ENVIRONMENTAL FACTORS AFFECTING NEST-SITE SELECTION OF BREEDING YELLOW-LEGGED GULLS IN CONTINENTAL SEMI-ARID AREA (ALGERIA)

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Abstract. As a colonial bird and the most abundant gull in the Mediterranean region, the yellow-legged gulls *Larus michaehellis* is considered as an ideal species to investigate effects of environmental factors change. The breeding ecology of the Yellow-legged Gull was followed for the first time in the continental semi-arid area in Algeria, during two consecutive years 2014 and 2015. The breeding site (Ain Zada dam) located in the Central Hauts Plateaux around 60 Km far from the Mediterranean Sea. Comparatively to previews observations, a rapid and massive growth of this marine species in the continental regions of the country was observed. In the aim to analyze factors affecting nest-site selection some environmental parameters influencing breeding parameters were surveyed such as nest density, vegetation density and height. Our results, showed the direct effect of water availability on the nest site selection and laying period in the semi-arid area. The mean nest density found in the study area (0.73 ± 0.15 nest/m^2) was higher than those reported in other Mediterranean colonies. However, nest density associated with vegetation density, but negatively correlated with island size.

Key words: semi-arid; breeding ecology; yellow-legged gull; environmental factors; nest-site.

INTRODUCTION

The annual breeding cycle of colonially breeding birds starts with the identification and selection of an appropriate breeding site to ensure protection from physical and biotic components of the environment [17, 4]. The selection of breeding site is considered an important factor that can affect the breeding success and the survival of of chicks [1].

Nest habitat selection could influence breeding success [1]. Birds with a wide distribution, such as most seabirds, select their breeding habitats at several different levels, for example, how the density of conspecifics affects the colony, sub-areas within the colony, and nest sites, protection from predators or accessibility of good foraging areas.

The yellow-legged gull (*Larus michahellis*) is the most abundant seabird in the Mediterranean region [23, 40, 4]. As opportunistic forager, the Yellow-legged Gull exploit a feeding source that has promoted rapid growth rates in their populations [14, 24, 49]. The knowledge of its population dynamics may provide information on the environmental quality [2]. However, Gull populations often benefit from anthropogenic activities extension [8, 14]. In the Mediterranean basin, yellow-legged gull has known a strong increase over the last four decades, particularly in the northern Mediterranean [47]. Many studies were undertaken on the nest site selection of Yellow-legged Gull in Mediterranean region [11, 22, 25]. However, on the southern shore of the Mediterranean, the yellow-legged gull populations remain less studied, only very few studies were conducted, by Bellout *et al.* (2021) [4] and Bellout *et al.* (2022) [5] in Morocco and Moulaï *et al.* (2005), in Algeria. In North Africa, all previous breeding colonies were located in the coastal regions; in fact, our study is the first contribution focused on the breeding ecology of Yellow-legged gull in continental islets in a semi-arid area. At Ain Zada dam about thirty pairs were observed on one islet in 2001. During the study conducted in 2014 and 2015, our objectives were to determine the nest site characteristics of breeding yellow-legged gulls on the continental island in the semi-arid area and to examine the effects of environmental factors (vegetation, islets characteristics) on some breeding parameters. Furthermore, we would compare the nest site selection features with those from previous studies in coastal habitats and other areas of the Mediterranean basin.

MATERIALS AND METHODS

Study area

This survey was conducted at Ain Zada dam (N 36° 80' 05", W 05° 18' 40"), this dam covers more than12 km^2, located around 60 Km far from the Mediterranean Sea in the Central Hauts Plateaux in the Bou Sellam sub-watershed (Algeria) over 9125 km^2 (Fig. 1). The Central Hauts Plateaux contain many natural and artificial wetlands. These wetlands are used by a large number of wintering and breeding waterbirds [6]. The study area has a semi-arid Mediterranean climate, characterized by a relatively temperate winter and dry summer with annual mean temperature about 18°C. The average annual rainfalls varies between 300 and 400 mm. The breeding colony took place in three islets in the middle of Ain Zada dam (Table 1). The vegetation is dominated by Tamarisk *Tamarix africana*, Saltbush *Atriplex glauca*, Mauritania grass *Ampelodesmos mauritanica,* and Spiny rush *Juncus acutus*.

