Research Use of GIS for the Study of the Impact of Habitat Change on the Structure and Dynamics of Avifauna in Wetlands (Chott Echchergui, Algeria)

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Abstract

The Chott EchChergui is rich in diversity and a wintering place par excellence for water birds. But currently it is facing a strong destructive pressure which results in a drastic decline in the avian populations. The study focuses on an experimental mapping of the ecological habitat of this ecosystem in order to ensure good monitoring of the dynamics of its avian community over a period of 20 years. The approach adopted consists in the development of a new methodology based on the combination of applications from Geographic Information Systems, with fields observation data obtained through field surveys.

The results made it possible to establish a list of 72 species of birds belonging to 27 families and 13 orders. The mapping of the habitat made it possible to establish a georeferenced database on avian biodiversity and also to produce four thematic maps by means of an interpolation by continuous coloring of the four parameters acting on the evolution of avian numbers. These results only confirm the state of degradation of this ecosystem which is at the origin of the erosion of its avian biodiversity.)

Keywords: -avian biodiversity, monitoring, GIS, habitat, wetland, Algeria.

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Introduction

Currently, the destruction of wetland habitats poses a serious environmental problem which has serious consequences for biodiversity. While these environments play a key role for the human use of natural territories [1]. Mediterranean habitats are 72% degraded today [2]. These environments are to this day almost completely ignored and are the subject of very few conservation measures [3].

Since February 2, 2001, Chott EchChergui has been classified as a wetland of international importance by the Ramsar convention. It has an area of 8,555 km² which has given it the particularity of having several types of habitats and of containing several endangered and vulnerable plant and animal species. But unfortunately in these recent decades, strong human pressures have affected both quantitative and qualitative impacts on its biodiversity [4]. This worrying situation has its origins in several factors such as excessive pumping, uncontrolled urbanization, pollution, poaching [5], [6] which has led to an unprecedented drying out of this ecosystem and also to a considerable loss of its avian biodiversity which is reflected in an alarming decline in many birds that nest regularly as well as rare birds. According to [7] the many species are being threatened due to loss of habitat, human activity and climate change.

This alarming situation motivated this study, with three objectives: (1) study of avifauna in relation to the dynamics of vegetation (2) characterizing the structure and dynamics of the avian community over a period of 20 years (3) characterization of changes in ecological habitat by spatial analysis. The originality of this model lies in the fact that it makes use of new techniques such as Geographic Information Systems in the study of the dynamics of avifauna and also in the quantification of the loss of habitat. In addition, these techniques have become essential tools for mapping wildlife habitats and it serves as a decision-making way for the sustainable management of this fragile ecosystem.

1.Materials & methods

1.1.Study area

The study area, located 80 km south-east of the province of Saida and is 530 km south-west of Algiers (Figure 1) on the north-east part of Chott EchChergui. It fits into the space bounded in longitude by 0.6 ° E to 0.9 ° E and in latitude by 34.4 ° N to 34.6 ° N, extending over an area of 404 km2. Administratively, this area is located in the province of Saida, district of Hassasna, municipality of Ain Skhouna [4]. The study was carried out in ten stations whose demarcation was made in order to guarantee a good count of birds.

