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Research Article

Coastal zone habitat-use by birds in Qatar: Insights from a rapid assessment method during spring migration

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Abstract

In the western part of the Arabian/Persian Gulf, coastal habitats such as intertidal wetlands and mangroves are scarce and poorly studied. We conducted a rapid assessment survey of bird species richness and abundance at the Fuwairit khor lagoon in northern Qatar, using a line transect count scheme to collect data from six different generic habitat types, repeated during five consecutive days in late April 2013. To further analyze the ecological requirements of the surveyed bird assemblage per habitat type, we assigned ecological guild categories to each species and distinguished among migrants, local, and regional breeders. Mangrove and intertidal mudflats hosted the highest bird densities and the most distinctive assemblages, while the beach habitat had high concentrations of birds but relatively few species. In contrast to the wetland habitats, near-shore marine areas and dune habitats had very limited numbers of birds and a relatively depauperate species assemblage. Employing a habitat perspective in a quantitative bird survey method shows that birds are effective biodiversity indicators for a rapid survey of coastal features in a poorly-studied region of the Arabian/Persian Gulf.

Titre : Utilisation des habitats côtiers par l'avifaune au Qatar: Aperçus d'une brève évaluation durant la migration printanière

Les habitats côtiers, tels que les lagons, les zones intertidales associées et les mangroves, sont particulièrement rares et peu étudiées dans la partie occidentale de l'Arabie/Golfe Persique. Pour la planification de la conservation en milieu côtier, il est crucial d'effectuer un suivi de la biodiversité, et l'avifaune peut constituer un bon bio-indicateur pour la définition des mesures de conservation prioritaires. Dans le présent cas d'étude, des échantillonnages printaniers des populations d'oiseaux et de leur richesse spécifique par type d'habitat ont été entrepris dans la zone côtière du lagon de Fuwairit dans le nord du Qatar. Pour cela, des comptages par transect linéaire ont été répétés durant cinq jours consécutifs fin avril 2013. Afin d'analyser plus en détail les exigences écologiques locales de l'avifaune, les espèces d'oiseaux ont été regroupées par guilde écologique, et une distinction a été faite entre les espèces migrantes, celles se reproduisant localement et celles se reproduisant dans la région. Les mangroves et les baies ensablées se sont avérées être les milieux accueillant les plus grandes densités d'oiseaux et les assemblages les plus originaux, tandis que les plages présentaient une forte densité mais une faible diversité d'espèces. Contrairement aux milieux aquatiques situés plus dans les terres, les habitats marins côtiers et les dunes accueillaient un nombre très limité d'oiseaux et un assemblage d'espèces relativement pauvre. L'utilisation d'une classification des habitats dans le cadre d'un suivi quantitatif des populations d'oiseaux a permis de montré que l'avifaune pouvait constituer un indicateur efficace dans le but de réaliser une évaluation rapide des caractéristiques écologiques d'une zone côtière sensible au sein d'une région peu étudiée. Cette approche représente ainsi une procédure pertinente de suivi des populations dans le but de mettre ne places des mesures de conservation.

Key words: Conservation assessment, birds, biodiversity, habitat, Qatar, coastal zone

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Introduction

Coastal zone wetland areas are among the most threatened landscape features in the arid Middle Eastern countries. Wildlife-rich habitats such as intertidal lagoons and mangroves are spatially scarce and poorly studied in the western part of the Arabian/Persian Gulf. In several rapidly developing areas in this region, human-induced pressures seem to especially stress coastal zone habitats [1]. Qatar is a good example of a country where industrial and housing development is occurring at an unprecedented rate along the coast, and biodiversity surveys are scarce and seldom systematically updated [1,2]. The human population has boomed after industrial oil production, and landscape conservation awareness has only recently begun to influence protected-area policies [1,3]. Anthropogenic pressures and threats to coastal ecosystems can only be rationally managed through strategic conservation planning, immediate site protection, and conservation measures. Biodiversity should be given utmost consideration, and certain indicator species groups, such as birds, may provide useful, practical guidelines for conservation planning [4].

In areas lacking organized biodiversity inventories, rapid assessment procedures using birds can build biodiversity knowledge baselines [4]. In our case study, we conducted a rapid assessment of bird numbers and their habitat use in different habitat types during a spring migration at Fuwairit, a small intertidal inlet system in Northern Qatar. In order to best depict bird habitat use and preliminarily assess relevant biodiversity patterns, analyses were made at three levels of organization: habitat-based bird assemblage, food-centered ecological guild, and species residence status.