The fauna is very rich, where 63 bird species, 9 species of mammals, and 20 species of amphibians [15], and 11 species of ichthyofauna were assessed [32].

The Yellow-legged Gull bred on three islets of different area and characteristics at Ain Zada dam. The breeding habitats differed between rocky habitats in

Islets 02 and 03 and grassy habitat in islet 01. Where the soil texture of this last islet is dominated by sand.

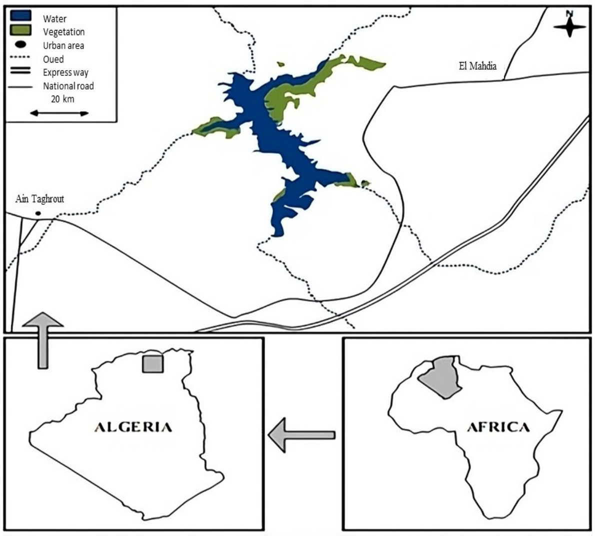

Figure 1. Location of the study area, Ain Zada dam, Algeria.

Data collection

Fieldwork was conducted during two consecutive years 2014 and 2015 between March and mid-July. The colony settlement was detected from the shore using a telescope. However, nests were located through systematic searches within breeding islets. Most of them were monitored to the hatching of the last egg by means of regular visits, every six days. Each nest was marked using small, individually numbered pegs placed close to the nest. The nest parameters we measured were: nest placement (distance between nests and nest to the islet shore) and nest diameters (internal, the ‘cup’ in which the eggs are placed, and external, the extent of the nest materials). The nest density was calculated based on counts of active nests in random plots located in different isle zones [12].

For each nest monitored, we noted clutch-size and determined laying-date. A nest was considered active if it had at least one egg, and abandoned if the eggs remained in the nest for 30 days without hatching. Clutch-size was determined for complete clutches only, when all eggs were laid, and there are no more new eggs being added to the nest from visit to visit. The date when the first egg of a clutch was laid was considered as the laying date of a nest. When nests were first recorded during incubation, laying-date was calculated by backdating from the known hatching date, considering the incubation period is 28 days, and eggs are laid at 1–3 day intervals [41].

A nest was considered successful if at least one egg hatched, otherwise the nest was considered to have failed. When the same number of eggs remained in a nest after the expected date of hatching it was considered abandoned. When eggs disappeared before the expected hatching date, they were considered predated by terristral predators mainly the Feral cat and Black rat, which considered the top predators of seabirds and other mammals [31].

The hatching success is the ratio (%) of hatched eggs over laid eggs, the fledging success is the ratio (%) of fledged individual over hatched fledglings, and breeding success is the ratio (%) of fledged individual’s total eggs that were laid. The hatching was defined as the state where the fledgling was totally out of its eggshell, and fledging was defined as the state where the fledgling stably flew to top of the tree once leaving the nest.

Environmental parameters were measured for all islets and both study years 2014 and 2015 such as islet area, vegetation density, vegetation height. The surface area of the islets was calculated using GPS points taken around their shores. Google Earth software was used to analyze these points and calculate the islets' areas for each study year**.**

Vegetation density (%) and vegetation height (m), were randomly estimated using a square-quadrats (4 x 4 m). We measured the height of the tallest vegetation in the quadrate, which gave a good indication of vegetation height.