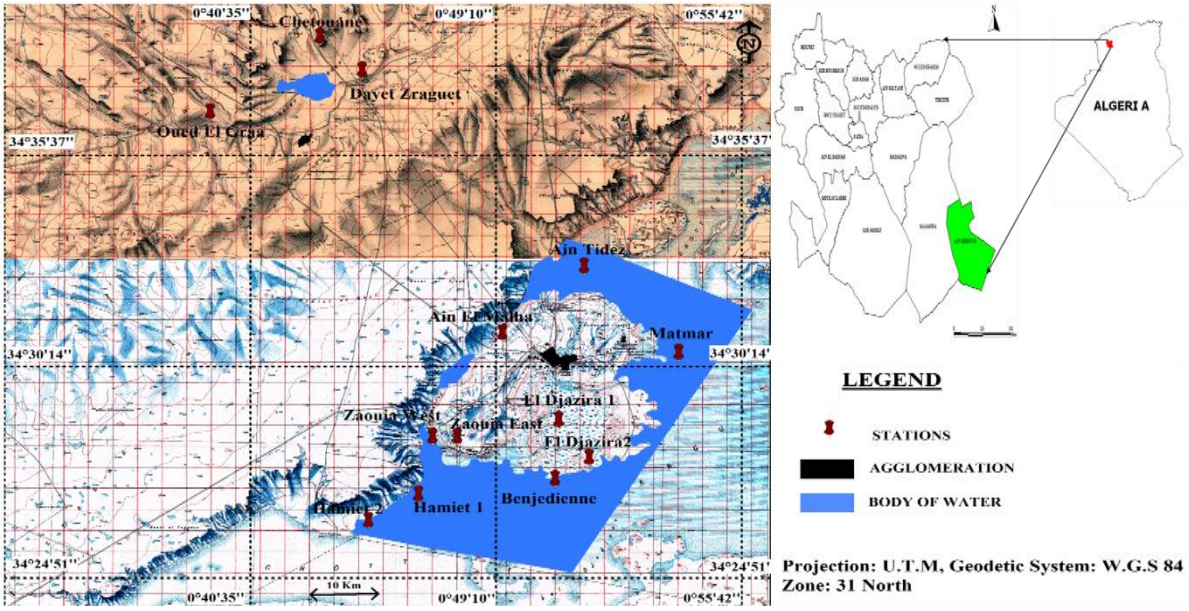

Figure .1. The location of the study area

This work is based on count data collected from the Forest Conservation of the province of Saida for a period of 20 years (2000-2019) and also field data collected while the winter seasons during four successive years (2016–2019). This new approach, which goes beyond traditional techniques, is used for experimental mapping via GIS Geographic Information Systems which are used in the mapping of wildlife habitats [8], [9].

1.2.Collecting historical data

The data were collected in the form of count sheets in the raw state without any treatment and they are extracted from the Bird winter counts that were made annually within the setting of the National counting of nesting birds operation launched by the Directorate General of Forests.

Collecting cartographic data

To optimize this part of the research, it is based on GIS technology. It turned out to be a lot of software to use: MapInfo 8.0, Google Earth Pro. Other primary sources of information were shared. All of these maps were digitized and then georeferenced in the UTM coordinate system (WGS 84, Zone 31 North), allowing them to be superimposed. The maps that were used are: Staff Map (DayetZraguet n° 335 and Skhouna n° 363); vegetation map of [10] and land use map [11]. We also used vegetation maps from old studies to characterize the regressive dynamics of vegetation [12], [13] to characterize old vegetation and to properly determine the change in facies

Bird study

Field prospecting studies have been carried out since 2016, during the period from December 15 to January 15 using the following equipment: a pair of binoculars and a telescope belonging to the

Forest Conservation of the province of Saida, a camera and a GPS. The determination of the taxa was made from two bird guides proposed by [14]. These studies referred to classical methods of studying aquatic avifauna based on counting methods, according to the technique of counting by foot which is the most used [15].

For the study of the ecology of the avian population in order to characterize its balance, three ecological indices were calculated, namely: total abundance index, species richness, frequency of occurrence. The total abundance expresses the total number of all the water bird species that frequented the Chott EchChergui between 2000 and 2019. The specific richness is the number of species encountered at least once at the end of N surveys [15]. The frequency or constancy C (%) is the ratio between the numbers of existing "Pi" or "x" species and the total number "P" of surveys taken, most often expressed as a percentage [16].

As for the study of the phenological type of the avian population, it was made on the basis of other additional field trips which were made using the same technique described previously but during the period from the month of April to the month of July.

