Spatial distribution and nesting behavior of the Black-winged Stilt (*Himantopus himantopus*, Linnaeus 1758) in the peri-urban wetland of Dakar Technopôle (Senegal, West Africa)

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Abstract

This study focused on the spatial distribution and nesting of the Black-winged Stilt (*Himantopus himantopus*) at the Dakar Technopôle in 2017 and 2018. The Technopôle constitutes a particular wetland ecosystem, playing a determining role in the reproduction and survival of many bird species, and it is part of the Niayes Important Bird & Biodiversity Area (IBA). The maximum numbers of Black-winged Stilt counted during breeding periods are 766 individuals in 2017 and 1506 individuals in 2018. However, numbers decrease on arrival of the rains. Data on reproduction (79 nests in 2017 and 71 nests in 2018) show that this peri-urban wetland is a favoured environment for Black-winged Stilt nesting. This is the first time that such a large number of Black-winged Stilt nests have been reported in Senegal. In spite of disturbances linked to anthropogenic factors, the reproductive success of Black-winged Stilt reached more than 85% during the two years of monitoring. The Technopôle requires protection measures for better preservation of biodiversity, particularly for birds, especially noting the site's recent status as a nature reserve (Réserve naturelle urbaine de la grande Niaye de Pikine) and the growing popularity of the site for birdwatching and ecotourism.

Keywords: Black-winged Stilt, Niayes of Dakar, Nesting, Technopôle, Urban wetland.

INTRODUCTION

Waterbirds, most often migratory, fly very long distances during their annual migration cycles and follow "migration routes" linking their breeding sites to other areas important for their survival. They are a marvel of nature and a vital global resource for animal biodiversity. In the Important bird and biodiversity areas (IBAs) of the Niayes of Dakar, the few existing scientific studies have reported a significant presence of birds during a certain period of the year (Diallo, 2012; Diop, 2012; Dione, 2014; Gadiaga, 2014). Presence and breeding of Himantopus himantopus himantopus in Technopôle were reported in Diallo (2012). Presence of H. h. himantopus in Senegal precisely in Saloum Delta National Park (PNDS) were reported in by Morel, they are more than 20 years. These sub-species lives mainly near freshwater and salt marshes, in saltlick, shallow lakes, coastal lagoons, flooded fields and rice paddies.

The species is represented by four subspecies: H. h. himantopus, H. h. knudseni, H. h. melanurus et H. h. leucocephalus. The subspecies H. h. himantopus is made up of six groups (Birdlife International, 2016) that are the following: himantopus, West and South-West Europe, West Africa (group 1); himantopus, Central and East Europe, East Mediterranean (group 2); himantopus, South-West Asia (group 3); himantopus, Sub-Saharan Africa (group 4); himantopus, Meridionalis (group 5); himantopus, Madagascar (group 6).

Only groups one and four concern Senegal. Group 1 is estimated between 71,000 and 82,000 individuals and group 4 is estimated between 100,000 and 200,000 individuals. The world population is estimated between 450,000 to 780,000 individuals. The species breeds generally in shallow freshwaters and brackish wetlands with substrates of sand, mud or clay and open margins, islets or spits from the nearby water level (Birdlife International, 2016).

The nesting period is between April and June. The female lays four olive-green eggs stained with gray and black. The incubation is biparental and lasts 22 to 26 days. At birth, the chicks are covered with dark down, with gray spots or blackish brown. The lower parts are white. This juvenile plumage is preserved until the ninth month. The chicks are nesting and leave the nest to hide in the surrounding vegetation. They are fed by both parents. They fly away after four weeks after birth and become independent two to four weeks later (Rihane, 2007; Adamou et al., 2009; Birdlife International, 2016).

In this paper we contribute to the production of data about this species in Senegal, particularly in the peri-urban wetland of Technopôle. These data are about the distribution and reproduction of the Black winged-stilt (*Himantopus himantopus himantopus*).

METHODS

Location of the study area

The Niayes system stretches along the main Senegalese coast to the heart of the Cape Verde peninsula. The Niayes consist of inter-dune depressions where the touch of the water table is conducive to the development of a Guinean-type climate. It is a market garden, arboreal and poultry area of the first plan that supplies the agglomerations of Dakar and surrounding areas. In the Dakar region, many of the areas formerly occupied by the Niayes (Figure 1) have now disappeared because of the strong demographic pressure. The breeding data of *Himantopus himantopus* presented in this document come from the peri-urban wetland named Technopole (geographical coordinates 14° 45' 16.69" N and 17° 24' 48.41" W), which is part of the Niayes of Dakar (the Niayes of Pikine, the catchment area, the Mbeubeuss lake, the Retba lake, the Mbaouane lake and the Pink Lake or Tanma lake). The surface of the Technopole is about 200 hectares. It is bordered to the north by the Golf-Nord district of Guediawaye, to the south by the highway, to the east by the Pikine agglomeration and to the west by Camberene.

The Technopole project on the Niayes site was authorized by the Senegalese state by Law No. 96-36 of December 31st, 1996. The aim was to host research and teaching centers as well as companies developing technological innovation. Thus, a protective wall had been erected on the side of the highway. The wetland area of the Technopôle was declared “Réserve Naturelle Urbaine de la Grande Niaye de Pikine” by Decree number 2019-748 of 29 March 2019.

