

# **Bird communities of contrasting semi-natural habitats of Lac Bay, Bonaire, during the fall migration season, 2011**

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## Abstract

We documented the bird communities of five contrasting natural habitats of Lac Bay, Bonaire, South-eastern Caribbean, during the fall migratory season of 2011. A total of 420 point counts were conducted and 63 bird species were detected. Of these, 31 (49%) were migrant, 24 (38%) were resident, 6 (10%) occurred both as resident and migrant and 2 (3%) were migrant species that possibly or irregularly breed. The majority of the migratory species were shore birds and waders (76%). Bootstrapping showed that the chosen level of sampling was adequate for both statistical comparisons and for community description. Large and statistically significant differences were found in the bird communities of the five habitats studied.

Mangrove thicket and salt flat habitats had a roughly two-fold higher total species richness and a four-fold higher migrant species richness compared to woodland habitats. The bird communities of the woodland habitats were dominated by breeding resident species, while that of the salt flat habitat was dominated by migratory shore and water birds. The Northern Waterthrush, *Parkesia novaeboracensis*, and Barn Swallow, *Hirundo rustica*, were the numerically most important migratory passerines. The Reddish Egret, *Egretta rufescens*, a globally Near-Threatened species, ranked among the top 10 most abundant species of the Lac Bay salt flat habitat. Results suggest that Lac Bay may be of local significance as a breeding and foraging site to this species, and as breeding and roosting habitat for the Scaly-naped Pigeon, *Patagioenas squamosa*, but further observations are needed.

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# 1 Introduction

The mangrove and seagrass lagoon of Lac Bay on Bonaire covers an area of roughly 700 ha. It is home to endangered green sea turtles, *Chelonia mydas*, and the Caribbean queen conch, *Strombus gigas*, and is a roosting and breeding area for several birds. Other endangered species include the threatened corals *Acropora palmata* and *A. cervicornis* and the Rainbow Parrotfish, *Scarus guacamaia*. Based on its nature values this 7 km<sup>2</sup> bay has been designated as a legally protected Ramsar site (Stinapa Bonaire 2003) and is identified as a Birdlife International IBA (Important Bird Area) (Wells and Debrot 2008). The area falls under the management responsibility of the National Parks Foundation of Bonaire (STINAPA Bonaire) which tries to address several problems based on their 2009 management plan. Lac Bay is under increasing development pressure for recreational use and more effective management is needed.

As a Ramsar area, several international obligations need to be met, including the documentation of changes, management according to wise use and regular reporting on changes and status. Based on concerns about Lac and the international commitments, in 2010 the Ministry of Economic Affairs, Agriculture and Innovation, or EL&I, of The Netherlands, commissioned IMARES to assess the situation (Debrot et al. 2010a) and come with a shortlist of action points (Debrot et al. 2010b) that address the principal information gaps. This ministry continues to actively exercise its mandate with respect to the biodiversity of the Caribbean Netherlands and commissioned this study to shed light on the potential importance of Lac to birds.

Bonaire's avifauna amounts to 55 resident or breeding species and 167 migratory species (Prins et al. 2009). One of the identified information gaps for Lac was the knowledge pertaining to the value of Lac and its adjacent natural vegetation as bird habitat, particularly with respect to fall migrants. In the past, many casual and incidental observations have been made on the bird fauna associated with Lac but no quantitative assessments have so far been conducted. Van Moorsel and Meijer (1993) provided a list of 30 species documented in February and March 1992, while Voous (1983) provides older bird sighting records for the bay. In this study we conducted semi-quantitative point counts in contrasting habitats of Lac Bay during the fall migratory season to provide insights into the bird communities and bird species use of those habitats.

## 2 Study sites & methods

### 2.1 Study sites

Bonaire is located in the Southern Caribbean Sea, about 87 km north of the coast of Venezuela and 40 km east of Curaçao, within the so-called 'Caribbean dry region' (Sarmiento 1976). Average rainfall in Bonaire is 463 mm/yr, most of which falls in the last three months of the year. The island is 35 km long, 8–15 km wide, and consists of a volcanic core, surrounded by limestone formations. The island's surface area is 288 km<sup>2</sup> and its highest point is the 241m high hill of Brandaris, situated on the north-west side of the island. The south-east side of the island, where the Lac bay is located is characterized by low, flat limestone terraces. The island's vegetation is generally xerophytic with many areas dominated by columnar cactus, intermixed with low scrub and large expanses of land largely devoid of vegetation, especially along the eastern shoreline which receives slightly less rainfall on average than the western side of the island. While destructive land-use practices such as wood cutting for charcoal production have all but ceased, free roaming goats and donkeys continue to impact native vegetation throughout the island (Freitas et al. 2005). Lac Bay supports Bonaire's only significant mangrove woodland.

Five representative habitats in and around the Lac area as based on vegetation (Freitas et al. 2005) were selected for sampling (Figure 1). These were 1) *Rhizophora salina* (mangrove thickets), 2) *Sesuvium salina* (Lac salt flats), 3) *Coccoloba-Melocactus* middle terrace (dry evergreen woodland), 4) *Prosopis-Euphorbia* middle terrace (dry deciduous woodland) and 5) *Lithophila-Euphorbia* lower terrace (coastal barrens) (Freitas et al. 2005).