Data analyses

Statistical tests were performed using SPSS 17.0 with a significance level of $p<0.05$. The main aim was to investigate the possible effects of nest site characteristics on the following breeding parameters (i.e., laying period, number of nests, nest density, nest placement, hatching and fledging success). Data were analyzed using both parametric and non-parametric tests (chi-squared test, t-test, Mann-Whitney test, one-way and two way ANOVA and correlation tests). All means are shown with ± SE standard error unless stated otherwise.

RESULTS

Nesting and laying phenology

The number of breeding gulls starts to increase in the breeding area at the beginning of February then they started to hold territories in the colony in the mid-February. The laying period was spread over 47 and 44 days in 2014 and 2015 respectively. The first egg laying date in 2014 was earlier than in 2015, where the first recorded egg was laid on 15 March and the last one on 01 May in 2014, and from 23 March to 06 May in 2015.

Table 1. Topographic characteristics of breeding islets of the Yellow-legged Gull at Ain Zada dam, Hauts Plateaux of Algeria

Location	Elevation (m)		Islet distance to dam shore (m)		Shape	Length (m)	Width (m)	Water depth around islet (m)	
	Min	Max	Max	Min				Min	Max
Islet 01	0.8	8.2	50	0	Polygon	450	210	0	0.8
Islet 02	0.5	2.8	410	366	Circular	80	60	0.9	1.5
Islet 03	1.5	2.5	320	274	Polygon	100	50	1.4	2.8

Nest site selection

The breeding of the Yellow-legged Gull took place in two islets in 2014 but in all three islets in 2015 at Ain Zada dam (Fig. 2). A total of 380 and 358 nests were found in 2014 and 2015 respectively in all islets, which varied from year to year ($t=2.74$, $df=5$, $p<0.05$). However, the number of nests was not significantly different between islets (one-way ANOVA, $F_{2,3}=0.006$, $P=0.994$) during the study period. The breeding habitats differed between rocky habitats in Islets 02 and 03 and grassy habitat in islet 01. Where the soil texture of this last islet is dominated by sand.

Nest placement characteristics

The Yellow-legged Gull nests were found both in peripheral and central areas of islets, where the nesting was started in the top central towards the peripheral of islets. The mean distance of nest to islet shore in 2014 (2.39±1.35 m) was lower than in 2015 (6.18±10.08 m), where no significant difference between years was found ($t(29)=0.981$, $p=0.335$), but there was a marked variation between the different islets (one-way ANOVA, $F_{2,28}=6.275$, $p=0.006$) (Fig. 3).

Nest density

The mean nest density of Yellow-legged Gull in breeding site was 0.46±0.11 nests/m^2, in 2014 and 0.73±0.15 nest/m^2, in 2015, with no significant difference between years ($t(48)=1.29$, $p=0.203$) (Fig. 4). However, a significant difference was found between islets (one-way ANOVA, $F_{2.47}=11.99$, $p<0.001$). Two way ANOVA showed no statistically significant interaction between year and islet effects on nest density ($F(1, 45)=1.307$, $p=0.259$). Nest density, was significantly lower in peripheral of islet (0.16±0.045) than in the center (0.78±0.16), ($t(48)=5.599$, $p<0.001$). A significance Spearman's rank correlation was noted correlation was noted between nest densities and inter- nests distances.

Nest characteristics

Inter nests distance (IND)

The mean inter-nests distance in the breeding site was lower in 2014 (1.66±0.85m) than in 2015 (4.38±1.99 m), where a significant difference was noted between years ($t (29)=3.47$, $p=0.002$), and between islets (one-way ANOVA, $F_{2,28}=17.67$, $p<0.001$). Two-way ANOVA showed a significant variation of inter nests distance between islets but not between years (islets $F_{2,26}=11.22$, $p=0.000$; year, $F_{1,26}=2.18$, $p=0.151$; interaction, $F_{1,26}=0.868$, $p=0.360$).