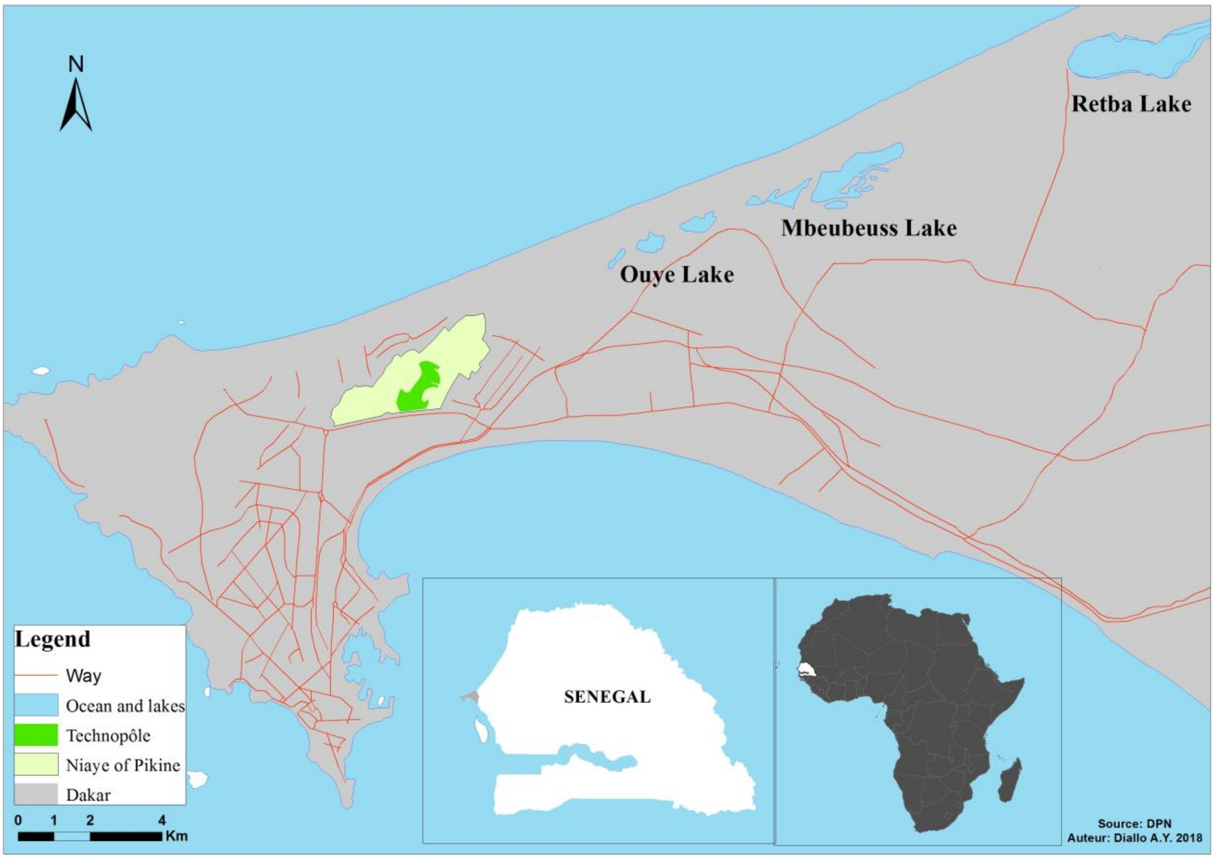

Figure 1: Location of Technopôle (ArcGIS)

Physical aspect and biological resource of the study area

The Niayes of Pikine belong to the sub-Canarian microclimate. Its climate is influenced by the maritime trade winds which are present all the year. These trade winds mitigate seasonal thermal contrasts and soften temperatures (Touré 2004). Annual rainfall is generally between 300 and 500 mm and their average reaches 469 mm. Maxims are recorded in August. The very short rainy season usually lasts three to four months. Annual temperatures vary between 24.5 ° C. The warmest month of the year is October, with an average temperature of 28.1 ° C and February is the coldest month with an average temperature of 21.7 ° C (Ndiaye et al., 2012). Vegetation is dominated by a typical Guinean species, *Elaeis guineensis*, which marks the contact zone between the bottom of the dune system and the depression. We also note the presence of *Cocos nucifera* and a large herbaceous layer conditioned by the topography of the environment (Touré, 2004).

These Niayes interdunal depressions are home to species with subguineous affinity (10%) such as *Detarium senegalense*, *Kigelia africana*, *Antiaris africana*, *Malacantha aulnifolia*, and Sudanian (12%) *Parkia biglobosa, Prosopis africana*.

In this vegetation cover lives a very diverse fauna, consisting of reptiles and soil organisms (protozoa, nematodes, rotifers, earthworms, ants, and other small apterygota insects) that constitute a large part of the bird's food. The latter represent the majority of vertebrate present on the science park and have about 150 species (Hopkins and Diop, 2011). Some water bodies, invaded by reeds, are rich in fish that are represented by three species (*Tilapia guineensis, Tilapia sp, Clarias anguillaris)* (A.Y. Diallo unpublished data).

Fieldwork

At the beginning of the fieldwork, we carried out preliminary surveys and prospecting at the Niayes level in Dakar. These surveys and prospecting enabled us to identify the Technopôle as a reproduction site for the Black Winged-stilt and track nesting behavior.

Spatial distribution

This part of the work was carried out from January 2017 to December 2019. For this, we divided the surveyed area in several zones indicated in the Figure 2. Thus we made a systematic count of all the Black Winged-stilts between 07:00 hr and 12:00 hr in each zone. This allowed us to locate the geographical distribution of Black Winged-stilts in the Technopôle. Data on the geographical distribution of Black Winged-stilts were analyzed using ArcGIS 10.3 and R-3.3.3 software.

Figure 2: Zoning of the site (Google Earth)

Nesting behavior

We identified the nests of Black Winged-stilt simultaneously to the study of the spatial distribution of these birds. The main objective of the protocol was to monitor the reproduction of the Black winged-stilt population in the Niayes of Pikine, thus making it possible to specify the life cycle of the species (laying dates, number of eggs laid, dates of hatching and incubation time). Thus, we carried out a regular check of the nests and their states of evolution. The parameters of whether or not the nest is occupied by the male or the female as well as the stage of reproduction (during laying or incubation) are recorded.

Statistical analysis

Data on nesting behavior of Black winged-stilt was analyzed using ArcGIS 10.3 and R-3.3.3 software. We also used the Kendall rate to measure the relationships between the measured quantities (nests / chicks), and Fisher's exact test (or then Chi-square test) to show that the changes in size between the different zones are significant or not. And, finally we use the statistical hypothesis test (T-test) to evaluate relationship between the presence of the Black Winged-stilts and the water level.