- 1) The *Rhizophora salina* habitat is concentrated along the western and northern shores of Lac and is dominated by the mangrove thickets of *Rhizophora mangle* and *Avicennia germinans*, whereas *Laguncularia racemosa* and *Conocarpus erectus* are also commonly found in the thickets. *Rhizophora* and *Avicennia* show a marked zonation in the Lac mangrove forest (e.g. Davaasuren and Meesters 2012) but in this study no distinction was made between the two as both types of areas were characterized by dense mangrove thickets of up to 5 m in height.
- 2) The *Sesuvium salina* habitat was concentrated in areas along the hypersaline backwater shores and mud pools of Lac (Figure 1) and was dominated by a low herbaceous vegetation of the halophytes *Sesuvium portulacastrum*, *Lithophyla muscoides* and *Salicornia perennis*.
- 3) The *Coccoloba-Melocactus* middle terrace sub-landscape is an evergreen woodland formation that covers a large part of southern Bonaire from the shores of Lac bay west across Lima and is also found on Klein Bonaire. It is dominated by the *Coccoloba-Metopium* vegetation type, consisting principally of low shrubs and the trees *Coccoloba swartzii*, *Haematoxylon brasiletto* and *Metopium brownei*. This habitat was surveyed for birds west of Lac.
- 4) The *Prosopis-Euphorbia* middle terrace sub-landscape sampled was found principally along the north-western shores of Lac towards Warahama (Freitas et al. 2005). The main vegetation types are the *Euphorbia-Sporobolus* type and *Casearia-Prosopis* type (Freitas et al. 2005). The vegetation is dominated by grasses (*Sporobolus pyramidatus*, *Eragostis urbaniana*, *Antheophora hermaphrodita*) and scattered trees (especially *Prosopis juliflora*, followed by *Casearia tremula*, *Randia aculeata* and *Caesalpinia coriaria*) and shrubs and prickly-pear cacti (*Opuntia wentiana*, *Croton flavens* and *Phyllanthus botryanthus*). The tree cover is less well-developed than in the *Coccoloba-Melocactus* landscape and more deciduous in nature. In the area studied (Figure 1), this vegetation is additionally characterized by the importance of large manchineel trees,

*Hippomane mancinella*. These trees are intensively used as roosting sites by mixed flocks of parakeets and native columbids (Harms and Eberhardt 2003).

- 5) *Lithophila-Euphorbia* lower terrace is a barren, windblown saline sub-landscape typical of the east coast of the island. In the study area it was characterized by scattered *Conocarpus* bushes interspersed with grasses, grass-like Cyperaceae, *Lithophila muscoides* and *Jatropha gossypifolia*. This habitat was sampled both on the north side of Lac and on the south side (Figure 1).

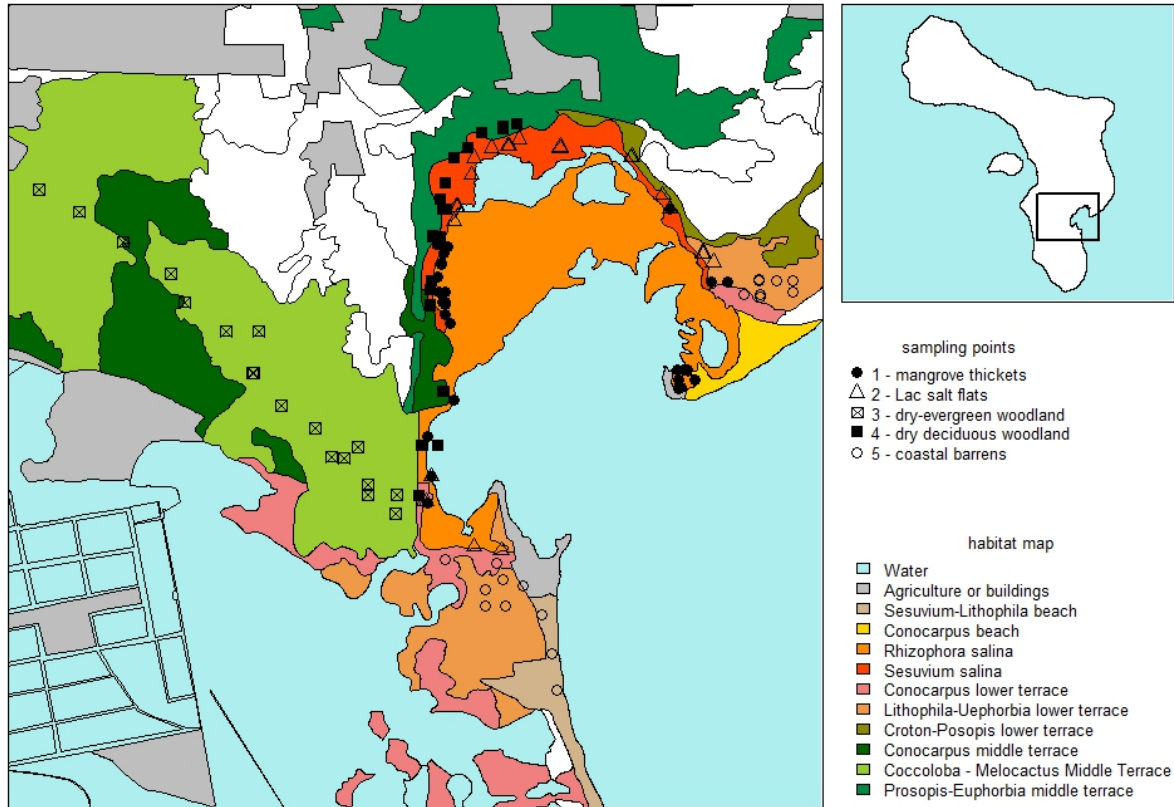


Figure 1. Map of Lac and its surroundings, showing the main habitat types and all sampling points. The habitat map dates from 1988-89, and the GPS points are known to show some inaccuracies, hence an apparent mismatch of habitat and sampling points can occur in some cases.

