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SUMMERING WADER COMMUNITIES OF THE KHNIFISS LAGOON (SOUTHERN MOROCCO): A SURVEY IN 1997

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RESUMEN

Las comunidades estivales de aves limícolas y marinas de la Laguna de Khniffiss, la zona húmeda marroquí más importante al sur de Agadir en el Sáhara, fueron estudiadas en julio-agosto de 1997 en términos de estructura de la comunidad, composición y uso del hábitat. Los limícolas mostraron una menor diversidad y abundancias moderadas en comparación con la comunidad invernante, aunque siguió un patrón similar de explotación de macrohábitats de alimentación que ésta. El Correlimos Común, el Chorlitejo Patinegro y el Ostrero dominaron la comunidad estival de limícolas, representando casi el 60 % de los efectivos censados. Los números de Chorlitejo Patinegro, Ostrero, Archibebe Claro y Andarríos Bastardo en verano fueron más altos en Khnifiss que en el Banc d'Arguin [el humedal más importante de la vía de migración del Atlántico este (EAF)] en trabajos previos realizados en la misma estación. El Flamenco, la Garza Real, la Garceta Común y la Espátula mostraron efectivos similares a los registrados en censos previos en Khnifiss. Los limícolas concentraron su actividad alimentaria en los lechos de *Zostera* de la sección más exterior de la laguna. Las densidades de aves en forrajeo fueron significativamente menores en la extensa marisma interior. Las amenazas derivadas de actividades y explotaciones humanas no controladas en la laguna y el desierto limitante puede conducir a un empobrecimiento crítico y pérdida de idoneidad de la reserva para los limícolas en particular y la avifauna en general. Por tanto es urgente la necesidad de una gestión sostenible diseñada para preservar este importante humedal en el contexto de la EAF.

Palabras clave: Estructura de la comunidad, Laguna de Khnifiss, limícolas, Marruecos, uso del hábitat de alimentación.

ABSTRACT

The summering waders and acompanying wading birds of the Khnifiss Lagoon, the most important Moroccan wetland in the Sahara Desert to the south of Agadir, were surveyed in July-August 1997 in terms of community structure, composition and macrohabitat use. Summering wader community displayed a relatively low diversity and moderate abundances but showed roughly the same pattern of feeding-macrohabitat exploitation than wintering assemblages. For foraging, waders concentrated on the *Zostera*-covered shallows in

the outermost part of the lagoon, densities being lower in the inner saltmarsh. Dunlin, Kentish Plover and Oystercatcher dominated the wader community, representing ca. 60 % of the birds censused. Numbers of Kentish Plover, Oystercatcher, Greenshank and Wood Sandpiper were higher in Khnifiss than in the Banc d'Arguin (by far the most important wetland of the East Atlantic Flyway) by the same season in previous reports. Greater Flamingo, Grey Heron, Little Egret, and Spoonbill numbers resembled the figures given by earlier surveys in the Khnifiss area. Threats posed by non-controlled human activities and exploitations in the lagoon and its desert boundaries may lead to a critical empoverishment and loss of suitability of the Reserve for waders and coexisting aquatic birds. There is an urgent need for a sustainable management schedule designed to preserve this important wetland in the context of the East Atlantic Flyway.

Key Words: Community structure, foraging habitat use, Khnifiss Lagoon, Morocco, waders.

1. INTRODUCTION

The southern Moroccan avifauna has been profusely studied under a systematic view since the 1950s (VALVERDE [20]; HEIM DE BALSAC & MAYAUD [7]; ETCHÉCOPAR & HÜE [5]; CONGOST TOR [3], THEVENOT *et al.*[18]; BEAUBRUN & THEVENOT [2]; see also reviews in VERNON [22] and MOREL [12]). Some of the most important bird areas in southern Morocco are, undoubtely, wetlands and its surrounding environments. The Khnifiss Lagoon and the adjoining Guelta El Aouina, to the south of Agadir (formerly Spanish Sahara) are of critical importance to waders aiming to reach their winter quarters in Mauritania, due to the presence of a wetland offering extensive feeding biotopes and roosting grounds. Some traditional works on the Khnifiss avifauna revealed it as an important bird area (VALVERDE [20]; ROBIN [16]). More recently, local and foreign researchers have become more interested on the whole fauna (specially birds) of this wetland and its surrounding desert habitats (BAOUAB [1], BEAUBRUN *et al.*[2], PARKER & DAKKI [13], THEVENOT *et al.*[19]). Along with the neighboring depression of Sebkha Tazra, Khnifiss is among the three most important wintering areas for waders and other water birds in Morocco, sheltering nearly 24,000 birds, figure that lies behind the Merja Zerga (35,000-45,000 birds) and the Golfe de Gabès (267,000 birds), both in Morocco (KERSTEN & SMIT [10]; BEAUBRUN *et al.*[2], SMIT & PIERSMA [17]). It has been pointed out that Khnifiss is actually the second most important wetland in Morocco for both migrant and wintering waders (PARKER & DAKKI [13]). The Khnifiss Lagoon is used regularly by waders and other marine birds migrating along the East Atlantic Flyway (hereafter EAF) (SMIT & PIERSMA [17]), although the area represents only 0.72 % of the birds wintering on the West of Africa (for comparison, the Banc d'Arguin, in Mauritania, gives shelter to 61 % of these waders, ca. 2 000 000 birds). The Khnifiss environment serves also as a breeding area for numerous palaearctic migrants and resident terrestrial birds (BAOUAB [1]; THEVENOT *et al.*[19]). It is also the southern palaearctic limit for some waterbird species, such as the Coot, *Fulica atra* and the Ruddy Shelduck, *Tadorna ferruginea*.