The Mayfield method described by the relationship below allowed us to estimate the probability of survival (daily) of nests and / or young chicks, an indicator of reproductive success.

$p = \frac{(a-b)}{a}$ {*p = daily survival probability / a = exposure days / b = failed nests*}

$P = p^x$ {*P = survival probability* / x = *nesting period*}

RESULTS

Evolution of the workforce

The following results will show the evolution of Black-winged Stilts numbers over the last ten years in Senegal during the International Waterbird Census (IWC). This will be followed by the monthly numbers during our study period.

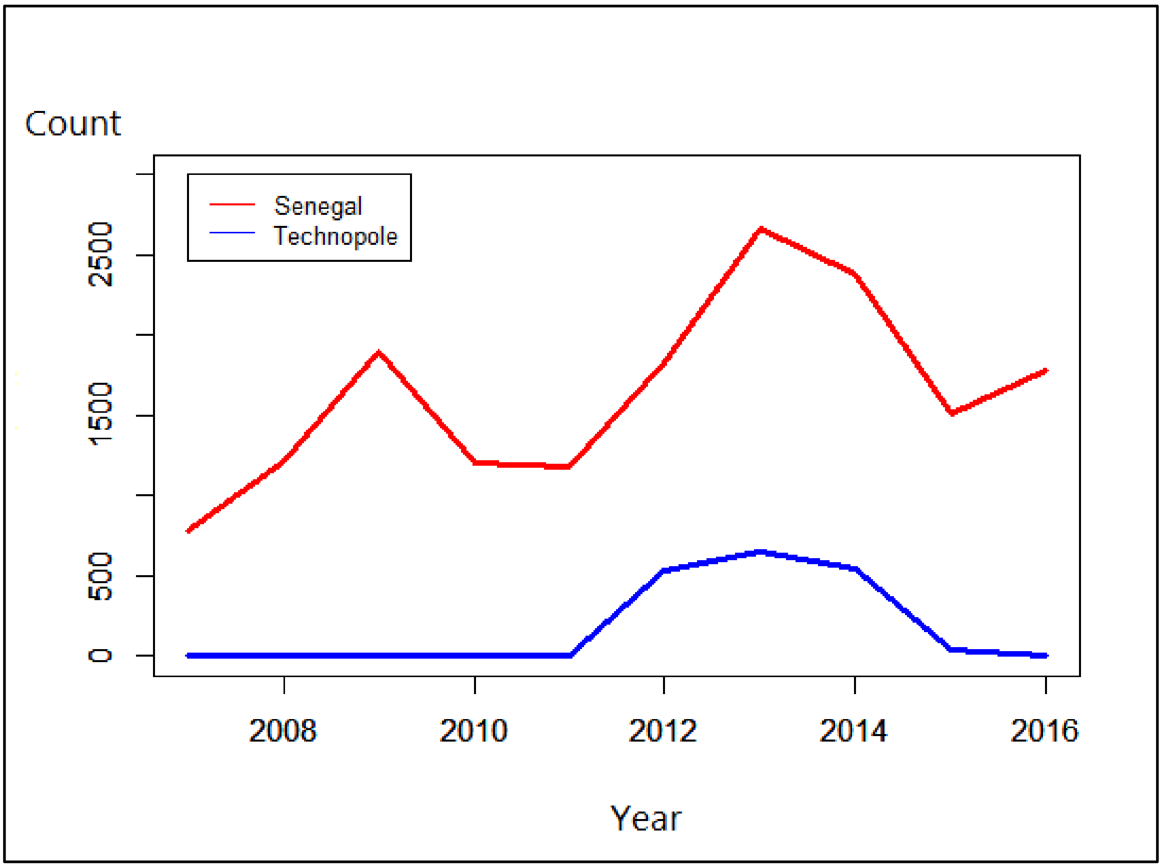

Figure 3: Evolution of the number of Black-winged Stilts in Senegal and in the Technopôle during the IWC from 2007 to 2019 (Source DPN)

Figure 3 shows two upward trend curves for the population of Black-winged Stilts in Senegal. And at the site level, in this case the Technopôle, the evolution of this population is in line with that of the national population. We therefore have a stable, rising population.

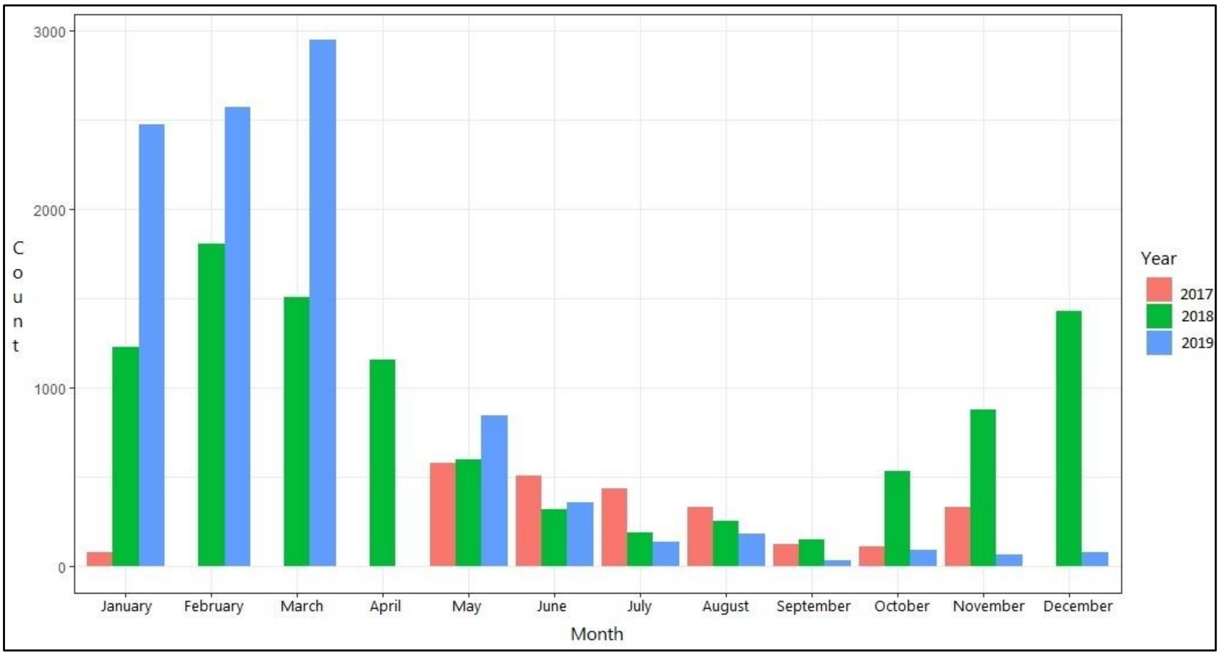

Figure 4: Evolution of the annual workforce at the Technopôle in 2017, 2018 and 2019.