## 2.2 Methods

Roughly every three weeks, bird point counts were conducted at pre-selected sites within the five habitat types in or in the vicinity of Lac, from September-December, 2011, during the peak fall migration (Prins et al. 2009). All counts were done by J. Ligon, who is a recognised and experienced birder with many first records and rare sightings to his name for Bonaire (Prins et al. 2009). On any given day, separate sites were no less than 100 meters apart. Counts were done by means of twenty-five meter, fixed radius point counts of 15 minutes each, and were done in the morning hours before 10 o'clock. All birds detected within a period of 6 minutes, and up to the cut-off distance of 100 m, were noted, with details of the number of individuals involved and the approximate distance to the birds at the moment of discovery. Effective bird detection differed between open and vegetated habitats as well as between large and small species. In the case of flamingos, which were readily identified at distance and where flocks often straddled the 100 m cut-off, birds standing beyond 100 m were included in the numerical

count of the flock concerned. In practice, shore birds in open salt flats were effectively identified out to about 75, while smaller passerines in thick vegetation were effectively recorded out to no more than about 30 m. Because of the variability in detection between species and habitats we did not calculate densities per unit area but used relative sighting frequency (regardless of flock size) as an index of relative abundance for comparison between habitats.

(Dis)similarities in community structure between the five habitats in terms of abundance (number of sightings) of functional groups was analysed using Classical (Metric) Multidimensional Scaling, also known as Principal Coordinates Analysis (Gower 1966), according to the methods outlined by Mardia (1978), using the function 'cmdscale' in the 'stats' package within the statistical software package R (R Development Core Team 2011).

Species richness per habitat was studied by analysing species accumulation curves using bootstrapping methods as implemented in the R-package 'vegan' (Oksanen et al. 2012). Per habitat type, the number of species were counted in 1000 random samples of one to 75 point counts. Subsequently, the shape of the resulting curves of number of point counts versus number of recorded species was used to infer differences in species richness. Furthermore, species richness was expressed as the estimated number of expected species, based on the species accumulation curves, the Shannon-Weaver diversity index  $H'$  (Shannon & Weaver 1949, Margalef 1958) and abundance evenness as Pielou Evenness  $J$  (Pielou 1966).



### 3 Results

A total of 420 six-minute point counts were carried out in the five habitats: 80 in mangrove thickets, 89 in Lac salt flats, 88 in dry evergreen woodland, 87 in dry deciduous woodland and 76 in coastal barrens. During 70 (7%) of the point counts, no birds were detected. In the remaining 150 counts 940 separate species sightings were made. Appendix A shows the number of sightings per habitat type and the total number of sightings and individuals.

In total, 63 species were recorded. Of these, the majority (n=39, 62%) were recorded on less than ten occasions. Among the 63 species, 24 (38%) were resident species; 6 (10%) had resident populations but also potentially occurred as migrants, 31 (49%) were migrants and 2 (3%) were migrants that are known to possibly or irregularly breed on Bonaire (based on Prins et al. 2009). Many of the more common marine bird species of Lac (Van Moorsel and Meijer 1993), such as the Brown Pelican, *Pelicanus occidentalis*, gulls and terns, the Oystercatcher, *Haematopus palliatus* and frigate bird, *Fregata magnificens*, were not recorded due to our restricted choice of habitats and restrictions of the method used (limited point counts).

Figure 2 shows the relative contributions of migrant species versus resident species according to major species groupings. Migrant species were significantly more abundant among the waterbirds (herons, flamingo, waders) where they made up 74% of the species documented, than among the remaining species, of which 43% of the species were migrants (Fisher's Exact Test with non-waterbirds and non-migrants pooled,  $p < 0.001$ ). Likewise, the majority (74%) of the migrants were waterbirds (Fisher's Exact Test with non-waterbirds and non-migrants pooled,  $p = 0.04412$ ).

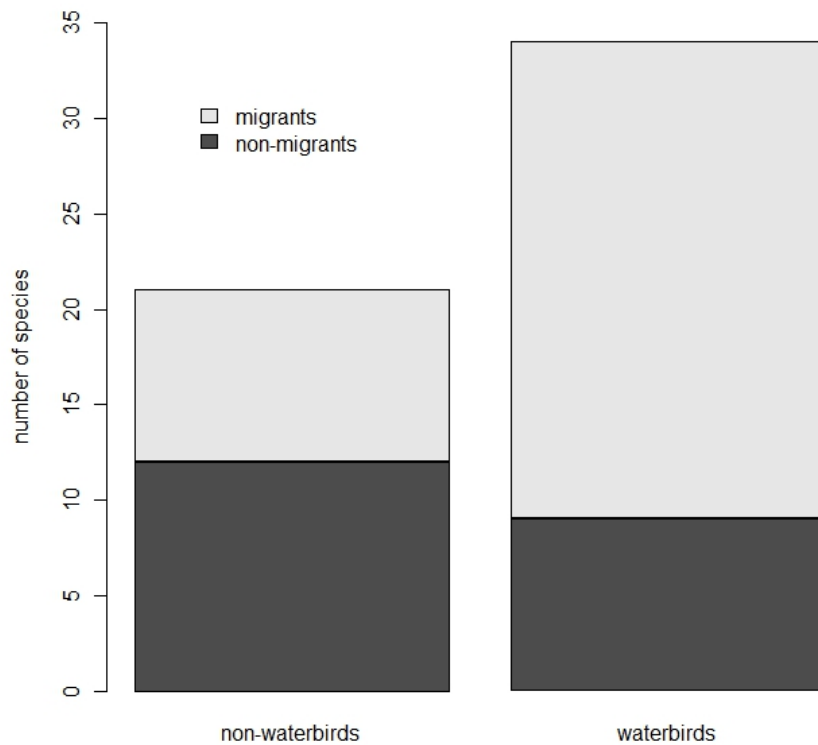


Figure 2. Composition of non-waterbirds and waterbirds according to whether they are migrants (including two irregular breeding waterbirds), or non-migrants (resident species and species that are mostly resident but of which migrants have also been documented).