Creation of a georeferenced database and spatial analysis

All cartographic and alphanumeric data are recorded and structured in a database (SGBD) and managed and analyzed using a Geographic Information System (GIS). This allowed us to create habitat maps for 2000 and 2019 as well as the map of plant groups.

Spatial analyzes of interpolation by continuous coloring make it possible to predict the distribution of the avian population over the whole of the study area even in places not sampled. According to the first law of geography: “Everything is related to everything else, but near things are more related than distant things“[17]. Weighting was done by inverse distance (IDW). This method makes it possible to estimate the value of a cell by performing a weighted average of the neighboring known points [18]. This is defined [19] by: with the distances for the points x 1, ..., x n and k the 'power' parameter chosen by the user (Bogaert, 2012 in [19]). It therefore depends on the Euclidean distance between the sampled point and the non-sampled point based on the principles that the closer the known point is to the center of the cell, the more influence it has on the averaging procedure than the furthest point. According to [19] the value of the attribute of a point to be estimated is equal to:

$$z(x_0) = \sum_{i=1}^{n} \gamma_i \; z(x_i)$$

$$\gamma_i = \frac{\frac{1}{||h_{oi}||^k}}{\sum_{i=1}^{n} \frac{1}{||h_{oi}||^k}} \text{ avec } k > 0$$

With z (x0) the value of the attribute at the unknown point x 0, z (xi) the value of the attribute at the known point i, n the number of known points, and γi the weight.

2.Results and discussion

Dynamics of the avian community

The study area presents a great wealth of birdlife which represents 39, 78% of the species and 49.1% of the families constituting the regular birdlife in Algeria. 72 species have been inventoried belonging to 13 orders (annexe 1) of which the Charadriiformes constitute the most dominant order and 27 families of which the families with the most responses are respectively: *Anatidae, Ardeidae,*Scolopacidae. The most representative species are: the Common Shelduck, the *CommonTeal, the Mallard, and the Greter Flamingo.*

2.1.Species richness

When specific wealth is important at the beginning of the period (Figure 2), then it begins to decrease from 2015 due to the strong destructive pressures which led to the scarcity and shrinking of habitat. The diachronic study shows that 18 species have disappeared and 10 others are endangered. And that 9 new species have just settled. Birds respond quickly to environmental upheavals by reducing their abundance, or even by the disappearance of certain species [20].