Methods

Study Area

Qatar is a small state (11,571 km^2) with approximately 900 km of coastline. As a subtropical desert peninsula, the mean annual rainfall is 81 mm, with an average annual maximum temperature of 31ºC [1]. During spring, a regionally important bird migration takes place along the eastern coast of the Arabian Peninsula, part of the West Asia-East Africa Flyway [5,6,7]. The study area, Fuwairit, is a small intertidal inlet known locally as a khor lagoon system, on the north coast of Qatar (26° 1'57.02"N, 51°22'17.55"E). Fuwairit is one of the few areas along Qatar's coast that hosts mangrove-fringed lagoon habitats. The grey mangroves *Avicennia marina*, although native to Qatar, are said to have been planted at Fuwairit during a rehabilitation initiative in 1981 [8], but although they grow in natural stands nearby, it is not certain whether or not mangroves existed on this site in the past. Today, since industrial oil production dominates the economy, pressure on wood-cutting and grazing of the mangroves has almost completely ceased, and these woodland patches are showing signs of local expansion. For the last decade, the 2.4 km-long marine beach of Fuwairit has been protected during the spring-summer period by the Qatar Ministry of Environment because it hosts the second-largest known sea turtle nesting rookery on mainland Qatar [9]. However, other biodiversity values, such as its ornithological importance, are poorly documented, and beyond the beach the site is not included in any protected-area designation [1].

Bird survey: A habitat approach

To record the abundance and differential use of the area's major habitats, we conducted a bird survey within a short time-window during the spring migration period, from April 24th to 28th, 2013. One experienced ornithologist (the first author) surveyed birds with binoculars (Zeiss 10x40B), using a modified line transect method [4]; birds seen within the designated habitat areas were counted. The transect survey followed a 3.7 km circuit route that was walked slowly with frequent stops on each of the five consecutive days (always during near-flood tide conditions during the early morning hours, between 5:00 and 9:00 a.m.). Bird numbers were recorded in six constituent lists according to the generic habitat type where they were first observed (*i.e.,* if a bird was flushed by the observer it was only counted in the habitat type where it was initially encountered). Total observation time amounted to 15 hours in good stable weather, most mornings being in nearly wind-still conditions. The survey start-point was the Qatar Ministry of Environment Research Camp at the north end of the beach, and the route always began from the inland lagoon-mangrove side of the coastal spit and turned back along the long marine beach, which is backed by dunes (Fig. 1). Unlike in other Eastern Middle East countries, bird shooting was not observed during the study, and anthropogenic disturbance to birds was minimal during the early morning hours; therefore, humans or domestic animals did not noticeably influence bird species' habitat use during the survey.

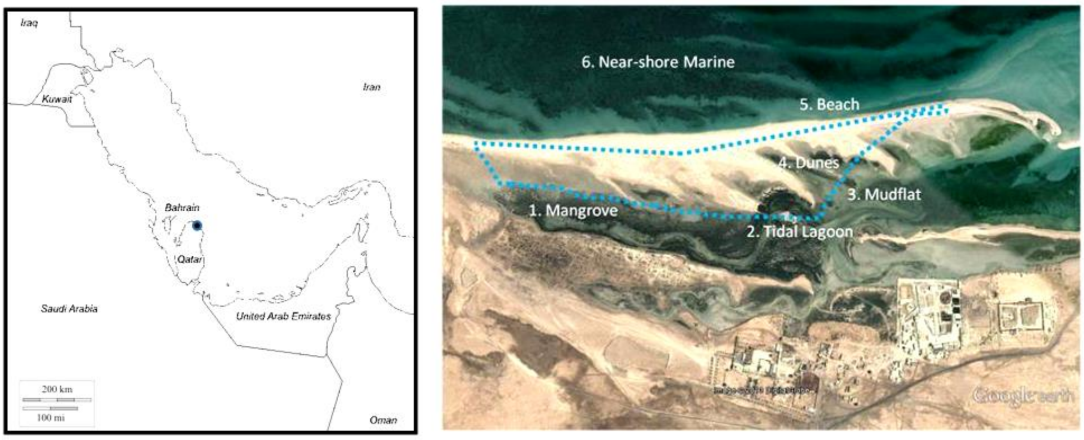

Fig. 1 Left: Map of Arabian/Persian Gulf, Qatar, and the location of Fuwairit (dot). Right: Fuwairit Khor study area. The transect route (3.7 km) for the ornithological survey taken by one observer during five trials at Fuwairit. Six generic habitat types were surveyed within representative area boundaries for each habitat (Satellite Image: Google Earth, August 11th 2012).