### 3.1 Bird species composition per habitat

Figure 3 shows the relative distribution of species between habitats according to feeding functional groups. The Lac salt flats (2) showed the highest concentration of shorebirds and larger waders, whereas evergreen woodlands (3) had the highest concentrations of frugi- and nectarivores. The coastal barrens characterized by low grasses and shrubs (5) had the highest relative presence of granivores. Arboreal insectivores were absent in the Lac salt flats and the coastal barrens while aerial insectivores were represented in all five habitats. Mangrove thickets had a high concentration of frugi- and nectarivores. This was especially due to the use of this habitat by the ubiquitous Bananaquit, *Coereba flaveola*, and its use as roosting and nesting habitat by the Scaly-naped pigeon, *Patagioenas squamosa*. These differences in community composition in functional feeding groups is clearly expressed in Figure 4, which shows the similarity of the dry-evergreen and the dry-deciduous forests, and the distinctness of the remaining habitats (Principal Coordinate Analysis; Goodness Of Fit = 0.96).

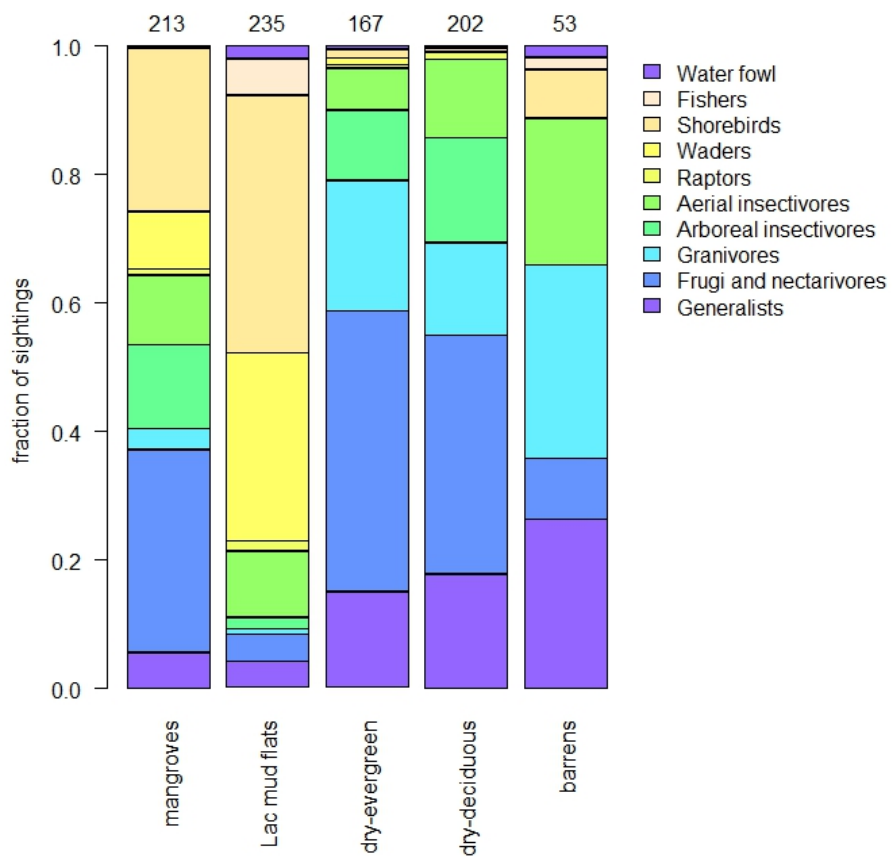


Figure 3. The relative bird community composition in terms of ten trophic guilds. The numbers above the bars represent total number of sightings per habitat.

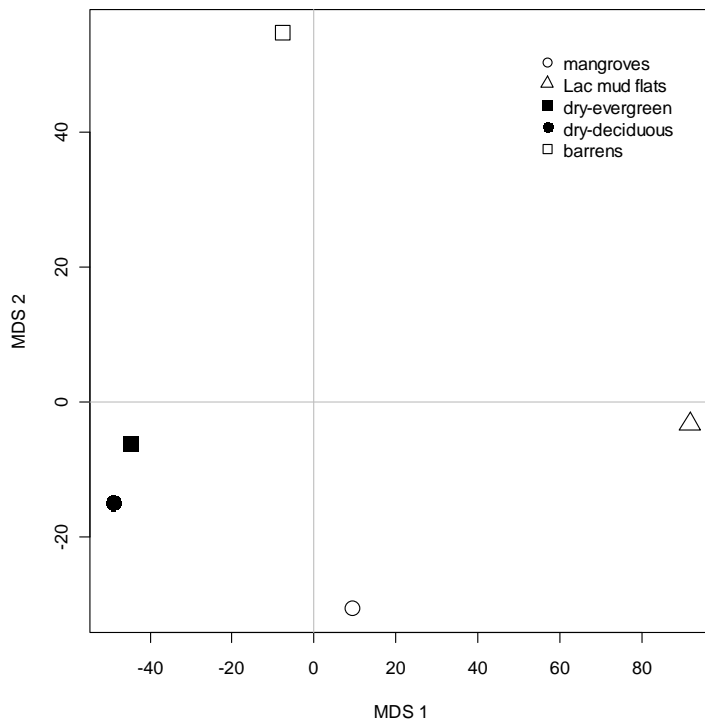


Figure 4. Classical Multidimensional Scaling plot showing Euclidian distances between the five habitats in abundance of functional groups.