This natural space (lagoon and surrounding desert habitats) was erected a Nature Reserve by a Ministry of Agriculture decree in 1962. In 1980, the Moroccan Government ratified its status of internationally important wetland, proposed by the RAMSAR

Convention in 1975. Finally, in 1983, the lagoon and its immediate environment were declared a Permanent Biological Reserve (BEAUBRUN *et al.*[2]). Actually, the reserve is subjected to several kinds of human exploitation, namely, salt extraction, fishing, shellfish cultivation, ovicaprine pasturing and naturalistic tourism. To date, however, there are few published studies characterizing the ecological structure of the aquatic bird communities of the Khnifiss Reserve, a necessary previous step towards the assessment of potential impacts of these activities on the biota of the zone (DAKKI & LIGNY [4]).

In this paper, we present the results of a short-term project developed in July-August 1997, attempting to describe the structure of the summering bird communities of the Khnifiss Lagoon (La' youne province, southern Morocco). Our aim was to study the composition, abundance, structure and macrohabitat use of the wader community (Charadrii) and other water birds sharing their foraging grounds; waders summering on the wintering grounds are less thoroughly studied than breeding, wintering or migrating ones, as reported for other important wetlands along the EAF, such as the most important of all, the Banc d'Arguin (VAN DIJK [21]). Also, we discussed some conservation issues posed by human activities for the management of the Reserve in relation to the coastal avifauna.

2. STUDY AREA

The Khnifiss Lagoon lies on the rocky coastal platform between Ras Akhfennir and La' youne, on the littoral of the Sahara desert, southern Morocco (28103°N - 12115°W, Fig. 1). The lagoon itself (~20 km long) comprises about 20,000 ha of subtidal areas, a huge salt-marsh with tidal channels covered by halophytic scrub, mud and sand banks, extensive beds of the seagrass *Zostera noltii*, and dense and patchy turfs of the graminean *Spartina maritima* interspersed with *Salicornia* sp. The northern shore in the outer section of the lagoon is surrounded by a low cliff with shrubby vegetation dominated by *Nitraria retusa*, *Lycium intricatum*, *Zygophyllum gaetulum*, *Launaea* spp., *Astydamia latifolia*, *and Euphorbia* spp. The lagoon and the adjacent depression of Guelta El Aouina (completely dry by the time of this survey) are encomprised in the 60,000 ha that forms the overall protected area. More detailed information about the geography, vegetation, and natural history of the area can be found in DAKKI & LIGNY [4] and contributions therein. Maps presented in DAKKI & LIGNY [4] were used to orient ourselves in the field and to locate the main study areas.

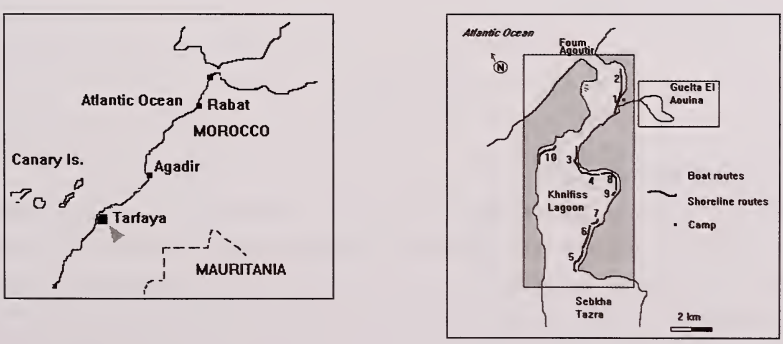

Figure 1. Location and schematic map of the study area showing census itineraries.