Fuwairit's khor lagoon system conveniently provides an opportunity to survey six different generic habitat types nearly simultaneously during a fairly short line transect. In the Arabian/Persian Gulf the term khor lagoon refers to a shallow tidal inlet usually bordered by intertidal and subtidal mud and sand flats and supratidal dune beaches and inland salt flats. These coastal zone features usually exhibit distinct habitat formations along a marine-terrestrial gradient. In this study, a generic habitat type unit was defined as a spatially contiguous landscape feature that appears more or less homogenous throughout and is physiognomically distinctive from other such units [see 10]. The generic habitat type's approximate area boundaries visible to the observer were visually estimated. The six habitat types surveyed were: 1) low mangrove with *Avicennia marina*; 2) lagoon pool (at near high tide flood level); 3) exposed intertidal mudflat (within the khor lagoon); 4) beach dunes; 5) beach shoreline including sandflats; and 6) near-shore marine waters (Fig. 2). Fuwairit's coastal wetland area, although not yet officially delineated, covers approximately 150 ha with approximately 20 ha taken up by mangrove vegetation.

In order to interpret the ecological significance of the observed patterns, bird species were used as ecosystem indicators through analyses of the collected data. Each bird species was assigned an *a priori* ecological guild category on the basis of food and foraging style following Weller's approach [11], where ecological guild refers to a functional trait categorization of "species (related or not) that exploit the same resources in a similar way." The guild assignment to species (Appendix 2) was constructed using available knowledge of a bird's ecology in the region [7, 12, 13] and based on feeding-behavior ecological guild categorizations adapted from other wetland habitat-based analyses [11, 14]. The residence status of the species (migratory, resident breeder, breeder within Qatar) was also defined with the best available knowledge and corroborated by the Qatar bird checklist [12], as follows: M: migrants, birds that only pass through the country or may also overwinter there; LB: birds that were confirmed to breed locally in the study area or the immediate vicinity during the study; QB: birds that are known to breed within or near the territory of Qatar but for which no local breeding evidence was recorded during the survey. Descriptive statistics, multidimensional scaling (NMDS) and relevant indices of biodiversity were used to interpret ecological patterns; the data were analyzed using MS Excel and the statistical software package R, version 3.2. [15].

Fig. 2. Low *Avicennia marina* mangroves within tidal lagoon mudflats and the research camp at the north end of Fuwairit beach in the background (Photo: S. Zogaris).

Results

A total of 53 taxa (including two taxa classified to genus level) were identified at Fuwairit; 2,163 individuals were recorded (Appendix 2). Overall there was a significant relationship between bird species richness and abundance per habitat type (Fig. 3), but the correlation was weak (R^2=0.17, p=0.013) because of the extremely high abundance of Lesser Crested Tern *Thalasseus bengalensis* roosting at high tide on the beach habitat. Removing these samples from the analysis led to a stronger correlation (R^2=0.67, p<0.001). Despite the peak abundance of Lesser Crested Tern, most species were sighted in relatively lower numbers. Six species were sighted with only one recorded individual, and 13 species were recorded on only one of the five count days.

Habitat type was a strong discriminator of bird composition. Mangroves and mudflats were inhabited by the most distinct species assemblages, clearly differentiated from the other habitat types in the NMDS ordination plot (Fig. 4). Most species concentrated on the mangrove and mudflat habitats (of the six generic habitats surveyed). Moreover, 14 species appeared only in mangrove and nine only in mudflats. Numbers of land birds (relative to seabirds and waterbirds) were rather low, but the species richness within the mangroves was high (warblers, shrikes, and several widespread land bird passerines). Numbers of seabirds and shorebirds were relatively high (especially concentrating on the beach's spit cape). This provides local evidence that shallow intertidal mudflats of the khor lagoon system are an important shorebird foraging area. As to be expected in a small wetland area along an arid coastline in the Western Arabian/Persian Gulf, the numbers of breeding bird species were low. Marine, dune and beach habitat exhibited very low species numbers: there were two species recorded only in the dune habitat, one species only in the beach habitat, and one only in the marine habitat.

In terms of residence categories, 40 species are migrants and only eight are considered to breed locally; the remaining five are known to breed in and around the Qatar Peninsula, but our observations did not confirm breeding on site. Local breeders included some naturalized alien species (such as Common Myna *Acridotheres tristis*) and one feral or escaped species (Rock Dove *Columba livia*), perhaps due to the proximity of a small holiday home development nearby. Despite the large difference in species richness, the total abundance of the three residence categories are similar, but they are distributed very unevenly among the different habitat types in both abundance and species richness, as the Kruskal Wallis results show (see Appendix 1). Migrant species dominate in the mudflats (accounting for 76% of mudflat's avifauna abundance and 81% of its species richness). Local breeders are more commonly observed in the mangroves (accounting for 56% of mangroves abundance but only 30% of its species richness). Local breeders are the dominant species group in the dunes (where they are 88% of the avifauna abundance and 69% of its species richness).