Environmental factors

Vegetation density

Most of the nests were found in areas with medium vegetation cover (20% to 45%). The mean vegetation density where the yellow-legged gull nested was 30.3±15.5% in 2014 and 34.66±20.82% in 2015 (Fig. 5). However, there was a significant difference between two study years ($t=10.75$, $df=49$, $p<0.001$) and between islets (one-way ANOVA, $F_{2,47}=12.53$, p<0 001). Otherwise, there was no statistically significant interaction between year and islet effects on vegetation density ($F_{1,45}=1.040$, $p=0.313$). Most of nests were located in area with vegetation density less than 60 %. The vegetation density and vegetation height were correlated significantly (Pearson's rank correlation r=-0.36, n=50, p=0.017). The vegetation density, had statistically significant lower in peripheral (20.60±14.33) than in central of islets (45.24±20.84), ($t(48)=4.870$, $p<0.000$) (Fig. 6).

Vegetation height

The mean vegetation height in the breeding site was 91.55±79.02 cm in 2014 and 67.65±62.26 cm in 2015, with no significant difference between years (($t(48)=1.197$, $p=0.237$) and between the islets (one-way ANOVA, $F_{2,47}=2.562$, $P=0.088$) (Fig. 7). Also, no year and islet effects were detected on vegetation height ($F_{1,45}=0.367$, $p=0.548$). A significant, positive correlation with islet area (Pearson's rank correlation r=–0.971, n=5, p=0.006) was observed. The vegetation height, was statistically significantly lower in the peripheral parts of the islets (25.48 (1SE: 17.14) than in central parts of islets (128.84(1SE: 63.69), ($t(48)=7.83$, $p<0.000$). The vegetation density and vegetation height were correlated significantly (Pearson's rank correlation r=–0.36, n=50, p=0.017).

The relationship between vegetation characteristics and nest density

Vegetation density and nest density were found to be positively correlated (Pearson's rank correlation r=0.65, n=50, p=0.000) (Fig. 8), but a strong, negative correlation was found between vegetation height and nest density (Pearson's rank).

Relationship between vegetation characteristics and breeding parameters (hatching success and fledging success)

No significant difference in hatching success was found between years ($t (3)=1.57$, $p=0.179$), and between islets (one-way ANOVA, $F_{2,2}=0.186$, $P=0.843$). Also, the fledging success was not different between years ($t(3)=1.65$, $p=0.198$) and islets (one-way ANOVA, $F_{2,2}=0.143$, $P=0.875$). Correlation analysis showed no significance relationship between hatching success and environmental (vegetation density: r=0.117, p=0.852; vegetation height: r=0.284, p=0.643; nest density: r=0.471, p=0.424) and fledging success (vegetation density: r=0.12, p=0.848; vegetation height: r=-0.259, p=0.674; nest density: r=0.455, p=0.442).

Causes of breeding failure

During the breeding seasons 2014 and 2015, hatching failure of yellow-legged gulls were 7.14% (1SE:1.19) and 20.83% (1SE: 7.8) respectively. In all breeding islets, the main causes of hathing failure were: abandoned (34%) and predation (66%). Like hatching

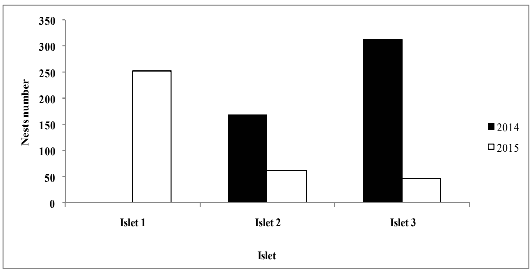

Figure 2. Number of Yellow-legged Gull nests in different islets for both years 2014 and 2015

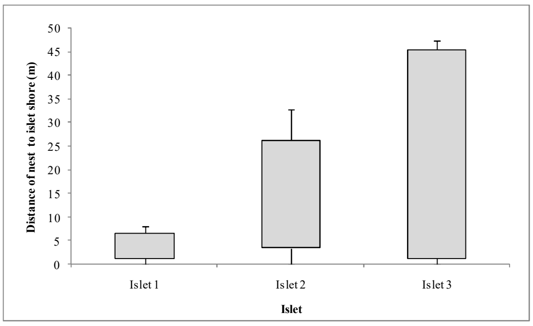

Figure3. Variation of distance of Yellow-legged Gull nest to islet shore in breeding islets