3. METHODS

Wader censuses

Waders were censused by two observers between July 27th and August 4th. These followed predetermined walking routes along the shoreline of the lagoon and the Sebkha Tazra (an extensive saline inland depression; see Fig.1), but not along the sides of the Guelta El Aouina depression (dry during the study period). In order to study the avifaunal composition and structure associated to apparently homogeneous vegetation and physiographic zones, two major habitat categories were differentiated as follows (see map in Fig. 1, Table 2): 1) 'Lagoon': the open water next to the lagoon mouth, limited laterally by wide sandy beaches and dune fields (erg), and by the begining of the channel zone in the lagoon interior; 2) 'Saltmarsh': shallow mud banks with *Zostera* and tidal channels divided by muddy tussocks covered by *Spartina*, *Salicornia*, and other halophytes.

Birds were counted along ten transects, totalling 8.5 km (range 0.2-1 km; Table 1), begining at dawn (moment in which the tide was low) and ending within 3-4 hours (see below). On each route, number of birds sighted (using 7 x 35 and 10 x 50 binoculars) up to 150 m distant on each observer's side were noted along with the substrata they were on (see Results for substrate identification), and the foraging activity was noted for solitary individuals or groups. On moderately windy days (a common weather by the season), transects were realized against wind direction in order to facilitate birds contacted to move away towards the observer's back, thus reducing the chance of replication. Progression speed in the transects averaged 1.31 km h^{-1} (±0.35, SD). Due to the huge geographical dimensions of the lagoon, and to logistical and time constraints, we could not perform censuses in some different routes the same day, but transects were enough apart to lower the risk of pseudoreplication of contacts. Although low-water counts can underestimate bird numbers due to dispersion during foraging activity, we perform counts at low tide because it was impossible to check all the potential high-tide roosts in a feasible time. Nevertheless, feeding areas were relatively localized and after several previous inspections of the lagoon we achieved a reasonable knowledge of their ubication. For this reason, however, some small species may have been somewhat underestimated (e.g. Kentish Plover, *Charadrius alexandrinus*). We calculated kilometric abundance index (KAI), percentual composition and species richness (as species number, S), diversity (Shannon's H'), and dominance (Simpson's D) indices (MAGURRAN [11]). Apart from data taken by means of shoreline transects, additional boat itineraries allowed us to assess more accurately the numbers of flamingoes, little egrets, spoonbills and grey herons (Fig. 1).

4. RESULTS

Waders and other wading birds

Table 1 shows the composition and relative abundance of waders summering in Khnifiss in 1997. Families represented were Haematopodidae (1 species), Charadriidae (3 species) and Scolopacidae (11 species). As a whole, the wader community was dominated by scolopacids (59.6 % of the total assemblage), charadriids (28.3 %) and a haematopodid (Oystercatcher, *Haematopus ostralegus*, 11.7 %). Feeding densities of waders (Charadrii) in Khnifiss averaged 9.01 birds ha^{-1} (±5.8 SD). For the larger wading species, excepting Grey

Heron, *Ardea cinerea* (namely Oystercatcher, Curlew, *Numenius arquata*, Little Egret, *Egretta garzetta*, Spoonbill, *Platalea leucorodia*, and Greater Flamingo, *Phoenicopterus ruber*) boat surveys revealed larger numbers than those obtained by mean of walking censuses (Table 3). For the Greater Flamingo, the former figure represents a final estimate resembling the average number given by BEAUBRUN *ET AL.* [2] for the period between July-18 (79 individuals) to August-1 (256 individuals). This seems to indicate that the population of this species was similarly increasing by mid- to late summer in our survey. Waders not recorded in this survey but reported in previous ones in the same season were *Pluvialis squatarola*, *Limosa limosa* and *Gallinago gallinago*. Furthermore, we did not detect grebes, ducks, storks, coots or moorhens in the Lagoon.

Common name	Scientific name	No. Ind.	%	KAI
Oystercatcher	*Haematopus ostralegus*	85	11.69	10
Ringed Plover	*Charadrius hiaticula*	74	10.18	8.70
Kentish Plover	*Charadrius alexandrinus*	126	17.33	14.82
Turnstone	*Arenaria interpres*	6	.82	0.70
Curlew Sandpiper	*Calidris ferruginea*	31	4.26	3.65
Dunlin	*Calidris alpina*	213	29.30	25.06
Knot	*Calidris canutus*	25	3.44	2.94
Sanderling	*Calidris alba*	9	1.24	1.06
Redshank	*Tringa totanus*	76	10.45	8.94
Greenshank	*Tringa nebularia*	13	1.79	1.53
Wood Sandpiper	*Tringa glareola*	1	0.14	0.12
Curlew	*Numenius arquata*	10	1.37	1.18
Whimbrel	*Numenius phaeopus*	14	1.93	1.65
Bar-tailed Godwit	*Limosa lapponica*	38	5.23	4.47
	Calidris sp.	3	0.41	—
	Undetermined species	3	0.41	—
	Total	**727**		

Table 1. Individual numbers (No. ind.), percentual composition, and kilometric abundance indexes (KAIs) for waders censused in the Khnifiss Lagoon in July-August, 1997.