### 3.2 Community characteristics

Bootstrap results show that total species richness in the five habitats differed considerably (Figure 5). Most importantly bootstrapping showed that the chosen level of sampling (i.e. 76-89 samples per habitat type) was sufficient to detect community differences. The levelling-off of the curves beyond 60 point counts and the small difference between the number of observed species and the estimated expected species richness (Table 1) showed that the chosen level of replication was also adequate for meaningful description of the bird fauna as well as its migrant component (Figure 5).

Results showed that overall species richness was similar between mangrove thickets and salt flats as well as between the two woodland habitats. The coastal barrens habitat clearly showed the lowest number of species. When only migrants were considered (Figure 5, **Error! Reference source not found.**) the salt flats and mangrove thickets also had the highest species richness (cumulatively 24 species), whereas the remaining habitat types showed similar, low species richness (cumulatively 6 species).

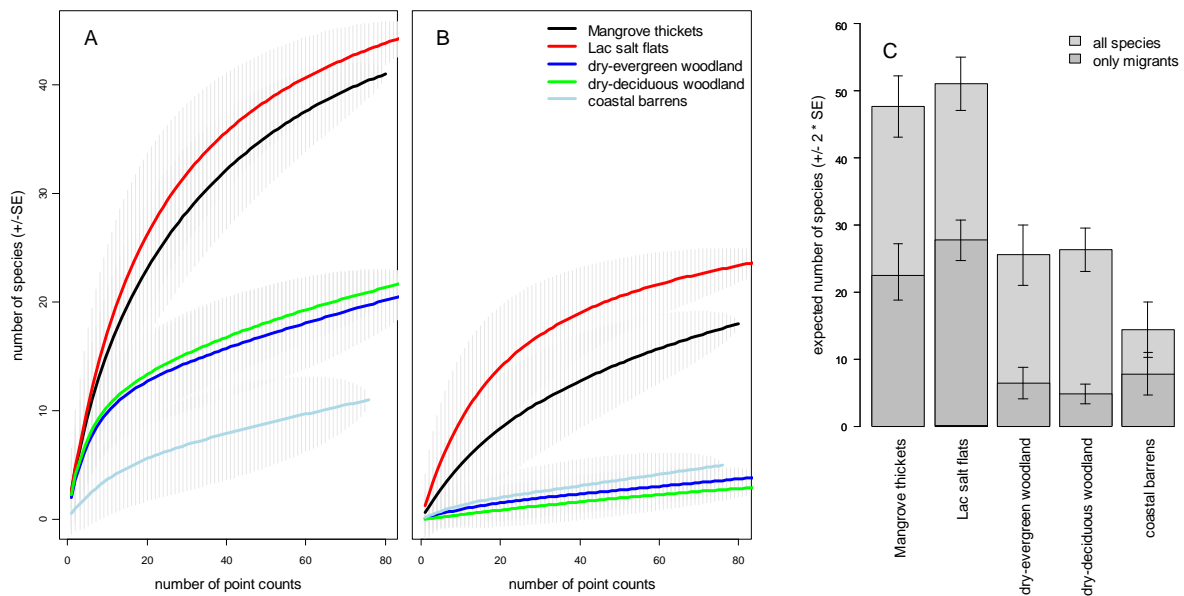


Figure 5. Species accumulation curves for all species (A) and only migrant species (B), based on bootstrap results with 1000 permutations, and estimated extrapolated species richness (C) per habitat. The mangrove thickets and Lac salt flats clearly stand out in species richness, both for all species and for migrants.

Figure 6 and Figure 7 show the ten most abundant species in the habitats as a relative contribution to the total species presence as based on sighting frequency. For both the mangrove thickets as well as the salt flats, the most frequent ten species were in low abundance compared to the large number of species seen rarely ('other'). Hence these habitats were the most species-rich habitats with a roughly twofold higher species count compared to both woodland habitat types (Table 1). These habitats were even more important when considering only the migratory species. The mangrove and salt flat habitats showed four to five times more migrant species sightings compared to the other three habitats studied. The bird communities of evergreen woodland and deciduous woodland were quite similar both in principal species as in evenness of the community and were dominated by common resident breeding species. The bird community of the coastal barren was the most truncated in terms of species contributions and had lowest species richness and diversity.