We designated seven different ecological guild groups as ecological functional groups in the recorded avifaunal assemblage [11] in order to report ecological functional diversity patterns and assess habitat conditions [16]. All 53 taxa are assigned to the following guilds: 1) foliage-foraging insectivore (8 spp.); 2) marine forager/fish-eater (4 spp.); 3) dry-ground forager (9 spp.); 4) flight insectivore (4 spp.); 5) raptor-like forager (6 spp.); 6) wading carnivore (3 spp.); 7) wet-surface carnivore (19 spp). Dominant in abundance was the marine forager/fish-eating guild, which accounted for 46% of the birds observed, but this was a species-poor group including only terns, gulls, and one cormorant species. The most species-rich guild was the wet surface carnivores, which accounted for 23% of the total abundance. The distribution of these guilds among habitat types is very uneven, as is the number of guilds observed in each habitat (Appendix 1). The most functionally diverse bird assemblage per habitat was recorded in the mangrove habitat (both overall and in each sample), followed by the mudflats and dunes (with the same total number of guilds observed but fewer groups observed in each sample). At the other end, the lowest functional diversity was the marine waters with only two guilds recorded.

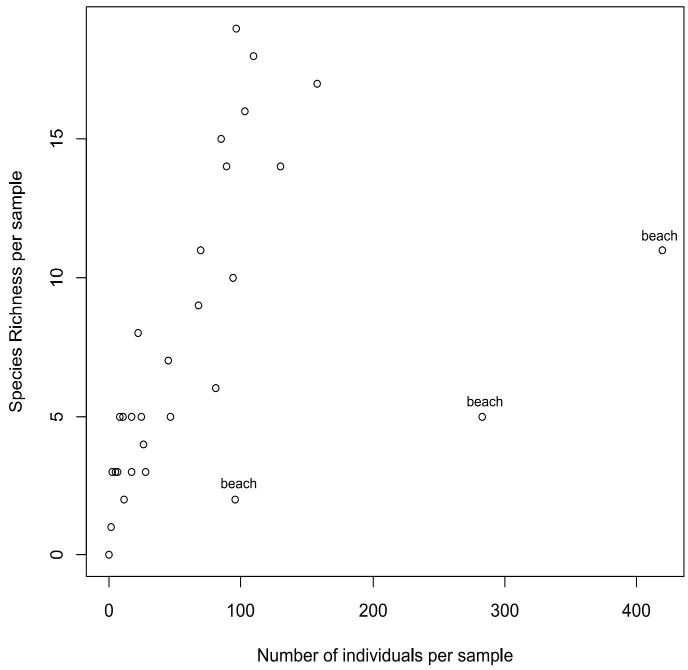

Fig. 3. Plot of species richness to number of individuals per sample; the beach habitat shows higher bird number concentrations.

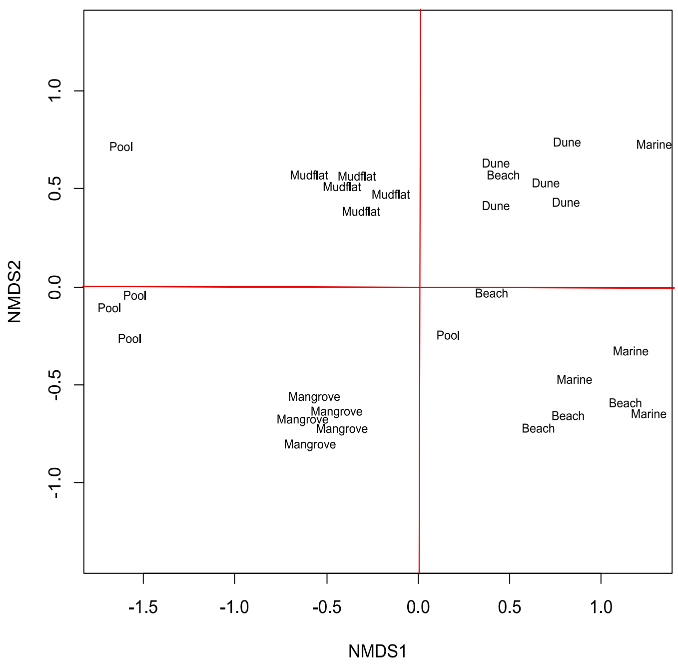

Fig. 4. Non-metric multidimensional scaling plot of sites showing habitat type categories based on recorded bird populations per day-count sample.