This graph allows us to see the evolution of the Black-winged Stilts population staying at the Technopôle from 2017 to 2019. The striking finding here is the fact that there are more individuals (between 1,500 and over 2,500) on the site before the breeding period (December to March), especially in 2018 and 2019; and that during the breeding period itself (April to July) the number of individuals rarely reaches 1,000. This could be explained by the fact that only those individuals able to reproduce or sexually mature remain on the site and that the rest of the (younger) population disperse to other favourable locations for food, recreation and rest, while avoiding territorial competition with the more experienced ones.

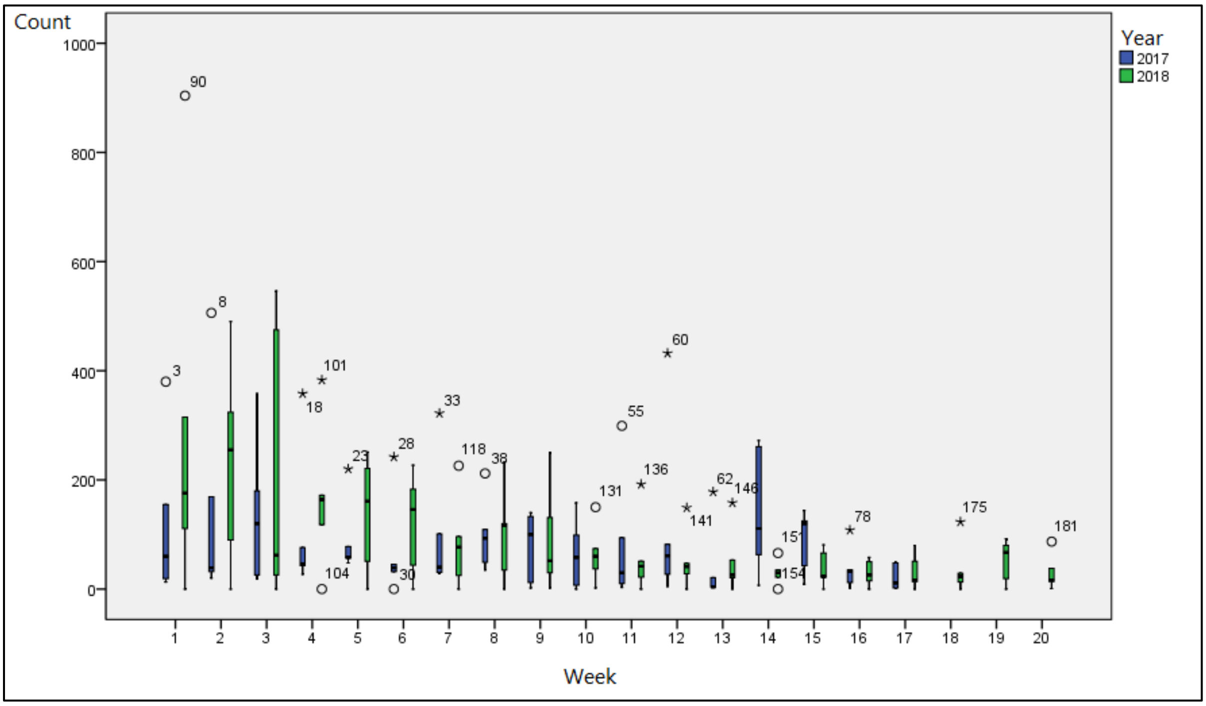

Figure 5: Evolution of numbers per week during the breeding period in 2017 and 2018.

The trend curve in figure 19 shows a decreasing evolution of the numbers of the Black-winged Stilt population during the breeding period at the Technopole. In 2017, the results show two peaks, one at the beginning of reproduction (766 individuals) and another after the middle of reproduction (714 individuals). In 2018, the maximum (1506 individuals) is reached at the start of reproduction at the Technopôle. This decrease in the site's population is accentuated over time with the arrival of wintering.

Spatial distribution of individuals

On the Technopôle site, the study area has been divided into 5 parts, and the following graphs illustrate the distribution of individuals in these different parts.