Wader diversity and dominance differed among the 10 census routes that covered the range of potential habitats whithin the lagoon limits (Table 2). Species number (richness) was significantly similar ($\chi^2_9 = 10.32$, $p > 0.05$), whereas total number of waders strongly differed among these transects ($\chi^2_9 = 278.01$, $p < 0.01$). Transect length was positively correlated with richness (Spearman correlation, $r_s = 0.687$, $p < 0.05$) but not with diversity, dominance or bird number. Thus, for instance, itinerary 9 (a 200 m length segment formed by rich *Zostera* mudflats and sandy beaches to the lagoon interior) showed a greater diversity than itineraries 7 (300 m) and 10 (1000 m) (Table 2, see Fig. 1 for orientation). Zones 1, 2 and 6 apparently supported the higher diversity of foraging waders. This suggest that these zones may produce a greater diversity of food than other areas in the lagoon. About a half of the total bar-tailed godwits and dunlins were detected in route 10, whereas the remaining common species were distributed more homogeneously across the different zones.

Route number	Macrohabitat type (dominant phanerophytes)	H'	S	D	N
1 (1)	Open beaches, mud, sand, beached seaweeds (*Salicornia*, *Spartina*)	2.02	11	0.16	78
2 (1)	Open beaches, mud, sand (*Zostera*, *Salicornia*, *Spartina*)	2.30	12	0.11	114
3 (1)	Mud flat, saltmarsh edge (*Zostera*, *Spartina*)	1.87	9	0.17	72
4 (1)	Saltmarsh, edge of sebkha, mud, dry sand (*Zostera*, *Spartina, Salicornia*)	1.71	8	0.22	27
5 (1)	Saltmarsh channel, mud, sand (*Zostera*, *Salicornia*, *Spartina*)	1.62	8	0.24	96
6 (1)	Saltmarsh channel, mud (*Zostera*, *Spartina*)	2.08	9	0.14	40
7 (0.3)	Saltmarsh channel, mud, sand (*Zostera*, *Spartina*)	0.64	2	0.55	6
8(1)	Saltmarsh, edge of Sebkha, mud, sand (*Zostera*, *Salicornia*, *Spartina*)	1.71	10	0.22	86
9 (0.2)	Saltmarsh, mud and sand (*Zostera*, *Salicornia*, *Spartina*)	1.49	7	0.31	40
10 (1)	Open mud flat (*Zostera*, *Spartina*)	1.44	14	0.35	168
	mean	1.69	9.00	0.25	72.70
	± SD	±0.4 6	±3.2 3	±0.1 3	±47.3 9

Table 2. Wader community descriptors for the 10 census routes in Khnifiss (between parentheses, length of transects in Km). See transect locations in Fig. 1. H': Shannon's diversity index; S: species number (richness); D: Simpson's dominance index; N: overall number of waders detected in transects.

Fig. 2 shows the trends of diversity and dominance for waders distributed over a gradient of 5 feeding substrata, ranging from the water edge to the upper dry sands with remains of beached seaweeds. Numbers of individuals using each substrate type were clearly different ($\chi^2_4 = 1195.8$, $p < 0.001$). As evidenced, the highly productive beds of *Zostera* support a higher summer density, richness and diversity of foraging waders than any other substrate type in the lagoon. Few species and individuals were found feeding at the high tide limit (beached seaweeds on sand), these being mainly *Charadrius* spp. The water edge was chiefly used by oystercatchers and bar-tailed godwits, along with larger wading species such as the Greater Flamingo or the Spoonbill. The main wader species foraged preferentially on *Zostera*-covered shallows (either on the open part of the lagoon or in the inner saltmarsh), with respect to sand or mud without plant coverage (Fig. 3). We found clear differences in macrohabitat preferences among main summering wader species (Fig. 3). Small species such as Ringed and Kentish plovers were prone to feed in higher densities in the *Zostera* beds of the inner-center saltmarsh (zone 2, see Study area), being less frequent on the exposed beds of the outer part of the lagoon (zone 1). Sandy beaches were not frequented by these species unless they were next to a *Zostera* bed. Contrarily, Redshank and Bar-tailed Godwit showed their higher densities on open areas of shallow water on mudflats. The Dunlin and the Curlew Sandpiper did not show a marked preference for any of these two *Zostera* bed locations, their foraging densities being similar at both zones.