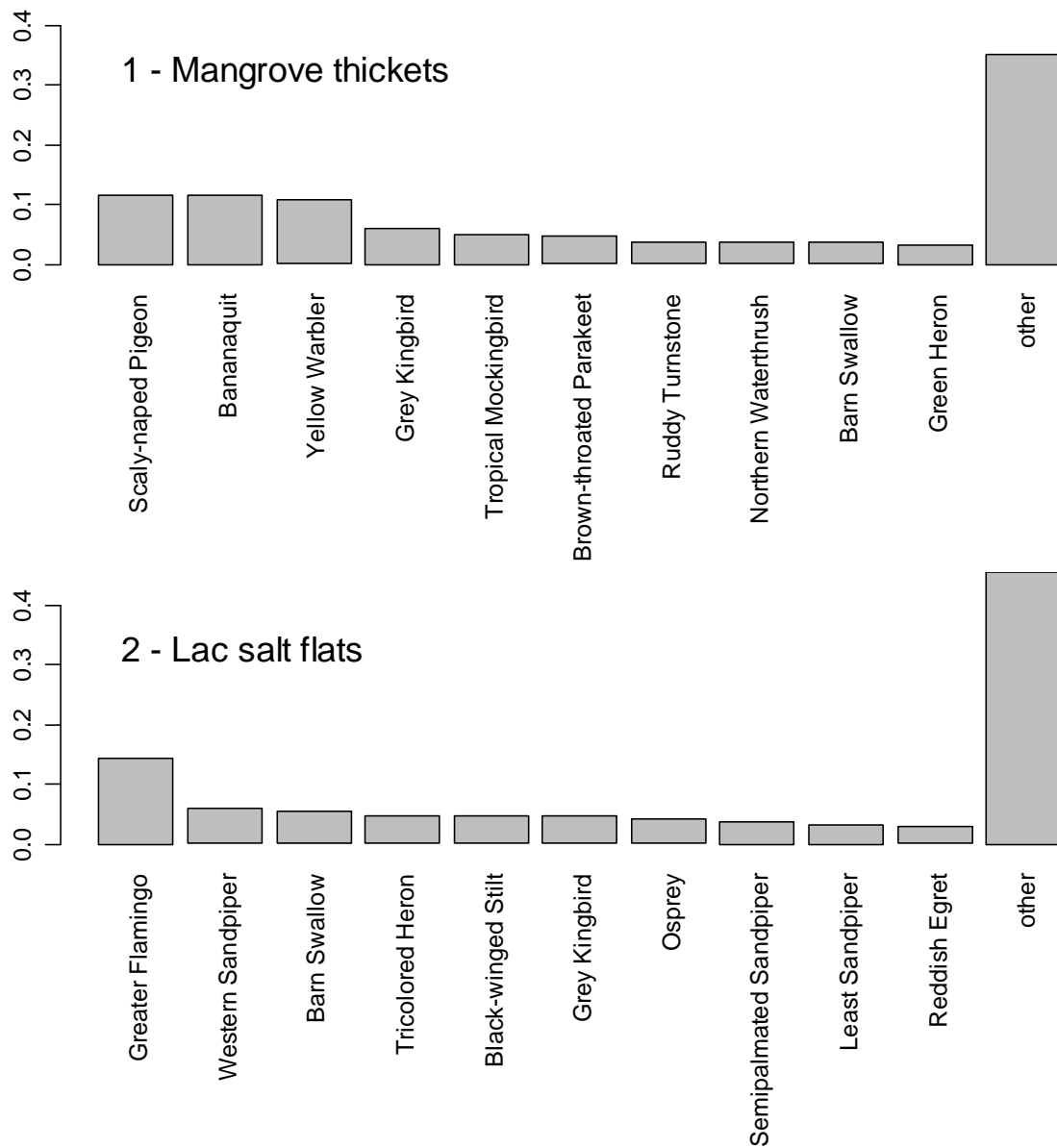


Figure 6. The 10 principal bird species in a) mangrove thickets (habitat type 1), b) salt flats (habitat type 2), as based on relative sighting frequency.