Finally, as expected during spring migration in the region, the bird species composition changed considerably from one day to the next. On a daily basis, we observed approximately half the species that were recorded over the five day period, indicating that more species would probably be recorded over a longer period of observation. Among habitats the average number of species recorded daily was strongly correlated with the total number of species recorded in the habitat (R^2=0.96, $p<0.001$). On average, the highest similarity in the avifauna species composition among days (*i.e.,* lowest species temporal turnover) was observed in the mangroves, followed by the mudflats (Appendix 1); these two food-rich habitats for birds seem to encourage some intercontinental migrants to stay longer and re-fuel. The highest temporal turnover was observed in the species-poor marine habitat, followed by the lagoon pool habitat. Among habitats, temporal turnover (beta diversity) was strongly and negatively correlated with species richness at both the sample scale (alpha diversity) and overall (gamma diversity) (spearman rank correlation $\rho>0.88$ and $p<0.02$). Only Whittaker's index was not significantly correlated (Spearman $p>0.2$).

Discussion

Method

This study may be more valuable as a survey method exercise than as an interpretive description of bird assemblages. Our short-term observations may overlook several factors that influence bird habitat use, including supra-landscape factors, such as intercontinental migration routes and migration timing [10], as well as stochastic factors (*e.g.,* weather events) that may also influence distributions, population density, and habitat use [17, 18]. Further study, through a simple monitoring scheme, is needed for a fine-scale description and interpretation of the bird communities and their habitat use along Qatar's coastal zone.

However, our work provides one of the few systematic accounts of quantitative habitat distribution of birds within the coastal zone in Qatar and is one of the few published examples in the Arabian/Persian Gulf region. Since this constant-effort survey trial was repeated over five consecutive days and there was no inter-observer bias during the counts, the method seems adequate to provide an initial comparison among the different habitats, especially since stable weather and similar tidal conditions persisted during each count. In support of this notion is the fact that the different facets of biodiversity (*e.g.,* mean daily species richness, total species richness, species turnover) were strongly correlated, indicating that we sampled the study period well, and the consistency of information among the days shows that most species were recorded. Overall, a longer period of observation during the migration period will reveal more species [4], but we believe among-habitat diversity patterns were satisfactorily represented during the study period. Furthermore, the use of ecological guilds and the habitat perspective provides an important foundation for further development of conservation-relevant monitoring and indicator development [14, 16].

Habitat-use insights

This study was appropriately timed since a high number of species utilized Fuwairit's habitats during this time. The majority of the species observed were long-distance migrants that target what we assume are biologically productive habitat types with important food sources (*i.e.,* many birds were observed actively feeding). Our study shows that two habitats had outstanding value for many bird species: mangroves and lagoonal mudflats. These "special habitats" for conservation at this site were the most bird species-rich habitats, with the most distinct bird assemblages, utilized by many narrow-niche, habitat-specialist species.

Although tropical mangroves are known for their biological productivity [17], very little ornithological research has been done on subtropical mono-species mangrove patches such as these in Qatar [see 8, 19, 20, 21 and references therein]. Mangrove habitat may be of significant value for biodiversity along a desert coastline such as on the Arabian/Persian Gulf, where any woodland-like structure is extremely scarce. In fact, the species-richness recorded at Fuwairit compares favorably to other mangrove bird studies where longer term surveys took place [17]. In adjacent Iran, Gashemi et al. [19] recorded the seasonal variation in the avifauna in a much larger deltaic mangrove forest-wetland system and observed 56 waterbird species. Given that in our case study we observed 28 species solely in the mangrove habitat in just 5 days (with an average of 15 species per day), it seems likely that with further study the total species richness at Fuwairit may probably reach the scale of the Iranian study. Mangroves are found in only half a dozen locations along Qatar's coast [22], and despite covering a small area of the coast, they mimic a woodland swamp environment that is especially attractive to many migrant birds.

Our work also shows that khor lagoon mudflats are extremely important, since they held the highest number of species and highest bird population densities during this spring migration survey. Obviously many waders that use mudflats are specialized feeders and are restricted to feeding in silty mudflats [11], which is why this habitat is inhabited by a species-rich specialized avifauna distinct from the bird assemblages in the other habitats. Nearly all long-distance migratory waders passing through the area were observed only in this habitat. In our study, intertidal lagoon mudflats, often occurring in close proximity to mangroves in the Gulf states, sustained the highest number of "Near Threatened" bird species [23,24] (four species listed in the IUCN Red List, see Appendix 2).

Other habitat types at Fuwairit were recorded as relatively species-poor during this brief study, but they may also prove to have specific conservation value for birdlife. Examples of this include the beach spit of Fuwairit, which is an important roosting location for hundreds of terns and gulls since it provides seclusion from predator/human disturbance and immediate access to adjacent food-rich lagoon environments. The beach dune area is important for three locally breeding species: Saunder's Tern *Sternula saundersi*, Kentish Plover *Charadrius alexandrinus,* and Greater Hoopoe-Lark *Alaemon alaudipes*. These ground-nesting birds are local breeders and are probably sensitive to anthropogenic disturbance in such beach-side environments. Fuwairit's marine habitat, although recorded as the most species-poor habitat type, hosted Socotra Cormorant *Phalacrocorax nigrogularis*, the only species in our study area classified as globally threatened (listed as IUCN Red List “Vulnerable” [23]).