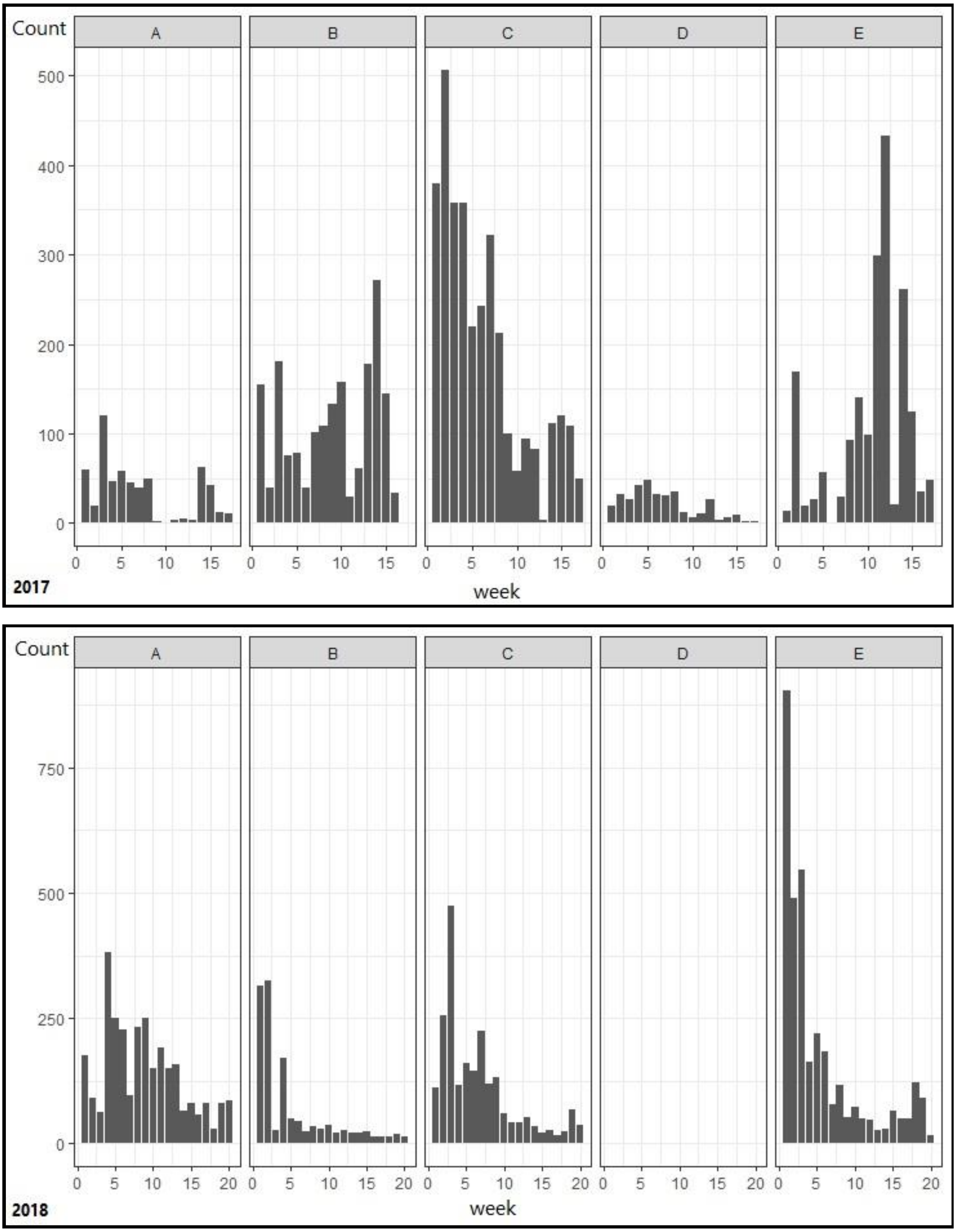

Figure 6: Spatial distribution of Black-winged Stilt at the Technopole during breeding in 2017 and 2018.

In 2017 the numbers are higher in zones B, C and E. In 2018, there are some changes in the relative abundance of birds with higher numbers in areas A, C and E. According to the Kruskal-Wallis test carried out, the significance level alpha = 0.050 the null hypothesis of no difference between the five zones can be rejected. In other words, the variation in bird numbers between these different zones is significant with a one-sided p-value of < 0.0001.

These results show that the spatial distribution of Black-winged Stilt at the Technopôle varied between 2017 and 2018. It is at the level of zones A and B that changes in the distribution of birds and especially in the distribution of nests were noted (see figures 6 and 7).