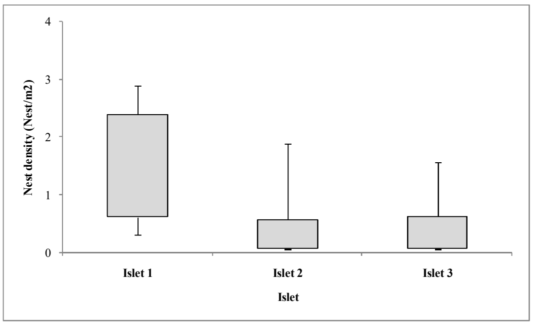

Figure 4. Mean variation of nest density in breeding islets

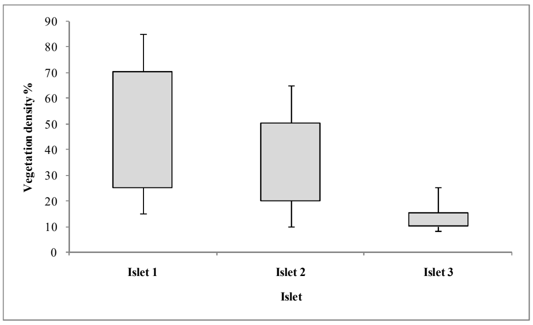

Figure 5. Mean distribution of vegetation density in different breeding islets

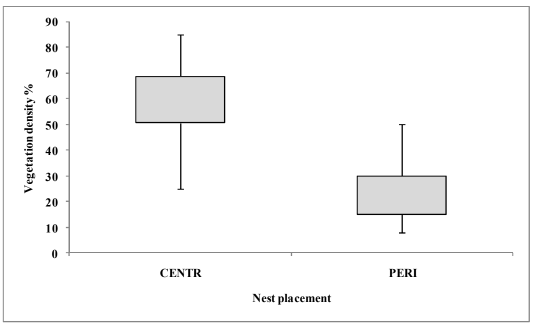

Figure 6. Mean variation of vegetation density following nest placement in islets

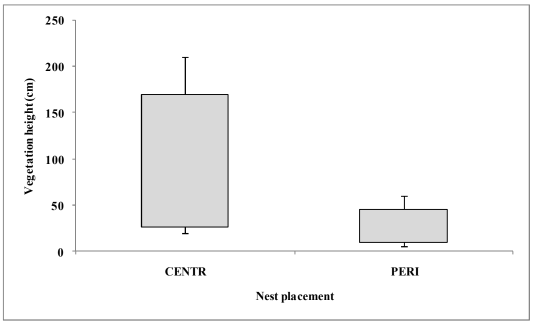

Figure 7. Mean variation of vegetation height following nest placement in islets

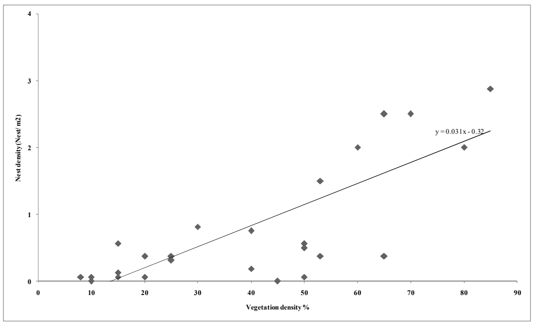

Figure 8. Relationships between vegetation density and nest density (p=0.424)

failure, mean fledging failure was 6.18% (1SE: 0.23) in 2014 and 16.5% (1SE: 6.24) in 2015. However, 'pecking', is the main cause of chicks dead.