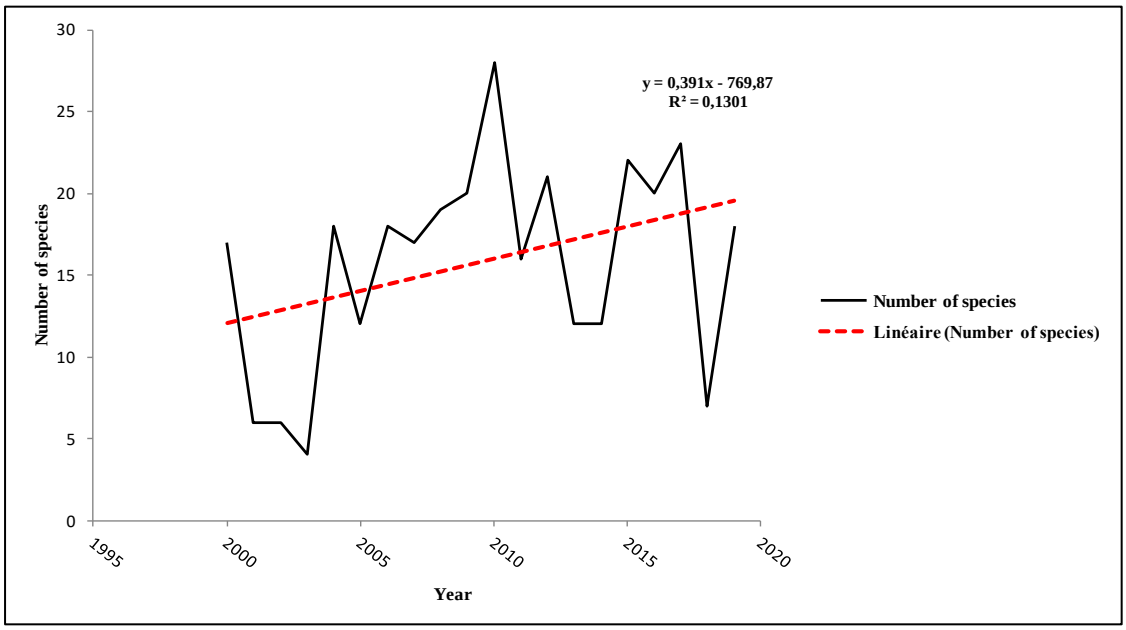

Figure .2. Fluctuation of specific richness (2000 - 2019).

Decrease in specific richness characterized by a massive drop in the number of aquatic bird species. Habitat fragmentation influences species richness [21]. This is coincides with the results of previous work in different ecosystems around the world [22].

The use of the results of the diachronic study indicates an upheaval in the structure of the avian community, because among the 72 species identified in our study area. We distinguish:

- **Extinct species:***Egrettagarzetta, Circus aeruginosus, Plegadisfalcinellus, Mareca strepera, Anas acuta, Aythyanyroca, Ciconia ciconia, Rallus aquaticus, Himantopus himantopus, Sturnus vulgaris, Phoenicopterus roseus, Fulicaatra, Aythya ferina, Gallinula chloropus, Pteroclesorientalis, Ardea alba, Charadrius alexandrinus, Chlidonias hybridus.*

- ***Endangered species:*** *Grus grus, Tringanebularia, Anas platyrhynchos, Marecapenelope, Anas clypeata, Anas crecca, Tadornaferruginea, Tadornatadorna, Ardea cinerea, Bubulcus ibis.*

- ***New species:****Calandrellabrachydactyla, Alauda arvensis, Branta leucopsis, Pteroclesalchata, Corvus corax, Phalacrocorax carbo, Podiceps grisegena, Columba livia, Streptopeliaturtur.*

2.2.Frequency of occurrence

Analysis of the frequency of occurrence of species makes it possible to identify 05 classes with the total absence of rare species and the presence of a single ubiquitous species (Table 1), the *Mallard. Among* the accidental species the *Marbled Teal* which is less represented and less frequented at the level of Chott, according to [23]. In Algeria, this species has a fragmented distribution and it is present in coastal wetlands, semi-arid environments.

Table 1. Percentages of species by frequency of occurrence index.

Index	Type	Number	Percentage
0<FO<5%	Rare species	00	0%
5≤FO<25%	Accidental species	53	73%
25≤FO<50%	Accessory species	06	8%
50≤FO<75%	Regular species	09	12%
75≤FO<100%	Constant species	04	6%
FO=100%	Ubiquitous species	01	1%

The high rate of accidental species is only proof that Chott Ech Chergui plays the role of a stopover station for passing birds and also a place of refuge for wintering migratory birds.

Algerian wetlands represent, for migratory avifauna, favoured places of rest, wintering or reproduction between the Mediterranean and sub-Saharan Africa [24].

2.3.Phenological status

The phenological status of the species is characterized by the existence of 04 phenological categories (Figure 3). This testifies to a mosaic of habitats promoting the nesting, reproduction and wintering of several species. Gross changes in phenological status have been reported following environmental changes. Other species belonging to different sub-populations of the same taxonomic group have the distinction of having a double and triple phenological status.