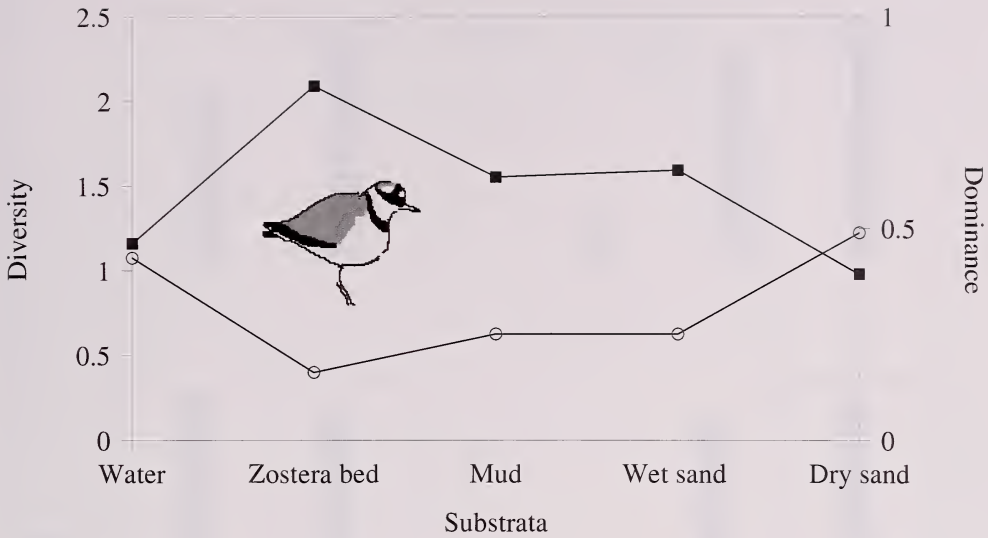

Figure 2. Variation of diversity and dominance of foraging waders in Khnifiss as a function of the substrate type in July-August, 1997.

5. DISCUSSION

Wader figures for the summer period in Khnifiss are well below the huge numbers reported for the Banc d'Arguin, and even for other important areas in Morocco (Table 3; see also VAN DIJK *et al* [21]). Only four species of our survey, namely Oystercatcher, Kentish Plover, Greenshank and Wood Sandpiper, were in higher densities in July-August in Khnifiss than in the Banc d'Arguin in the same season. Average feeding densities in the summer period in Khnifiss (~9 birds per ha) is far below the 40 birds per ha reported for the Banc d'Arguin in winter (ZWARTS *et al.* [24]). The numbers reported in our study may be conservative estimates, due to our logistical and time constraints. Summer numbers are well bellow the figures obtained for the autumn-spring period at several wetlands in North-West Africa (e. g. PIERSMA *et al* [14], BEAUBRUN *et al.* [2], SMIT & PIERSMA [17], WOLFF & SMIT [23]). However, we should make sure that the numbers recorded are actually summering birds and not only residuals of late-departing or early-returning migrants. In this sense, we did not observe any massive arrival or departure during the study period in Khnifiss, which encomprised the center of the summer period. In the Banc d'Arguin, massive wader arrivals or departures were hardly observed after June 5, 1988 (VAN DIJK *et al.* [21]). Nevertheless, other authors have previously noted that wader number may increase at a higher rate during July (VAN DIJK *et al.* [21]).

