not confidence   |
| 31  | 6       | 0.352910261  | 0.724155718 | 10           | 0      | Not confidence   |
| 32  | 16      | 0.360177788  | 0.718714185 | 11           | 0      | Not confidence   |
| 33  | 26      | 0.097866755  | 0.920308099 | 9            | 0      | Not confidence   |
| 34  | 11      | 0.111898376  | 0.910903985 | 10           | 0      | Not confidence   |
| 35  | 5       | -0.629698228 | 0.528892046 | 8            | 0      | Not confidence   |
Table 4: Explain Coordinates of all site and total number of species per each site

| OID | Site | Y                | X                | Species Number |
|-----|------|------------------|------------------|----------------|
| 1   | T-1  | 32°25'32.368"N  | 47°11'1.273"E   | 19             |
| 2   | T-1  | 32°25'15.9"N    | 47°11'46.977"E  | 12             |
| 3   | T-1  | 32°24'44.119"N  | 47°10'19.701"E  | 13             |
| 4   | T-1  | 32°26'39.674"N  | 47°10'59.061"E  | 6              |
| 5   | T-1  | 32°22'57.194"N  | 47°12'52.006"E  | 11             |
| 6   | T-2  | 32°23'6.303"N   | 47°21'3.4"E     | 13             |
| 7   | T-2  | 32°23'47.771"N  | 47°24'37.06"E   | 7              |
| 8   | T-2  | 32°21'50.709"N  | 47°21'15.127"E  | 15             |
| 9   | T-2  | 32°27'7.112"N   | 47°22'13.311"E  | 4              |
| 10  | T-2  | 32°23'0.084"N   | 47°17'18.968"E  | 10             |
| 11  | T-3  | 32°18'8.902"N   | 47°14'5.314"E   | 8              |
| 12  | T-3  | 32°17'26.322"N  | 47°14'8.53"E    | 4              |
| 13  | T-3  | 32°17'54.53"N   | 47°16'11.743"E  | 7              |
| 14  | T-3  | 32°16'26.642"N  | 47°15'42.223"E  | 9              |
| 15  | T-3  | 32°16'16.876"N  | 47°16'56.664"E  | 13             |
| 16  | T-4  | 32°5'3.93"N     | 47°35'0.447"E   | 23             |
| 17  | T-4  | 32°5'8.43"N     | 47°32'7.734"E   | 16             |
| 18  | T-4  | 32°4'49.137"N   | 47°36'43.323"E  | 12             |
| 19  | T-4  | 32°3'58.604"N   | 47°34'55.437"E  | 3              |
| 20  | T-4  | 32°5'8.43"N     | 47°37'59.222"E  | 5              |
| 21  | T-5  | 32°1'23.155"N   | 47°21'3.439"E   | 6              |
| 22  | T-5  | 32°5'24.592"N   | 47°17'58.773"E  | 22             |
| 23  | T-5  | 32°1'11.137"N   | 47°17'1.017"E   | 18             |
| 24  | T-5  | 31°59'15.766"N  | 47°23'45.31"E   | 25             |
| 25  | T-5  | 32°1'1.343"N    | 47°20'57.176"E  | 5              |
| 26  | T-6  | 32°1'40.278"N   | 47°30'13.613"E  | 8              |
| 27  | T-6  | 31°58'37.663"N  | 47°29'47.249"E  | 17             |
| 28  | T-6  | 32°2'51.237"N   | 47°29'7.462"E   | 9              |
| 29  | T-6  | 32°0'49.642"N   | 47°30'30.616"E  | 14             |
| 30  | T-6  | 32°2'5.087"N    | 47°31'42.491"E  | 12             |
| 31  | T-7  | 32°3'10.96"N    | 47°36'54.462"E  | 6              |
| 32  | T-7  | 32°3'0.21"N     | 47°35'4.423"E   | 16             |
| 33  | T-7  | 32°3'6.737"N    | 47°38'41.758"E  | 26             |
| 34  | T-7  | 32°1'54.932"N   | 47°36'23.999"E  | 11             |
| 35  | T-7  | 32°2'33.375"N   | 47°39'21.118"E  | 5              |
Figure 6: Modeling Hotspot figures showing Gi-Bin, Gi-P, Gi-Z, and N-Neighbor’s values label per each site on Teeb regional raster.
Based on the results shown above, it seems that there is a variation in the distribution of bird species over different habitats within Teeb protected area. This variation in distribution was created due to the diversity of landscape and plant-cover. It is obvious that specific areas has gotten the highest rank of importance in comparison with other locations that have been surveyed by the team. Mapping these important areas for the birds in Teeb area shows clearly the importance of some areas over other areas ecologically, subsequently, it illustrates the ecological hotspots in Teeb protected areas. The findings of this study provides the foundation for future studies in Teeb area that target birds and their habitats (in addition to other biodiversity components) in order to assist in addressing the limited resources towards better management of this important area.

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