Fig. 5. Characteristic species at Fuwairit: 1) Lesser Crested Tern, 2) Saunder’s Tern, 3) Indian Reef Heron, 4) White-eared Bulbul, 5) Kentish Plover, 6) Socotra Cormorant. (Photos: A. Vidalis).

Implications for conservation

Qatar's baseline knowledge of its avifauna has much room for improvement; there is no state-wide monitoring program for birds [12], and an official survey delineating important bird areas is outdated [24, 25]. This situation of poor ornithological and biodiversity surveying, even along quite accessible coastal areas, is by no means unique in the states of the Western Arabian/Persian Gulf [26]. Readily documented biodiversity indicators such as birds are important in conservation planning, but they have been largely neglected in many parts of the Arabian Peninsula [13,27]. Our study shows that an organized rapid survey or monitoring scheme of this type will help identify and delineate areas with outstanding conservation values and help associate their biodiversity with particular habitat features. Despite the lack of organized bird survey data, the Western Arabian/Persian Gulf coast has been considered as “one of the most important areas for wintering waders in the world” [28], justifying more ornithological attention to Qatar’s coastal wetlands. Even today, knowledge of migratory birds that use the East African-West Asian flyway has lagged behind the western Europe-west Africa and the Nearctic flyways [6, 13]. Our research exercise at Fuwairit promotes the wider development of basic survey procedures based on rapid assessment approaches [29] in order to support policy-relevant nature conservation in the region.

While Qatar is currently developing legislation and management agencies for nature conservation [2], protected area creation is still in the early stages of implementation [3]. There is abundant evidence that anthropogenic pressures and threats to natural habitats concentrate on the country's coastal zone. Important sites for biodiversity, such as mangroves and coastal lagoons, are under imminent threat from poorly planned development [22]. The rapidly expanding capital city of Doha is also likely to negatively influence Qatar's coastal natural areas with fringing holiday home developments, road expansion, and increased recreational disturbance [30]. In our opinion, Fuwairit’s coastal zone and the surrounding landscape should be specifically studied for inclusion within a protected area. This is clearly justified by the site’s rich habitat composition, its scarce "special habitats" for migratory and breeding birds, other biodiversity values such as the marine turtle rookery [9], and its outstanding educational potential (Fig. 5).

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Appendix 1. Avifaunal diversity and abundance during the spring 2013 survey at Fuwairit. Diversity is estimated as gamma diversity (total number of species observed throughout the sampling period); as alpha diversity (mean number of species or mean Shannon diversity index observed per sample, which in our case corresponds to per day of sampling); and as beta diversity indices, which are either the ratio of gamma over alpha diversity or the mean value of similarity indices among the samples collected in each habitat (we used Jaccard and Sorensen similarity indices for presence/absence data and the Bray Curtis index with respect to abundance). We classified birds according to their ecological guild (feeding-based functional guild), residence type, and current information on their diversity and abundance. For each mean value we also present the standard deviation. For each variable we compared the value among the different habitats using the Kruskal Wallis test.