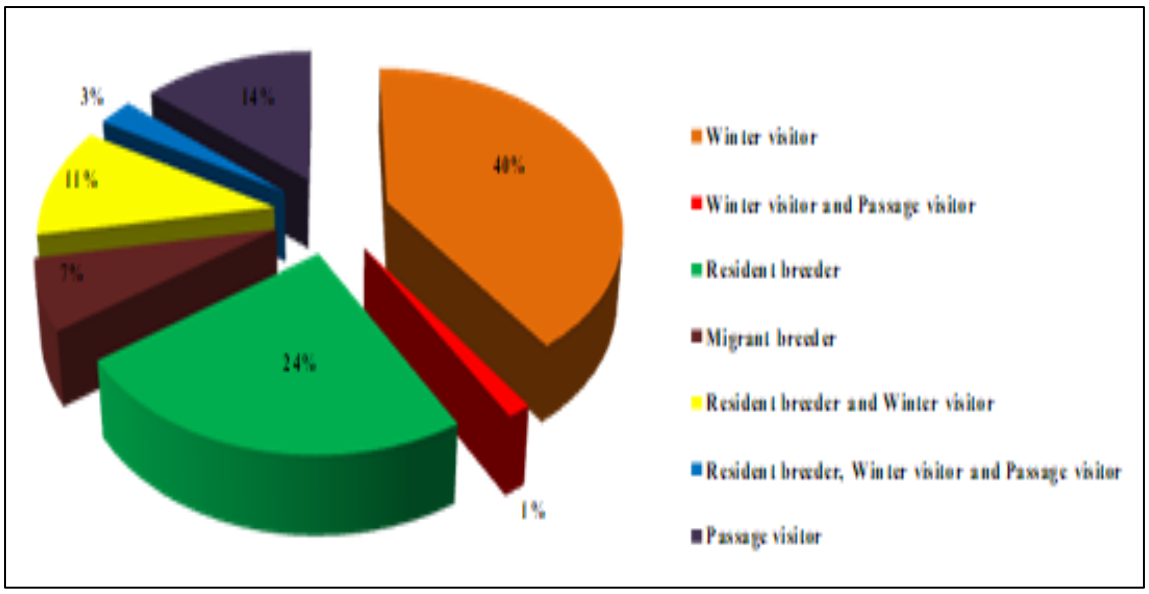

Figure.3. Percentages of the different phenological type of Chott Ech Chergui.

The comparison of the results obtained with the results of previous studies of [25] clearly shows a gross change in the phenological groups (Fig. 4) from which the disappearance of 05 phenological groups composed by 13 species with double and triple status is recorded and the appearance of a new phenological group of Migrant breeder represented by 05 species. The sedentary and wintering breeding bird's phenological group is the only group that has retained its status with no change in species.

Table.2. Change in phenological status between 2000 and 2019.

phenological type	Actual status	Old status [25]
Winter visitor	29	8
Winter visitor and Passage visitor	1	20
Resident breeder	17	9
Migrant breeder	5	0
Resident breeder and Winter visitor	8	8
Resident breeder, Winter visitor and Passage visitor	2	10

Passage visitor	10	1
Vanished breeder and Winter visitor	0	1
Vanished breeder , Passage visitor and Winter visitor	0	1
Migrant breeder and Winter visitor	0	1
Migrant breeder and Passage visitor	0	5
Migrant breeder, Winter visitor and Passage visitor	0	5

Change in phenological type of avian species due to changes in environmental conditions. According to [26] birds are key ambassadors for understanding the effect of these climate changes on biodiversity. This change shows that Chott Ech Chergui is an important wintering site and passage for many birds; this is explained by the particular position of this wetland at the level of the Tellian region interface in the North - Saharan region in the South. In addition, our country is located between the classic migration routes of Gibraltar (West route) and the Siculo-Tunisian strait (East route), which therefore allows Algeria to be both a large reception area and stopover for trans-Mediterranean migratory birds [27].

2.4.Structure of the avian community

The spatial analysis recommends capitalizing all the results of the research carried out in order to create a database with spatial references. The digitization of the maps made it possible to create a vector file in (.tab) format on which all the data were injected in order to make the link between the graphic data and the numerical data, which allows the comprehension of the existing relations between the environmental variables (figure 4).