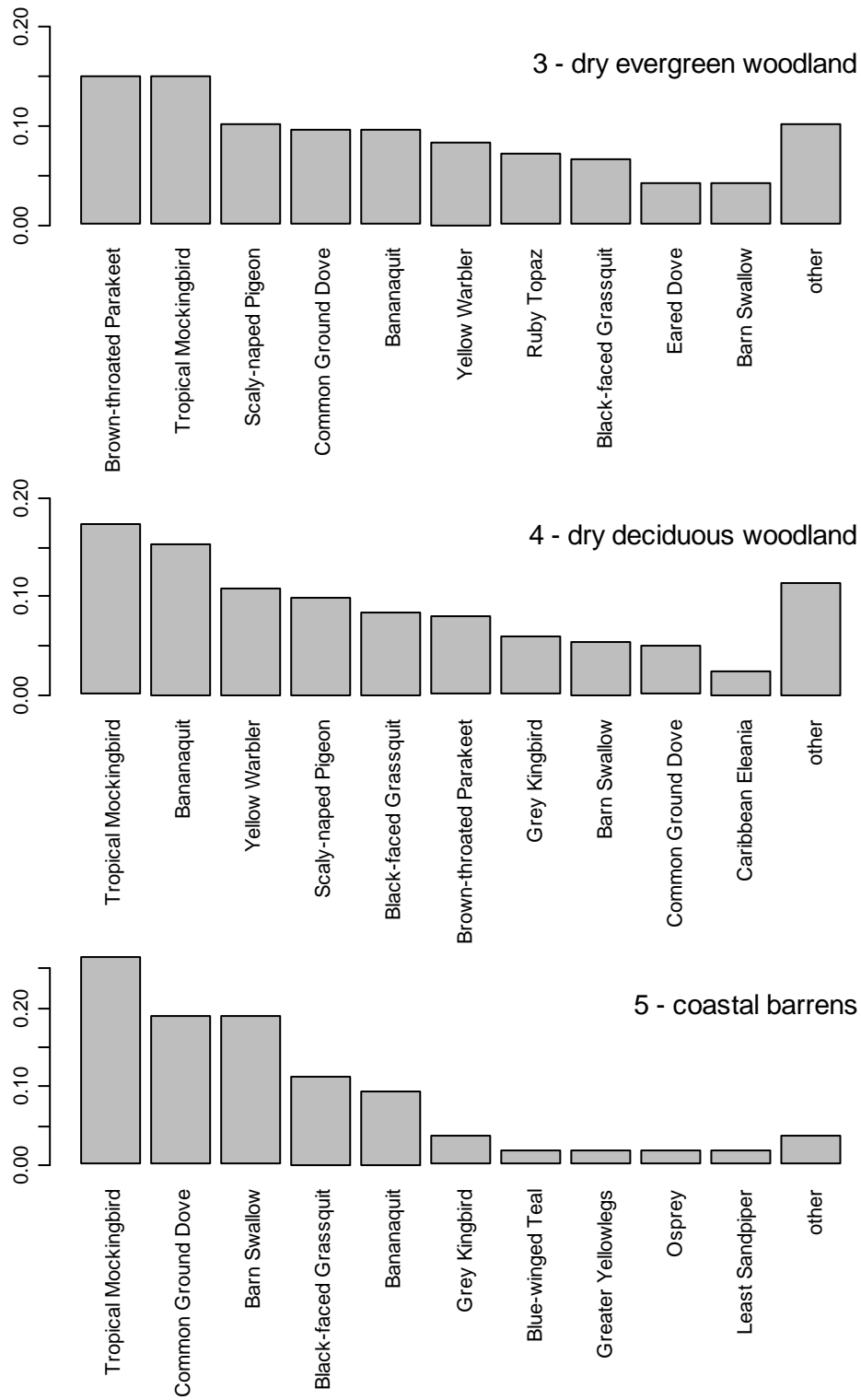


Figure 7. The 10 principal bird species in a) evergreen woodland (habitat type 3), b) deciduous woodland (habitat type 4) and c) coastal barrens (habitat type 5), as based on relative sighting frequency.

While in this study many small and unobtrusive birds were commonly detected such that we were able to establish them as main species for several vegetation types (e.g. Bananaquit, *Coereba flaveola*, Black-faced Grassquit, *Tiaris bicolor*, Yellow Warbler, *Dendroica petechia*), the detection of migratory warblers was very low. Only one migratory species of warbler (Northern Waterthrush, *Parkesia novaeboracensis*) was found among the top ten species in the mangrove thickets. While with our method no special measures were taken to attract warblers, we can conclude that migratory passerines were not a major component of the bird fauna of the Lac area. The key migratory species we detected were shorebirds and waders (Figure 6) which did constitute a major portion of the avifauna of salt flat habitat of Lac. The only migratory passerine to rank consistently among the 10 main species for all five habitats was the Barn Swallow, *Hirundo rustica* (Figure 6, Figure 7).

Table 1. Bird community descriptors for the five habitat types. The extrapolated species richness is based on bootstrap results, see the main text and Figure 5.

Habitat type	Number of species recorded		Extrapolated species richness	Shannon-Weaver diversity (H')	Pielou Evenness (J)
	Total	Migrants			
Mangrove forest	42	21	47.6	3.22	0.86
Lac salt flats	46	26	51.1	3.43	0.89
Evergreen	22	6	25.5	2.54	0.82
Deciduous	23	5	26.3	2.55	0.81
Coastal barrens	12	6	14.3	2.02	0.81

### 3.3 Passerine migrants

Of the 27 migratory Parulidae known from Bonaire (Prins et al. 2009, Boer et al. 2012 add *Dendroica dominica*), we documented only two species during our point counts. These were the Northern Waterthrush and the Prothonotary Warbler, *Protonotaria citrea*. Of the combined passerine migrant species recorded, only Barn Swallow and Northern Waterthrush were recorded on more than two occasions. Whereas the number and encounter probability of Barn Swallows clearly decreased in October compared to September, sightings of Northern Waterthrush occurred throughout the study period, with no clear temporal pattern (Figure 8a,b). Whereas sightings of Barn Swallow were well distributed across the habitat types, they appeared slightly more concentrated in open and sparsely vegetated habitat where the aerial pursuit of insect prey was easiest. Northern Waterthrushes were primarily encountered in the mangrove thicket habitat (Figure 6, Table 2). The observation of the Black Whiskered Vireo, *Vireo altiloquus*, in the mangrove thickets is interesting considering the fact that the species is polytypic, known both as a scarce breeding resident but also as a migrant. Further study is needed to evaluate whether the Lac mangroves are of significance as habitat of the resident subspecies (which is restricted to the Dutch leeward islands, Los Roques and Margarita) or to migrant birds.