	Mangrove	Mudflat	Beach	Dune	Pool	Marine	Total	Kruskal Wallis p
Total taxa richness (gama diversity)	28	29	17	12	6	9	53	
Species richness per sample (mean±standard deviation alpha diversity)	15.40±3.21	13.80±3.96	6.80±2.49	5.20±1.79	3.00±0.70	2.20±1.92	7.73±5.69	<0.001
Shannon diversity index (mean±standard deviation per sample)	2.21±0.35	1.99±0.21	0.85±0.63	1.43±0.35	0.89±0.22	0.41±0.51	1.29±0.75	<0.001
Abundance (mean±standard deviation per sample)	108.2±31.1	93.6±25.7	167.8±175.7	17.8±6.4	10.6±9.2	34.6±39.4	72.1±89.4	0.005
Functional diversity (total number of different *ecological guilds*)	6	6	4	6	4	2	7	
Functional diversity (mean±standard deviation number of different *guild* per sample)	5.20±0.45	4.20±0.84	3.40±0.55	3.80±0.84	2.00±0.70	1.00±0.70	3.27±1.55	<0.001
Beta diversity Whittaker index (gamma/mean alpha)	1.82	2.10	2.50	2.31	2.00	4.09	6.59	
Beta diversity mean±standard deviation pairwise Jaccard similarity	0.48±0.10	0.41±0.07	0.29±0.09	0.40±0.17	0.23±0.17	0.27±0.26	0.35±0.18	0.002
Beta diversity mean±standard deviation pairwise Sorrensen similarity	0.32±0.05	0.29±0.03	0.22±0.06	0.28±0.09	0.18±0.10	0.18±0.16	0.24±0.11	0.002
Beta diversity mean±standard deviation pairwise Bray Curtis	13.96±2.33	13.99±2.15	8.42±2.03	5.35±2.13	4.33±1.31	2.77±1.31	8.18±4.88	<0.001
Distribution of species richness per guild (mean±standard deviation per sample)								
foliage insectivores	4.8±1.6	0.0±0.0	0.0±0.0	0.8±0.4	0.0±0.0	0.0±0.0	1.00±1.56	<0.001
dry ground	5.0±1.0	1.2±1.3	1.4±0.5	1.8±0.8	0.0±0.0	0.0±0.0	1.57±1.85	<0.001
flight insects	1.6±1.34	0.8±0.4	0.4±0.5	0.4±0.5	0.2±0.4	0.2±0.4	0.60±0.81	0.122
fish	0.0±0.0	0.4±0.5	2.0±0.7	1.0±0.0	0.4±0.9	2.0±1.6	0.97±1.10	0.004
raptor	2.0±1.0	0.4±0.5	0.0±0.0	0.4±0.5	0.0±0.0	0.0±0.0	0.47±0.86	0.001
wading	1.6±0.55	1.2±0.4	0.0±0.0	0.0±0.0	1.4±0.5	0.0±0.0	0.70±0.79	<0.001
wet surface	0.4±0.55	9.6±2.5	2.8±1.9	0.8±0.4	1.0±1.0	0.0±0.0	2.43±3.60	<0.001
Distribution of abundance per guild (mean per sample)								
foliage insectivores	16.6±10.5	0.0±0.0	0.0±0.0	0.2±0.4	0.0±0.0	0.0±0.0	2.80±7.39	<0.001
dry ground	66.2±23.9	2.2±2.1	4.8±2.7	5.6±3.8	0.0±0.0	0.0±0.0	13.13±25.88	<0.001
flight insects	9.4±11.0	2.2±1.3	2.4±4.3	0.8±1.3	0.2±0.4	0.2±0.4	2.53±5.51	0.058
fish	0.0±0.0	1.2±1.8	152.0±169.0	6.8±4.4	4.4±9.8	34.4±39.8	33.13±85.05	0.004
raptor	6.2±4.6	0.4±0.5	0.0±0.0	0.4±0.5	0.0±0.0	0.0±0.0	1.17±2.89	0.001
wading	5.8±3.4	3.6±3.2	0.0±0.0	0.0±0.0	4.8±4.2	0.0±0.0	2.37±3.43	<0.001
wet surface	1.4±2.2	83.8±25.7	8.4±10.5	3.2±2.1	1.2±1.1	0.0±0.0	16.33±32.51	0.001
Distribution of species richness per residence type (mean per sample)								
migrants	9.2±3.1	11.2±2.9	2.8±2.1	1.2±0.8	2.8±0.4	0.6±0.9	4.63±4.52	<0.001
local breeders	4.4±0.5	2.6±1.5	3.2±0.8	3.6±0.9	0.2±0.4	0.8±0.4	2.47±1.71	<0.001
Qatar breeders	1.2±0.4	0.0±0.0	0.8±0.8	0.4±0.5	0.0±0.0	0.8±0.8	0.53±0.58	0.015
Distribution of abundance per migration type (mean per sample)								
migrants	39.2±18.2	71.4±18.5	12.4±14.9	1.6±1.1	9.8±7.7	6.0±11.8	23.40±27.90	0.001
local breeders	65.2±22.7	22.2±10.8	10.2±3.3	15.6±6.9	0.8±1.8	2.2±1.8	19.37±24.23	<0.001
Qatar breeders	2.8±1.9	0.0±0.0	145.2±173.2	0.6±0.8	0.0±0.0	26.4±38.9	29.17±85.01	0.021

Appendix 2. Species names, ecological guild category, residence status (M: Migrant, LB: Local Breeder, QB: Qatar Breeder), IUCN Red List Status (for codes see: *www.iucnredlist.org* and *www.birdlife.org/datazone/country/qatar*) and total (summed) number of birds recorded during the five-day survey. Taxonomy and nomenclature follows Qatar Bird Records Committee (*www.qatarbirds.org/list.htm*).