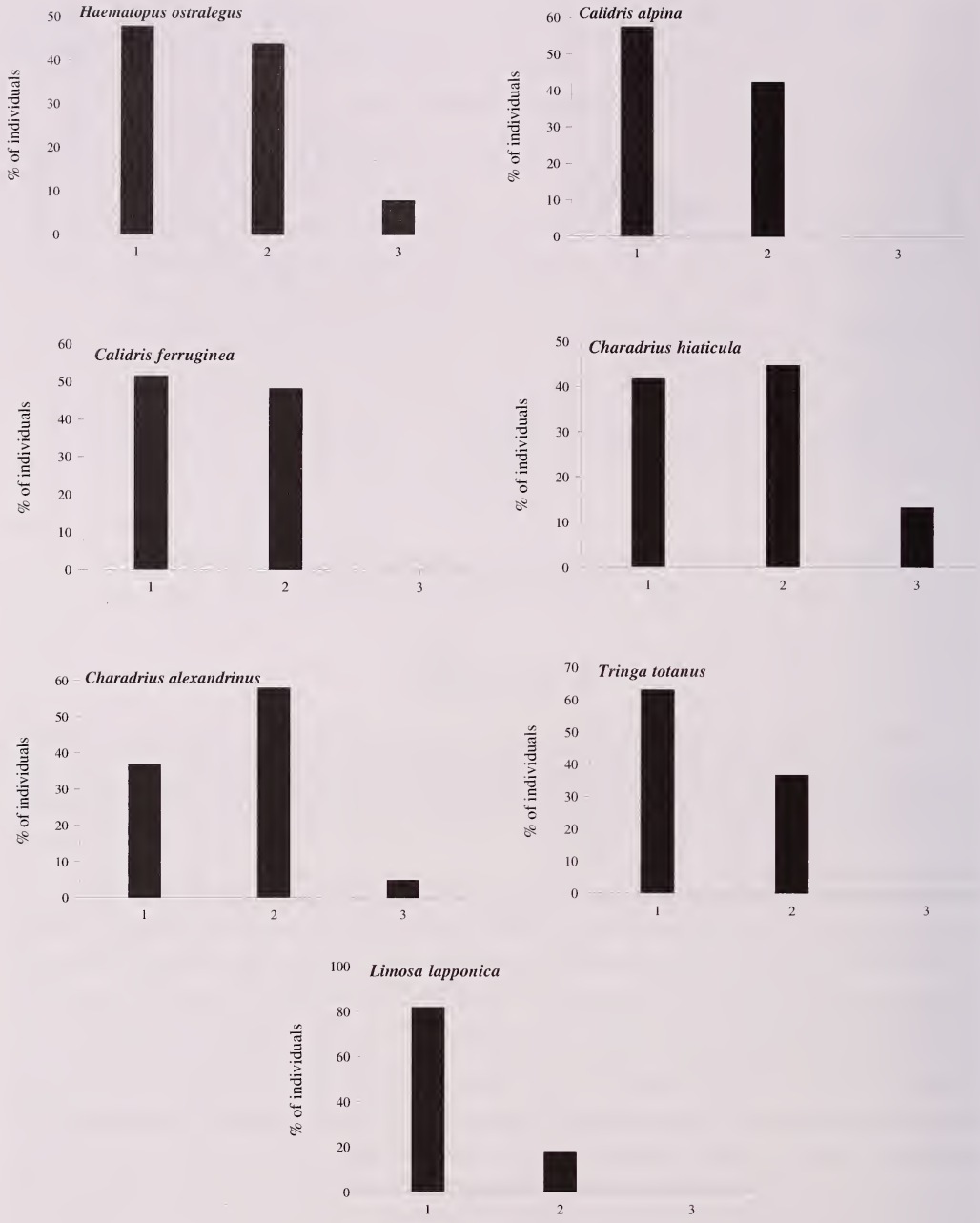

Figure 3. Relative macrohabitat exploitation of the Khnifiss Lagoon for the main wader species recorded in in July-August, 1997.
1 = Open *Zostera-Salicornia* beds (outer part of the lagoon); 2 = *Zostera* beds in the saltmarsh tidal channels; 3 = Muddy or sandy beaches without *Zostera*.

	Sebkha Bou Areg (1981)[1]		Merja Zerga (1981)[1]		Sidi Moussa-Oualidia (1981)[1]		Khnifiss (1985)[2]		
	July	August	July	August	July	August	July-18	Augus-1	August-28
Ardea cinerea							18	22	28
Egretta garzetta			0	0			4	28	36
Platalea leucorodia	0	0	130	0	0	0	32	23	67
Phoenicopterus ruber	411	0	2282	0	7		79	256	827
Haematopus ostralegus	4						303	295	887
Charadrius hiaticula							10	8	200
Charadrius alexandrinus							44	6	24
Arenaria interpres	1						178	53	15
Calidris ferruginea							0	10	0
Calidris alpina							199	82	1204
Calidris canutus							0	50	920
Calidris alba							0	232	280
Tringa totanus	37						15	31	198
Tringa nebularia	2						0	1	2
Tringa glareola							0	0	0
Numenius arquata	9						8	37	104
Numenius phaeopus							5	0	80
Limosa lapponica							0	15	932

Table 3. Comparison of numbers of waders and other wading birds in the summer period at important coastal wetlands in Morocco and Mauritania. Source: 1: Thevenot *et al.* (1982); 2: Beaubrun *et al.* (1988); 3: Dijk *et al.* (1990); 4: Wolff & Smit (1990). Only species recorded in this study are included for comparison. Figures between parentheses for the present study represent birds recorded in boat surveys (only shown for the larger species). Blank spaces are due to absence of data for that species.

	Guelta El Aouina (1981)[2]			Khnifiss (1997, present study)	Banc d'Arguin (1988)[3]	Banc d'Arguin (various dates)[4]
	July-18	August-3	August-28	July-27 - August-4	June	July = August
Ardea cinerea	11	0	0	14 (6)	15700	
Egretta garzetta				6 (12)		
Platalea leucorodia			13 (16)	7200		
Phoenicopterus ruber	37	22	195	36 (141)	26900	
Haematopus ostralegus				85 (215)	1000	75
Charadrius hiaticula				74	12600	200
Charadrius alexandrinus				126	900	50
Arenaria interpres				6	2600	60
Calidris ferruginea				31	16000	200
Calidris alpina				213	141600	2000
Calidris canutus				25	26700	300
Calidris alba				9	8200	40
Tringa totanus				76	25000	70
Tringa nebularia				13	900	10
Tringa glareola				1		
Numenius arquata				10 (14)	1100	0
Numenius phaeopus				14	7400	140
Limosa lapponica				38	34800	300

Table 3.(Continued).