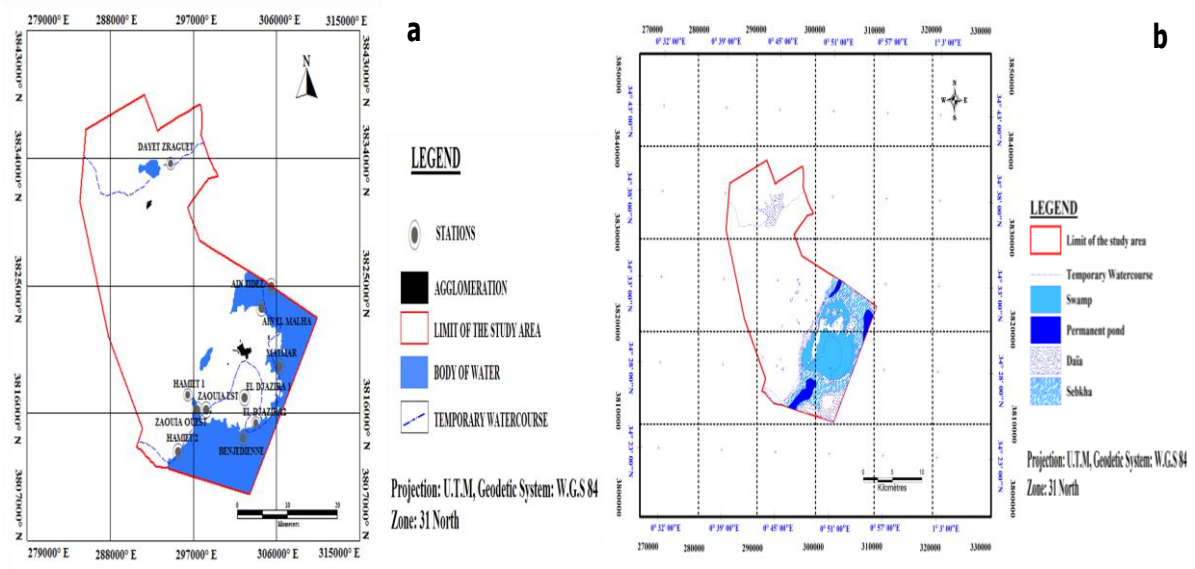

Figure .4. Destruction of habitat between (a)2019 and (b) 2000.

The results obtained compared with the reality on the ground make it possible to determine the plant groups currently existing in the study area (figure 5).