Nesting behaviour

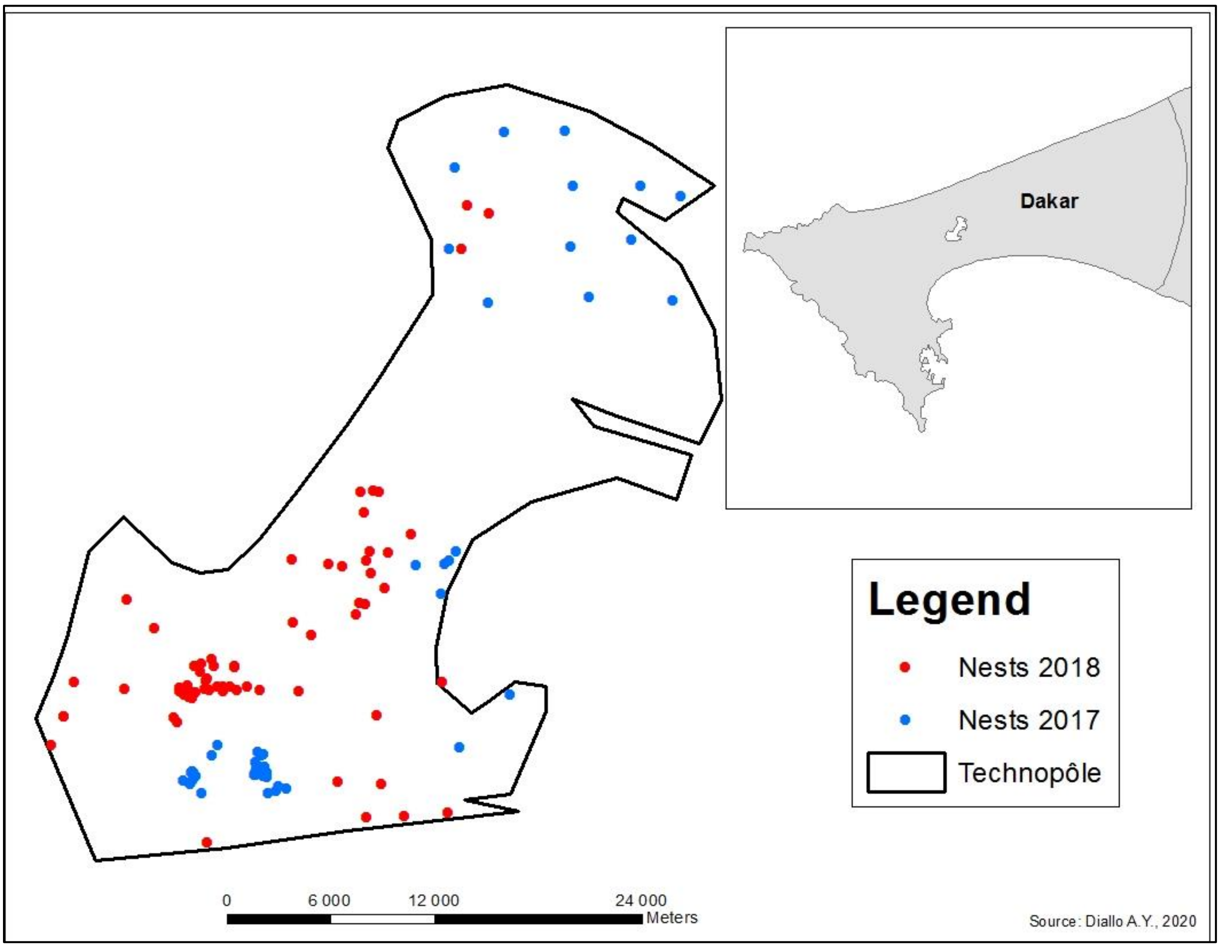

Figure 7: Maps of nest distribution in 2017 and 2018

A total of 79 Black-winged Stilt nests were identified and monitored during this study for the year 2017, however only 55 could be located on site. The 24 others were located in inaccessible locations and were projected on Google Earth. In 2018, the nests were even more inaccessible; a total of 71 nests were identified. These were projected directly onto Google

Earth using a site grid system to obtain geographic coordinates. The geographical distribution of these nests at the site level is shown in Figure 7. As a result, there was a real change in the location of the nests from one year to the next. They are concentrated between areas A, B and E (Fig. 6) in 2017, and at the level of areas A and C in 2018. Those in 2018 are located in more inaccessible areas than those in 2017. This may be due to external pressures (grass cutters, fishermen and especially stray dogs) on the accessibility of the breeding area during the first year of breeding. However, the majority of breeding still takes place in the southern part of the Technopôle, where the bodies of water are shallower than in the other basins further north of the site.

Figure 8: Some images of the reproduction of the Black-winged Stilt at the Technopôle in 2017 (Diallo A.Y.)

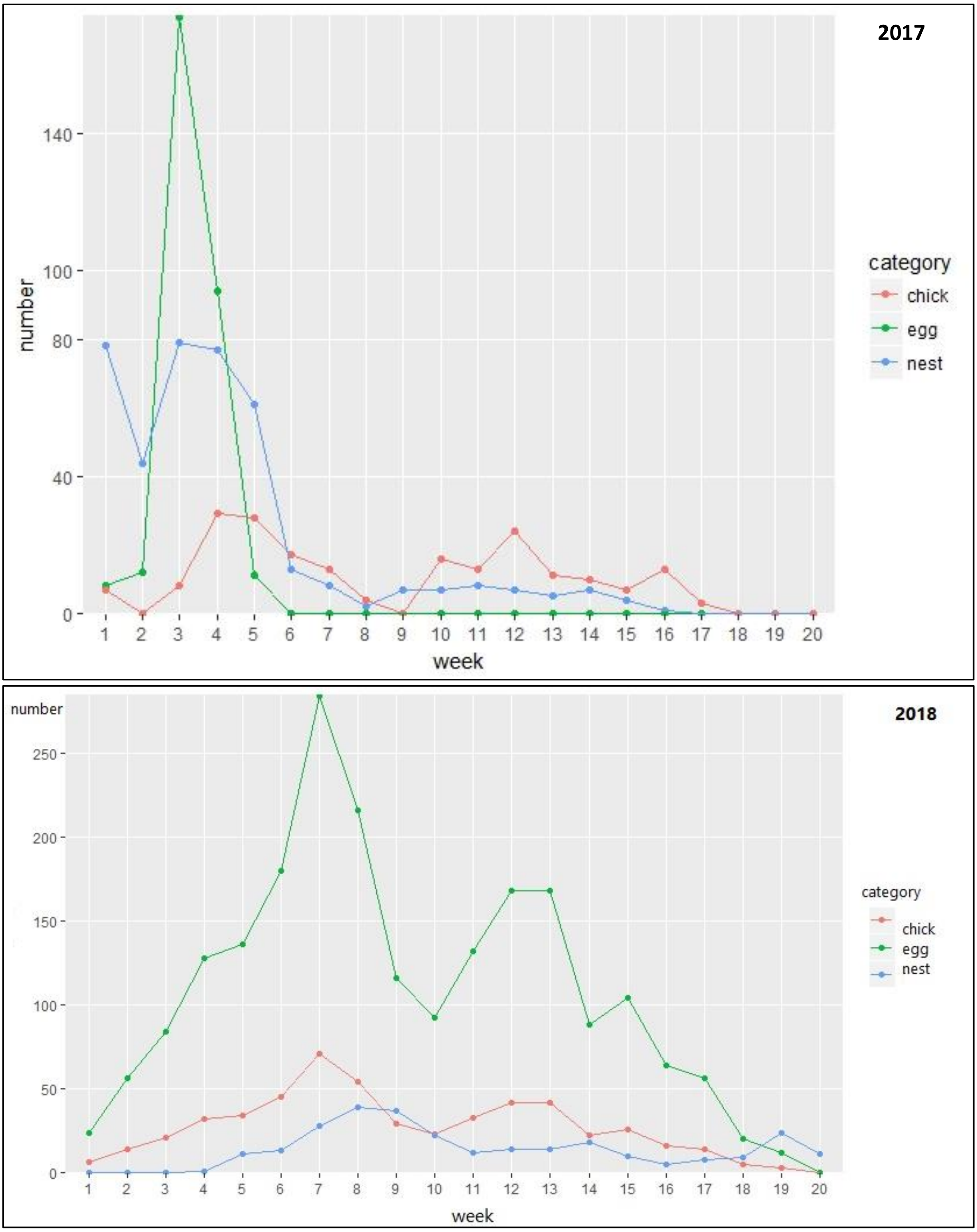

Figure 9: Evolution of the number of nests, eggs and chicks in 2017 and 2018

The distribution is not homogeneous for the two years of monitoring. According to the Kruskal-Wallis test Ch2 = 6.1111, df = 2 with a p-value = 0.0471 in 2017; and in 2018 Chi2 = 25.933, df = 2, p-value = 0.000002337.