As for the individual abundance, the species richness and the diversity diminished in the summering wader community compared with the wintering assemblage. This could lead to a diminished feeding pressure upon invertebrate populations, thus allowing the recovery of the food resources in this season (KALETJA [9]). Predation pressures upon these invertebrate resources may also vary among different zones of the lagoon, a fact that should be taken into account if management plans are to be implemented (PIERSMA *et al.* [14]). BEAUBRUN *et al.* [2] noted the higher wader foraging densities at sector 1A throughout the year. This sector roughly coincided with census routes 1 and 2 in our survey (Fig. 1), in which we recorded the greater density, diversity and species richness, along with route 10. These stations have more extensive and profitable feeding patches, mainly *Zostera* beds, but also *Spartina-Salicornia* shallows, and should be specially considered when human activities are likely to mean a threat.

The central (or inner) part of the lagoon is mainly represented by the huge saltmarsh area. This zone sheltered less individuals than the open shores near to Foum Agoutir (lagoon entrance). At low tide, however, there is an overall exposed mudflat surface that could be extensive enough to allow waders to forage efficiently whithin those channels. This area of tidal channels is also important because it supports higher plant cover and diversity in the muddy mounds that isolate the channels, thus providing a richer feeding environment and refuges for waders and other migrant and resident birds (e. g. *Motacilla flava*).

The observation of high feeding densities of waders could be biased towards the *Zostera* beds because this substrate type is almost ubiquitous in the lagoon. Nevertheless, the variation in bird diversity and density across different situations within this substrate suggest the existence of a certain degree of resource patchiness, that could be reflected in the distribution patterns of waders (HOCKEY *et al.* [8]). The invertebrate consumption of wintering waders is high compared to their food supply in the Banc d'Arguin (ZWARTS *et al.* [24]), contrasting with other sites along the EAF. Whether spatio-temporal variability in the macrozoobenthos of the *Zostera* beds is related to foraging bird densities needs research in the Khnifiss reserve (HOCKEY *et al.* [8], KALETJA [9]). The intertidal to supratidal meadows of *Spartina* are intensively grazed and shortened by sheep herds. This herbivore pressure have not yet been measured in quantitative terms, despite it may interact with the wader populations in several ways (e.g. reducing the availability of refuges and coverage, or/and reducing the primary productivity). All these aspects would provide an ecological frame for the evaluation of the mutual interactions among birds, habitat and human influence on the environmental resources of Khnifiss.

Present day considerations of prospective management plans for the reserve face the need of a better knowledge of the whole avifauna, and specially aquatic birds. Khnifiss is the only desert, coastal lagoon located to the south of Agadir. This circumstance makes it an essential stepping stone or coastal refuge for more than 150 migrant and/or winter and accidental visitor species (BAOUAB [1], THEVENOT *et al.* [19]). It should be emphasized that migrating waders are completely dependent on a reduced number of wetlands (PIERSMA *et al* [14], SMIT & PIERSMA [17]). The total size of these is very small and the habitat type is in great demand for various kinds of distinctive human exploitation. However, effects on bird populations due to changes in land use cannot be predicted whithout a basis of population dynamics (GOSS-CUSTARD & DURELL [6]), that is the main lack in the studies of the Khnifiss avifauna. For instance, a new winter survey is needed after more than a decade from the reports in DAKKI & LIGNY [4]. The area as a whole deserve special and active protection, and evaluations of possible human impacts and actual uses of the lagoon must

tend to consider both the terrestrial and aquatic avifauna as good indicators of ecosystem damaging and alteration. If adequately managed, the reserve has a potential interest as a scientific tourism centre, activity that could promote the local economy, which in turn would promote the long-term conservation of the area.

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7. REFERENCES

[1] BAOUAB, R-E. 1988. Checklist of birds observed in the Khnifiss-La'youne region between April 1985 and May 1986. *In*: DAKKI, M. & DE LIGNY, W (eds.): *The Khnifiss Lagoon and its surrounding environment (Province of La'youne, Morocco). Trav. Inst. Sci. Rabat, mém. hors série*: 115-124.

[2] BEAUBRUN, P-C., THEVENOT, M. & SCHOUTEN, J. 1988. Wintering and summering water bird populations in the Khnifiss Lagoon. *In*: DAKKI, M. & DE LIGNY, W. (eds.): *The Khnifiss Lagoon and its surrounding environment (Province of La'youne, Morocco). Trav. Inst. Sci. Rabat, mém. hors série*: 125-139.

[3] CONGOST TOR, J. 1973. Estudio ornitológico de la región de Seguiat-El-Hamra, Sáhara español, en Abril de 1973. *Miscelánea Zoológica* 3: 195-207.