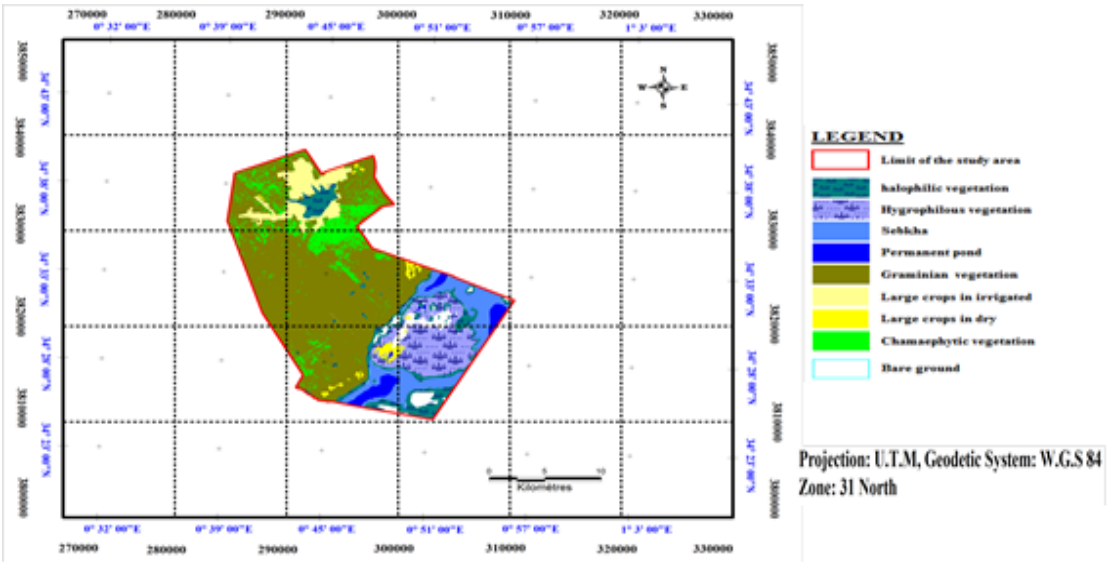

Figure .5. Map of plant groups for 2019.

The regressive dynamics of the vegetation characterized by a change of facies clearly shows the destruction of the ecological habitat of this ecosystem already weakened by severe climatic conditions (tab.3).

Table 3. Destruction of habitat due to changes in vegetation facies.

plant formation	Old vegetation [13]	Current vegetation	
		Facies	Characteristic species
Graminian vegetation	Facies of Stipa tenacissima	Facies of Stipa tenacissima	Lygeum spartum (in South), Stipa tenacissima (in North) and Peganum
		Facies of Lygeum spartum	
		Facies of Peganum harmala	
Chamaephyti	Facies of Artemisia	Facies of Artemisia herba	Artemisia herba alba,
		Facies of degradation	
halophilic vegetation	Association of Artemesia herba alba and	Facies of Atriplex halimus	Sueada fruticosa, Limonium Echioides, Atriplex halimus, atriplex glauca, Salsola vermicluata, salsola sieberi, Halocnemum strobilaceum, Tamarix gallica et Tamarix boveana
	Facies of Atriplex mauritanica and Suaeda fruticosa	Facies of Tamarix gallica	
		Facies of Sueda fruticosa	
	Facies of Halocnemum	Facies of Halocnemum strobaliceum	
Hygrophilous vegetation	Facies of Jancus maritimus	Facies of Jancus aquaticus	Typha angustifolia et Jancus maritimu, Juncus aquaticus
		Facies of Jancus maritimus	
		Facies of Thypha	

The spatial analysis by interpolation (Figure 6) allowed the generation of four raster maps revealing fluctuations in the number of families, numbers of individuals and also the rate of contribution of the species compared to all the space of the study area.