DISCUSSION

The Yellow-legged Gull is a coastal bird, but this study will look at how it breeds in a dry inland area. In the Mediterranean Sea region, the Yellow-legged Gull population has grown a lot over the past 40 years, especially in the northern part of the sea [43]. The fast population increase was partly due to the expansion of the species range into the western Mediterranean [16, 43, 47], and to the generalization constuction of large dumps [7, 8, 36, 46]. The number of Yellow-legged Gull pairs at the breeding site increased from 30 in 2001 to more than 380 in 2014. This rapid population growth is strongly linked to the expansion of the city and the development of dumps around the breeding site. A similar trend has been observed in other parts of Algeria, such as Bejaia [37], Jijel [9], Numidia [46].

Some Yellow-legged Gull colonies are heavily dependent on human food waste [12, 42]. selection a good breeding site is important for having successful breeding, so the factors that affect nest-site selection will vary depending on the specific features of the environment. [1, 38]. Colonial species often nest in places that are inaccessible to mammalian predators, such as islands or treetops [38]. Habitat features such as substrate, hydrology, topography, vegetation, local climate, and the presence or absence of conspecifics and (or) other species may have considerable influence on nest-site selection and reproductive success [1]. Laying period in the study area was shorter than other colonies located in the coastal regions of Algeria, where this period stretched over two months [2, 46]. Mark [30] reported that characteristics of the environment (water depth and vegetation structure and density) may affect prey availability and limits access to laying of some avian species. Previous studies revealed that water depth determines resource accessibility [49], the availability of these resources may affect directly the laying dates and period. In our survey, the difference of laying period between years was due probably to the variation in water depth and vegetation density. Nevertheless, our results are consistent with previous literature that demonstrates the importance of water depth to colonial waterbirds where water depth was very low in 2014 (0.60±0.11) than in 2015 (1.23±0.18), that corresponding the shorter laying period in 2014. The most important colonies are on the island [28, 35, 44, 45]. Overall, gulls, breeding in small dense sub-colonies are better protected from predators than those in large [25, 27].

At the Ain Zada dam, three islands of different sizes and distances from the mainland were used by yellow-legged gulls for breeding. These islands were considered sub-colonies of a larger colony. For birds that breed in large colonies, the entire area occupied by the colony is often divided into several sub-areas with different physical and social features, such as vegetation and isolation [17]. The preference for nesting on islands is commonly attributed to a reduction in the number of predators on islands [39]. Yellow-legged gulls occupied the larger islets respectively, mostly on elevated, highly vegetated zones, as previously reported for other Mediterranean sites [11, 20, 25]. Yellow-legged gulls were selective in the choice of nesting habitat. The variation of characteristics of islets (elevation, size, vegetation, water depth and soil substrate), could justify the spatiotemporal occupation of breeding yellow-legged gulls in sub-colonies. This species is a highly territorial species [10, 19], Yellow-legged Gull pairs that arrive first at a breeding site typically choose the best nesting spots, forcing later arrivals to take less desirable spots [40]. Most gulls generally prefer rocky-cliff habitats for breeding (e.g., herring gulls *Larus argentatus* [40], yellow-legged gulls [11]. In rocky-cliff habitat, gulls can reduce the threat of terrestrial or avian predators [48]. In our study, the breeding habitats differed between rocky-cliff habitat in islets 02 and 03, and sandy substrate in islet 01. The island isolation is considered as an important parameter of nest-site selection, which is the case in our study where the islets are located in the southern part of Ain Zada dam far from the main access road and urban habitats. On other hand, islets are isolated from the mainland. Most of the colonial seabirds prefer the most isolated nesting sites to seek out the tranquility necessary for nesting [48], and select nest sites that provide height protection during reproduction [17]. Overall, gulls occupy sites with topographical advantages such as easy access to foraging sites and difficult access by predators [48]. The breeding islets are surrounded by waters through the breeding period to minimum accessibility and to raise the colony protection against predators. The mean nest densities found in the study area (0.46±0.11) nest/m^2 in 2014 and 0.73±0.15 nest/m^2 in 2015), were higher than those reported in other yellow-legged gull Mediterranean colonies (0.04 nest/m^2 in Medes Islands colony, Spain [11], (0.021 nest/m^2 in Marseille archipelago, France [18], (0.01 nest/m^2 in Srigina Island, 0.008 nest/m^2 and in Lion Islet, Algeria [2, 46]. Nest density can affect the success of gull colonies. The distribution of nest density on each island is not uniform, and there is a significant difference in nest density between the sub-colonies on the breeding islands. Nest density was significantly lower in peripheral area due probably to the vegetation height in this part of islets, as has been reported in many other studies that yellow-legged gulls prefers habitats with a higher percentage of tall vegetation cover [5, 11].