[4] DAKKI, M. & DE LIGNY, W. (eds.): *The Khnifiss Lagoon and its surrounding environment (Province of La'youne, Morocco). Trav. Inst. Sci. Rabat, mém. hors série*: 165-172.

[5] ETCHÉCOPAR, R. D. & HÜE, F. 1967. *The birds of North Africa*. Oliver & Boyd, Edinburgh and London. 612 p.

[6] GOSS-CUSTARD, J. D. & LE V. DIT DURELL, S. E. A. 1990. Bird behaviour and environmental planning: approaches in the study of wader populations. *Ibis* 132: 273-289.

[7] HEIM DE BALSAC, H. & MAYAUD, N. 1962. *Les oiseaux du nord-ouest de l'Afrique.* Éditions Paul Lechevalier, Paris.

[8] HOCKEY, P. A. R., COOPER, J. & DUFFY, D. C. 1983. The roles of coastal birds in the functioning of marine ecosystems in southern Africa. *South African Journal of Science* 79: 130-134.

[9] KALETJA, B. 1992. Time budgets and predatory impact of waders at the Berg River Estuary, South Africa. *Ardea* 80: 327-342.

[10] KERSTEN, M. & C. J. SMIT. 1984. The Atlantic coast of Morocco. *In*: EVANS, P. R., GOSS-CUSTARD, J. D. & HALE, W. G. (eds.), *Coastal waders and Wildfowl in winter*: 276-292. Cambridge University Press, Cambridge.

[11] MAGURRAN, A. 1989. *Diversidad ecológica y su medición*. Vedrá, Barcelona.

[12] MOREL, G. J. 1980. Fifty years of ornithology in West Africa. *Bull. B.O.C.* 100: 66-68.

[13] PARKER, D. M. & M. DAKKI. 1988. The ecological significance of the Khnifiss Lagoon and adjacent desert and coastal areas (province of La'youne, Morocco). *Trav. Inst. Sci. Rabat, mém. hors série.*

[14] PIERSMA, T., BEINTEMA, A. J., DAVIDSON, N. C., MÜNSTER, O. A. G. & PIENKOWSKI, M. W. 1987. Wader migration systems in the East Atlantic. *Wader Study Group Bull.* 49, Suppl./IWRB Spec. Publ. 7: 35-56.

[15] PIERSMA, T., DE GOELJ, P. & TULP, I. 1993. An evaluation of intertidal feeding habitats from a shorebird perspective: towards relevant comparisons between temperate and tropical mudflats. *Netherlands Journal of Sea Research* 31: 503-512.

[16] ROBIN, P. 1967. Les oiseaux de la lagune de Khnifiss (Puerto Cansado). *C. R. Séances Soc. Nat. Maroc* 33: 56-58.

[17] SMIT, C. J. & PIERSMA, T. 1989. Numbers, mid-winter distribution and migration of wader populations using the East Atlantic Flyway. *In*: BOYD, H. & PIROT, J.-Y. (eds), *Flyways and reserve networks for water birds*: 24-63. IWRB Spec. Publ. 9, Slimbridge.

[18] THEVENOT, M., BEAUBRUN, P-C., BAOUAB, R. & BERGIER, P. 1982. Compte Rendu D'ornithologie Marocaine (Annee 1981). *Docum. Inst. Sci., Rabat* 7: 1-120.

[19] THEVENOT, M., BEAUBRUN, P-C. & SCHOUTEN, J. 1988. Breeding birds of the Khnifiss-La'youne region and its recent developments. *In*: DAKKI, M. & DE LIGNY, W. (eds.): *The Khnifiss Lagoon and its surrounding environment (Province of La=youne, Morocco). Trav. Inst. Sci. Rabat, mém. hors série*: 141-160.

[20] VALVERDE, J. A. 1957. *Aves del Sáhara Español (Estudio ecológico del desierto).* Instituto de Estudios Africanos. Consejo Superior de Investigaciones Científicas, Madrid.

[21] VAN DIJK, A. J., DE RODER, F. E., MARTEIJN, E. C. L. & SPIEKMAN, H. 1990. Summering waders on the Banc d'Arguin, Mauritania: a census in june 1988. *Ardea* 78: 145-156.

[22] VERNON, J. D. R. 1980. 50 years of ornithology in Northwest Africa 1930-1980. *Bull. B. O. C.* 100: 61-66.

[23] WOLFF, W. J. & SMIT, C. J.. 1990. The Banc d'Arguin, Mauritania, as an environment for coastal birds. *Ardea* 78: 17-38.

[24] ZWARTS, L., BLOMERT, A-M., ENS, B. J., HUPKES, R. & VAN SPANJE, T. M. 1990. Why do waders reach high feeding densities on the intertidal flats of the Banc d'Arguin, Mauritania?. *Ardea* 78: 39-52.