The number of nests starts to decrease with the arrival of wintering. At the same time, we are witnessing an increase in hatching. Figure 9 does not really reflect all the chicks born, but only those observed, as the fate of the chicks is often difficult to determine due to their down adapted to camouflage in the surrounding vegetation. Although the difference in the number of nests is not significant from one year to the next, there is a clear difference in the cumulative number of chicks observed throughout the breeding period. Indeed, there were a total of 203 chicks observed in 2017 and 276 in 2018.

Table 1: Probability of total survival (P) according to the Mayfield method

Week	**2017 (%)**	**2018 (%)**
1	89,6	100
10	100	100
15	53,1	31
20	0	0

Survival probabilities are very high at the beginning of reproduction with a success rate exceeding 85% in 2017 and reaching 100% in 2018. And in the middle of the breeding season survival is 100% for both years; and it is around 50% in 2017 and 30% in 2018 towards the end of breeding. Survival declines over time, probably due to diminishing resources in the middle and early part of the rainy season, which is unfavourable to building and maintaining good nests. As the water level in the site rises, survival is almost nil and individuals stop breeding around the 17th week.

DISCUSSION

The Black-winged Stilt population has been stable and increasing since 2016 in Senegal and this is in line with international standards, as according to the IUCN the species is considered to be of minor concern, stable and increasing overall (BirdLife International, 2019). Furthermore, our results on the annual workforce at the Technopôle from 2017 to 2019 (Figs. 3 and 4) support these allegations.

The decrease in the Black-winged Stilt population in the study area as soon as the rains arrived (Fig. 5) is explained by the fact that these species prefer to live in shallow water bodies. According to Yu and Swennen (2004), these species generally live at a depth of between 6 and 21 cm and that changes in water level have an effect on the abundance of wading birds and their feeding behaviour (Maheswaran et al., 2001).

At the Technopôle, sewage and runoff from the surrounding districts are dumped there, thus considerably increasing the water level. In 2012, this led to the early departure of these birds from the site (Diallo et al., 2019); hence the usefulness of the following hypothesis:

Some birds could stay all year round in the Technopôle, if the water discharged was limited and only rainwater was collected during wintering.

This hypothesis is more or less confirmed in 2017 and 2018 because well after the breeding period and throughout the rainy season, a small part of the Black-winged Stilt population (less than 500 individuals) remained on the site in less flooded areas.

However, this decrease in the abundance of Black-winged Stilt during the rainy season could also have another explanation: an increase in the number of wetlands during this period with more food available, thus favouring the dispersal of the birds.

Furthermore, if we consider the monthly / annual numbers (Fig. 4) there is also a very large decrease in the number of individuals in the site during the breeding period. Black-winged Stilts, as in most bird species, combine vigilance and search for prey; these two mutual activities are exclusive to ensure a minimum of collective vigilance according to Barbosa (2002). So this combined with reproduction increases the aggressiveness and vigilance of breeding pairs to ensure their survival. Thus, the immature and less able-bodied move away in search of suitable places.

The study of the spatial distribution of Black-winged stilts is also an essential step in understanding demo ecological processes. The statistical analysis of the numbers allows us to determine this distribution of individuals in space and time. There are several types of distribution (Ramade, 1984). For our study we have an irregular distribution of individuals during reproduction from one year to another (Fig. 6). It has been shown that the Black-winged stilts adapts to a diversity of artificial wetlands, including ponds (Tinarelli, 1991; Cuervo, 2003). In the case of the Technopole, some areas are more suitable than others for reproduction from the point of view of water depth. Thus, as this period approaches, the Black-winged stilts have to make a choice about where to nest. According to Jones (2001) the distribution of a species can be limited by the behaviour of individuals in their choice of habitat. In 2017 areas B, C and E were the most occupied by individuals and nests are more concentrated in areas A, B and E. However, there is a slight change in 2018 where individuals occupy zones A, C and E and nests are more concentrated in zones A and C. This change may be driven by the dynamics of the breeding individuals, as they choose locations that are less frequented by predators and/or the rest of the colony and are more conducive to good nesting. Indeed, in 2017 some nests were accessible by stray dogs (Diallo et al. 2019), which led to a change in the choice of nesting areas in 2018 (Figs. 6 and 7). Also, the choice of habitat can be determined by environmental indices and the area available on a site as a function of time. Habitat selection is crucial for both the health of individuals and population dynamics, so individuals are expected to be under strong selective pressure to make optimal siting choices (Kristan, 2007).

The rare existing information on Black-winged Stilt in Senegal was reported more than 25 years ago by Baillon and Sylla with observations of 2 nests on the PNDS bird island, 1 nest in Lake Retba, 1 nest in Tataguine, 1 nest in the Sine Saloum Delta and 8 nests on the shores of Lake Malika. The White Stilt nest is a shallow depression scraped into the ground. It is usually located on a pile of vegetation, in the water on aquatic grasses, or near water on the shore (del Hoyo et al. 1996). However, on the Technopôle site we observed nests on rocks or on piles of stones (Fig. 8).

Nest density and position within a colony can influence hatching success and the survival of young. The study by Lagrenade and Mousseau (1981) highlighted the spatial and temporal distribution of nest establishment within a colony. Younger birds, being ready to breed later in the season, would be pushed towards the periphery of the colony by older, more experienced individuals nesting in the centre (Ryder, 1975).

The species nests in small colonies of between 2 and 50 pairs, and the pairs formed vigorously defend their nests and territory (Urban et al. 1986; del Hoyo et al. 1996). However, in this study there were about 100 pairs over a staggered period, as the majority of nests are noted at the beginning of May each year; with 79 nests on 09/05/2017 and 71 nests on 13/05/2018. Many studies mention that early (or precocious) layers have significantly better hatching success than late layers (Chardine, 1976; Haymes and Blokpoel, 1978; Lagrenade and Mousseau, 1981).