Island size is considered as the second major factor influencing nesting density on sub-colonies [13]. Nevertheless, our results are in concordance with those reported by Buckley and Buckley [13], that the mean nesting density in the island was negatively correlated with island surface area and with the distance from the initial colony location.

Our results are consistent with previous literature that demonstrated that nest densities were highest on islands that were small, located at moderate distances from the mainland. Many species of waterbirds similarly prefer to nest on islands [18], and other studies have also revealed higher nest densities on smaller islands [4, 33]. A preference for smaller islands is often attributed at least in part to reduced nest predation by terrestrial predators [33]. For species that breed on islands, island characteristics can also influence nest densities and abundance. Island size can influence numbers of breeding birds, although its effect varies. Otherwise, larger islands may have more nests [4, 9, 26], but, for some species, island size may not affect the number of nests [4, 17]. One major reason given to account for related patterns of island nesting was the tendency of birds to avoid islands large enough to house mammal predators [13]. Gulls breeding in dense and small sub-colonies within the colony enjoy greater protection against aerial predation than those in large, loose aggregation. Wide variations in nesting densities can occur in gull colonies and can affect some demographic parameters. In a herring gull colony, the nest density displayed significantly higher breeding success (hatching and fledging success) than those nesting at a lower or a higher density [27].

The significant difference in nest placement between breeding islets could be related to the variation of islets topography such as elevation and substrate. Whereas, the islet 2 and 3 characterized by the presence of cliffs. In breeding colonies, differential reproductive success is often associated with the spatial location within the colony [48]. In colonially breeding birds, an individual pair in the center of a crowded colony may have to pay for the antipredatory advantages of nesting in a central location by suffering the costs of increased interference from conspecifics [33]. Our results are similar to other observations on the others gulls colonies where individuals prefer the center of the colony than peripheral. This distribution is probably affected by two main factors: security and vegetation characteristics. In concordance with literature, the difference between vegetation cover in the central and peripheral of the islet is one of the main factors that affect the distribution of yellow-legged gulls in our study. The classic pattern across taxa reported that peripheral nests and nests located closer to the ground, suffer greater losses due to exposure to predation and adverse weather conditions [3, 34].

The importance of vegetation cover in habitat selection by yellow-legged gulls has been pointed out by many authors [22, 25]. For ground-nesting birds, the height and distribution of vegetation is an important habitat feature. A number of studies have shown positive relationships between vegetation at the nest sites and breeding performance in various gull species [11, 29]. In the study area, the yellow-legged gull nests were found both in peripheral and central sites, where this species always preferring areas with the highest vegetation cover. The occurrence of vegetation could favor gulls in several ways: (1) protecting both eggs and chicks against predators and climatic factors [21, 38], (2) facilitating thermoregulation of adults [21]. Otherwise, the vegetation in grassy habitats provides greater shelter from some predators [21].

However, the significant difference in vegetation density is strongly influenced by the substrate of breeding islets, where islet 2 and 3 are rocky. Because the plant species on the islets are the same and have the same height, there is no difference in vegetation height between years and islets Despite the importance of tall vegetation in the sheltering effect, it was associated with a low nest density. This suggests that sub-areas with tall vegetation held more non experienced breeding pairs. The nesting in an area with tall vegetation may make individuals more vulnerable to predation risk by its effect on visibility [11, 38]. Otherwise, the vegetation height is positively correlated with the hatching success of Lesser Black-backed *Gull Larus fuscus* [17]. Conversely, our results suggest that gulls have a clear preference for particular vegetation density, and lower tall vegetation when selecting sub-areas of the colony. The lack of marked differences between years and subcolonies, and also the high rate of hatching success and fledging success suggests the good quality of this nest site even during the study period.

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