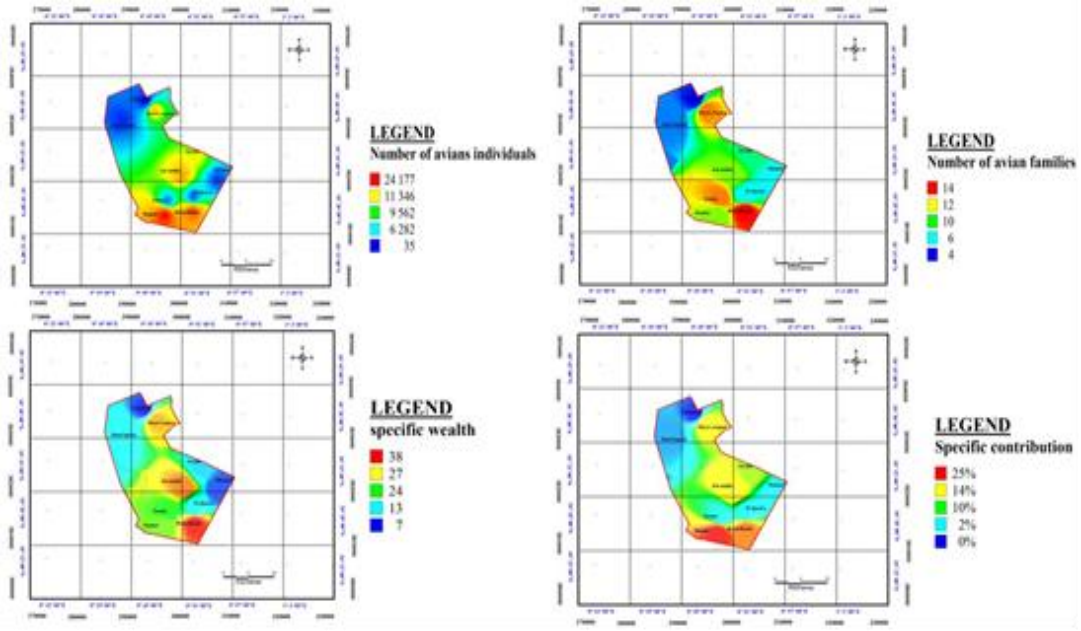

Figure .6. Maps of the four interpolated parameters,(a) number of avian individuals, (b) number of families, (c) specific wealth and (d) specific contribution.

These maps clearly show correlations between the estimates obtained and the land cover. The four parameters studied are decreasing when heading north, this is explained by the remoteness of the body of water on the one hand and also by the nature of the vegetation on the other hand which provides adequate habitat for avifauna south from the north of the study area. The southern part is very rich in hygrophilic and halophytic vegetation which provides birds, this vegetation consists essentially of tufts of *Thypha angustifolia, Jancus maritimus*, it represents a nesting place for *Anatidae and Rallidae*. The species with a high specific contribution are generally those which prefer the deepest places of the water like Benjedienne and Hamiat and the species with very low specific contribution are those which are endangered are those which are endangered such as the

Marbled duck, the Ferruginous Duckand the Purple Swamp-hen, which are poorly represented in Algeria [25]. It should also be noted that the wetlands named respectively (Oued Lagraa, Sed Mechrouk and Chetouane) appeared recently since 2017, the reason why they do not appear in the previous maps. This explains the low values recorded for the four parameters studied. Degradation of the plant cover with a displacement within the limits of the plant species, accompanied by a gross change of very marked physiognomic type, such as for example: *Stipa tenacissima and Artemisia herba alba* which have been replaced by undesirable species such as *Peganum harmala.*

We can conclude that Extinct or endangered species are generally species with a high heritage value. The majority of these species are species that are strongly linked to habitat. According to [28] disappearance, fragmentation or degradation of their habitat seems to be directly involved. The decline is more remarkable in Ducks; this is explained by the decrease in the reed bed which constitutes a source of food for the Ducks. The extension of agricultural land to the detriment of the natural vegetation of Chott, has affected these species. According to [28] this situation has led to eutrophication due to inputs (nitrates, phosphorus), which allows the establishment of more suitable vegetation such as *Thypha angustifolia*. But unfortunately, this type of vegetation is not appreciated by the Anatidea. While, New species are generally those which prefer open areas and crops such as bare lawns (*Calandrella brachydactyla, Alauda arvensis, Branta leucopsis* [29] fallow and uncultivated areas (*Pterocles alchata*) [30] anthropogenic zones (*Corvus corax*) [31] and in particular the urban fabric (*Columba livia, Streptopelia turtur*) [32].

Conclusion

The integration of the data collected into a Geographic Information System GIS has made it possible to concretize perfectly the current state of degradation that the Chott Ech Chergui is experiencing and regressive dynamics of the avian population.

The thematic maps obtained constitute a tool for understanding the functioning of the Chott Ech Chergui ecosystem because they allow the spatial localization of statistical information on the evolution of the four parameters acting on the distribution of the avian population.

We could then conclude that this study undoubtedly gave appreciable results through the use of innovative techniques based on Geographic Information Systems, which made it possible to greatly improve knowledge in terms of characterization of wetland habitats and ecological diagnosis. The maps produced in this way can be used as a fundamental decision-making support tool to guide future programs and apply wetland development policies in the (short, medium and long) term for better management of the problem of erosion of the biodiversity of Chott Ech Chergui.

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