The nesting period is generally between April and June, but in the case of our study it continued until the end of August. This may be due to the drop in rainfall in the Dakar region, so that problems of nest submergence were not posed. Also some inexperienced latecomers or new arrivals to the site did not start breeding in time. Ryder (1975) found that it is often young, less experienced birds that are found in the late period. According to Figuerola (2007) climatic conditions have important effects on bird philopathy, which in turn is linked to changes in breeding populations. Ultimately these changes lead to an increase in dispersal behaviour and a better ability to colonise new breeding localities.

The reproductive biology of stilts is poorly known, although some studies have been carried out in Italy (Tinarelli, 1990, 1992) and Spain (Castro, 1993; Arroyo, 2000 and Cuervo 2003, 2005, 2016).

Our results show that nesting success as measured by nest survival may differ between weeks and decreases significantly with the progression of the season (Tables 1 and 2). Breeding success increased from 89.6% in 2017 to 100% in 2018 at the start of the breeding season; note therefore that the change of stilt nesting location between 2017 and 2018 at the Technopôle was beneficial for this species and that the effect of predation by stray dogs was minimised. Also, throughout the monitoring, we noted that half of the nests were properly brooded, which is also a favourable element for breeding success.

Threats

Wetlands provide many ecological services, most of which are vital for all living things. In the case of the Technopôle's urban wetland, it is both a treatment plant and a groundwater recharge station for the environment. However, anthropic pressures have a negative impact on this environment, with the loss of habitats leading to a loss of biodiversity.

In the greater Niaye de Pikine, there are three zones that make up the wetland: a residential area, a farming area and the water body itself.

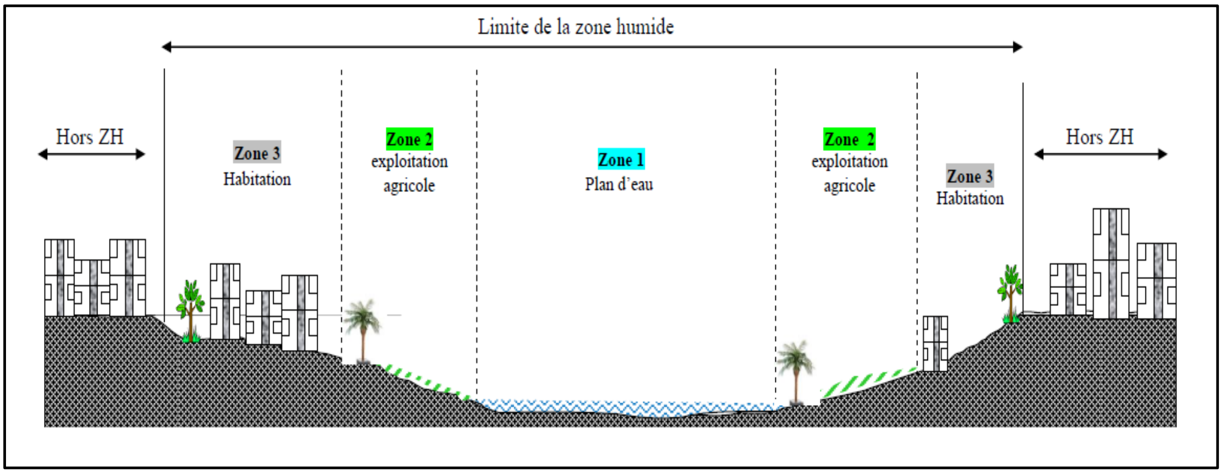

Figure 10: Scheme of space occupation in the Technopole (DAMCP, 2014)

Zone 1 was originally a natural receptacle for run-off water; however, in parallel to this natural phenomenon, there are the rainwater drainage channels from the Dakar suburbs and a treatment plant to the site. In addition, there is a proliferation of invasive plants and fishing activity is noted.

Then we have zone 2, where there is over-exploitation of the environment by market gardening, floriculture fields, hen houses, fodder areas, service equipment (antennas, electricity networks, etc.) and rubbish dumps.

Finally, there is zone 3, where there are many houses and other installations that are out of the norm because they are not allowed in a wetland area.

Dump for domestic waste

Invasive plants

Growing area

Urbanisation

Figure 11: A few illustrations on the anthropisation of the Technopôle

The threat to this area is largely urbanisation. Indeed, the Technopole is nowadays undergoing a conversion by filling in agricultural areas into work infrastructures. In the North-East basin, the depths reach or exceed 2 m in places. The bed height in this basin is in places below -1 m. The storage capacity of the basins is gradually being reduced by embankments, anarchic occupation and aquatic vegetation (DAMCP, 2014). In addition, household waste is dumped near water bodies and wastewater is illegally dumped, which has considerable environmental impacts (pollution of water tables, weakening of the ecosystem). The salinisation of the environment and the proliferation of aquatic plants remains a threat to the Technopôle. As is biological pollution in the area due to the use of pesticides in market gardening areas.

COCLUSION

The Niayes de Pikine are home to a wide variety of bird life throughout most of the year. We observed the breeding behaviour and dynamics of a Black-winged Stilts hooter population for two years. We have thus observed and understood how the resources of the environment are selected and exploited by this species. The conclusions drawn from the exploitation of the results show a fairly regular use of white stilt in the Niayes of Pikine. The nesting of Black-winged Stilts at the Technopôle is described for the first time in Senegal during our study. In addition, during this study, we found the highest number of nests (79 nests in 2017 and 71 nests in 2018) of stilt declared so far in Senegal. These data will contribute to the knowledge of Black-winged Stilts breeding in Senegal. However, efforts still need to be made within the framework of the protection and conservation of the site because anthropisation is increasingly recurrent, and in addition to this, the actions of stray domestic animals such as dogs are becoming more and more uncontrollable. It should be noted that this study was carried out before the Technopôle site was declared an urban nature reserve. However, the managers of this protected area will be able to rely on this document to better understand the site and to conserve it well.

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