Scientific Name	English Name	Ecological Guild	Residence Status	IUCN Red List Status	Total No. Recorded
Accipiter nisus	Eurasian Sparrowhawk	raptor-like forager	M	LC	1
Acridotheres tristis	Common Myna	dry-ground forager	QB	LC	14
Acrocephalus palustris	Marsh Warbler	foliage-foraging insectivore	M	LC	6
Acrocephalus scirpaceus	Eurasian Reed Warbler	foliage-foraging insectivore	M	LC	2
Acrocephalus sp.	Reed Warbler sp.	foliage-foraging insectivore	M	-	30
Alaemon alaudipes	Greater Hoopoe-Lark	dry-ground forager	QB	LC	3
Anthus cervinus	Red-throated Pipit	dry-ground forager	M	LC	2
Ardea cinerea	Grey Heron	wading carnivore	M	LC	11
Arenaria interpres	Ruddy Turnstone	wet-surface carnivore	M	LC	1
Butorides striata	Striated Heron	wading carnivore	QB	LC	1
Calidris alba	Sanderling	wet-surface carnivore	M	LC	6
Calidris alpina	Dunlin	wet-surface carnivore	M	LC	11
Calidris ferruginea	Curlew Sandpiper	wet-surface carnivore	M	NT	7
Charadrius alexandrinus	Kentish Plover	wet-surface carnivore	LB	LC	123
Charadrius leschenaultii	Greater Sand Plover	wet-surface carnivore	M	LC	1
Charadrius mongolus	Lesser Sand Plover	wet-surface carnivore	M	LC	155
Circus aeruginosus	Western Marsh Harrier	raptor-like forager	M	LC	2
Columba livia [var. domestica]	Rock Dove (feral/domesticated)	dry-ground forager	LB	LC	32
Egretta gularis	Indian Reef Heron	wading carnivores	M	LC	59
Falco tinnunculus	Common Kestrel	raptor-like forager	M	LC	1
Galerida cristata	Crested Lark	dry-ground forager	LB	LC	28
Haematopus ostralegus	Eurasian Oystercatcher	wet-surface carnivore	M	NT	4

Hirundo rustica	Barn Swallow	flight insectivore	M	LC	60
Lanius collurio	Red-backed Shrike	raptor-like forager	M	LC	22
Lanius minor	Lesser Grey Shrike	raptor-like forager	M	LC	3
Lanius phoenicuroides	Turkestan Shrike	raptor-like forager	M	LC	6
Larus genei	Slender-billed Gull	marine forager/fish-eater	M	LC	68
Limosa laponica	Bar-tailed Godwit	wet-surface carnivore	M	NT	2
Merops apiaster	European Bee-eater	flight insectivore	M	LC	10
Motacilla flava	Yellow Wagtail	wet-surface carnivore	M	LC	18
Muscicapa striata	Spotted Flycatcher	flight insectivore	M	LC	3
Numenius arquata	Eurasian Curlew	wet-surface carnivore	M	NT	8
Numenius pheopus	Whimbrel	wet-surface carnivore	M	LC	6
Passer domesticus	House Sparrow	dry-ground forager	LB	LC	46
Phalacrocorax nigrogularis	Socotra Cormorant	marine forager/fish-eater	QB	VU	5
Phyloscopus collybita	Common Chiffchaff	foliage-foraging insectivore	M	LC	1
Phyloscopus sp.	Leaf Warbler sp.	foliage-foraging insectivore	M	-	8
Phyloscopus trochilus	Willow Warbler	foliage-foraging insectivore	M	LC	34
Pluvialis squatarola	Grey Plover	wet-surface carnivore	M	LC	37
Pycnonotus leucotis	White-eared Bulbul	dry-ground forager	LB	LC	114
Riparia riparia	Sand Martin	flight insectivore	M	LC	3
Spilopelia senegalensis	Laughing Dove	dry-ground forager	LB	LC	120
Sternula saundersi	Saunder's Tern	marine forager/fish-eater	LB	LC	69
Streptopelia decaocto	Eurasian Collared Dove	dry-ground forager	LB	LC	54
Sylvia communis	Common Whitethroat	foliage-foraging insectivore	M	LC	2
Sylvia curruca	Lesser Whitethroat	foliage-foraging insectivore	M	LC	1
Thalasseus bengalensis	Lesser Crested Tern	marine forager/fish-eater	QB	LC	852
Tringa erythropus	Spotted Redshank	wet-surface carnivore	M	LC	1
Tringa glareola	Wood Sandpiper	wet-surface carnivore	M	LC	3
Tringa nebularia	Common Greenshank	wet-surface carnivore	M	LC	2

Tringa stagnatilis	Marsh Sandpiper	wet-surface carnivore	M	LC	4
Tringa totanus	Common Redshank	wet-surface carnivore	M	LC	11
Xenus cinereus	Terek Sandpiper	wet-surface carnivore	M	LC	90