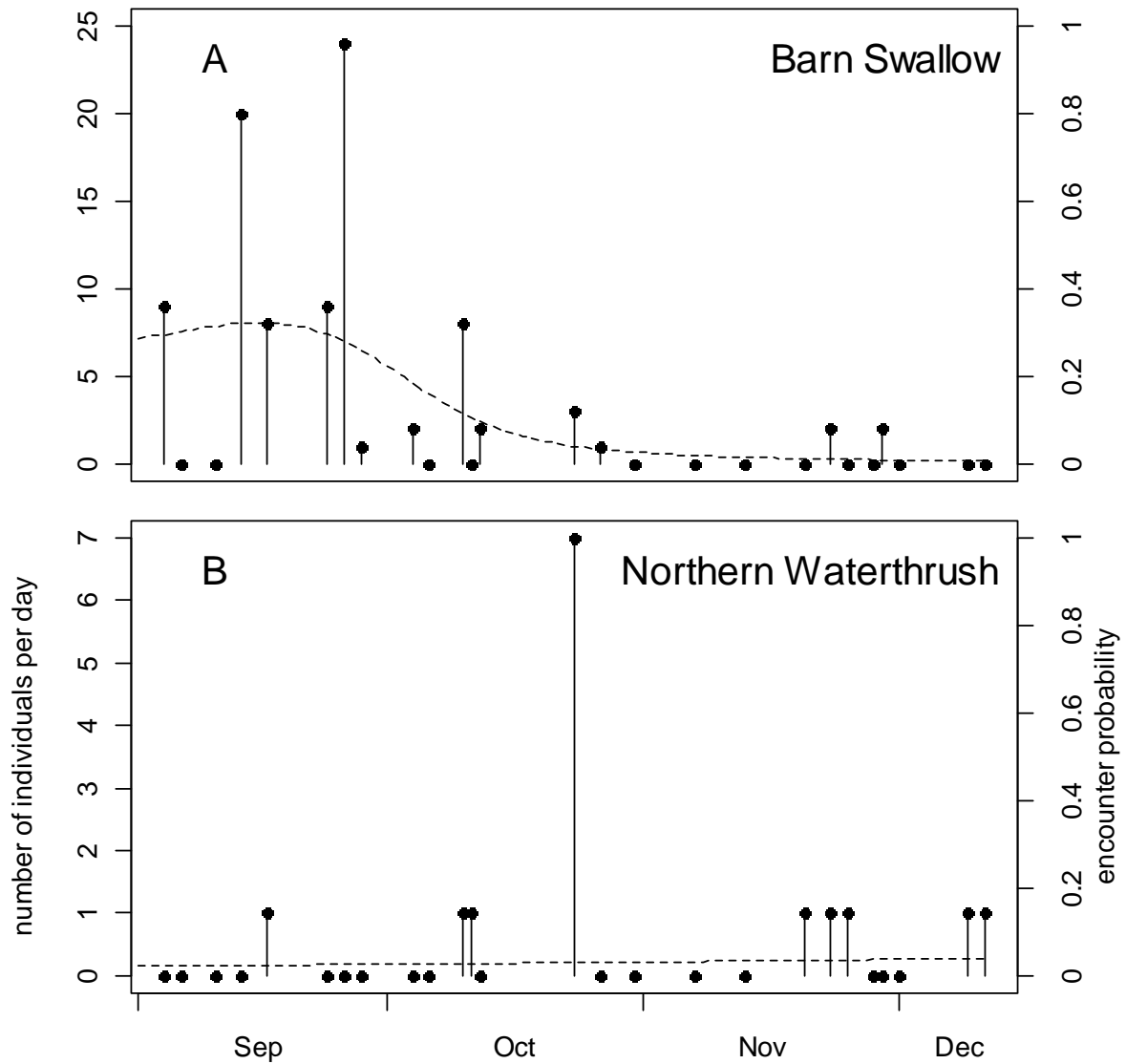


Figure 8. Temporal migration pattern for (A) Barn Swallow and (B) Northern Waterthrush in number of individuals seen per day (dots and vertical lines) and modelled encounter probabilities (dotted lines).

Table 2. Distribution of records of Barn Swallow and Northern Waterthrush across five habitat types.

Habitat type	Barn Swallow	Northern Waterthrush
1	8 (10%)	8 (10%)
2	13 (15%)	3 (3%)
3	7 (8%)	1 (1%)
4	11 (13%)	1 (1%)
5	10 (13%)	0 (0%)

## 4 Discussion and conclusions

While many publications report opportunistic observations on the birds of Bonaire, quantitative descriptions of the bird communities of the island have remained totally lacking until now. Neotropical migrants have been facing decades of population decline, most of which is attributable to habitat loss either on their temperate breeding grounds or in their tropical wintering sites, or both. Habitat loss in wintering areas has often been implicated because of the rapid alteration and degradation of these areas by human activities (Confer and Holmes 1995). Many species are known to use Bonaire as a migration stopover, or potentially as a wintering area, but nothing was known about relative or absolute species composition or density (Prins et al. 2009). In this respect, mangroves are particularly interesting as in nearby Venezuela they are known to be used by several Nearctic warblers such as the Northern Waterthrush, the Prothonotary Warbler and the American Redstart, *Setophaga ruticilla* (Lefebvre et al. 1994).

Of the three known migration flyways for North American birds overwintering in South America, the main route lies over land through Central America. A less-pronounced route follows the arc of eastern Caribbean islands down through Trinidad, while the third route includes flight paths across the Caribbean Sea from the Greater Antilles to Central and/or to South America, also via the leeward Dutch islands, including Bonaire. The conclusion is that these islands are not part of any main migratory flyway (Prins et al. 2009). So, while many species have been documented by birders during the course of some 60 years of birding on these islands, most reported species are only known from a handful of records. For instance, of the 27 Parulidae documented from Bonaire, only seven are based on more than 10 documented records while only three species can be considered relatively common. These are the Northern Waterthrush, the American redstart and the Black-poll warbler, *Dendroica striata* (Prins et al. 2009). Our results now suggest that the Northern Waterthrush (Fig. 8b) does not merely pass through Bonaire but actually uses the island (particularly the mangroves) as overwintering habitat.

Nine globally or regionally threatened species have been documented for Bonaire. These are the locally breeding Yellow-shouldered Amazon, *Amazona barbadensis* (Vulnerable), the Caribbean Coot, *Fulica caribbea* (Vulnerable), the Reddish Egret, *Egretta rufescens* (Near-Threatened), the Piping Plover, *Charadrius melodus* (Vulnerable), the Buff-breasted Sandpiper, *Trygites subruficollis*, the Chimney Swift, *Chaetura pelagica*, the Olive-sided flycatcher, *Contopus cooperi* (Near-Threatened) the Cerulean warbler, *Dendroica cerulea* (Vulnerable) and the Golden-winged warbler, *Vermivora chrysoptera* (Near-Threatened) (Prins et al. 2009). Only the Reddish Egret was observed during this study, but it ranked as relatively abundant and among the top ten species for the Lac salt flat habitat.

While the Lac mangrove thickets were formerly used by the Yellow-shouldered Amazon (Voous 1983), this no longer appears to be the case (Smith et al. 2012), and the species was not observed in this study. In former times, the species was actively persecuted by man and the surrounding woodlands suffered more extensive disturbance by agricultural activity and charcoal burning (Freitas et al. 2005). Under such circumstances, the mangroves of Lac apparently served as a roosting area for this bird. However, as awareness about the value of this bird has increased, and its persecution decreased, the species apparently no longer needs the shelter and isolation provided by the mangroves of Lac, and is no longer using this area. Also, the quality of the woodlands in many areas of Bonaire has improved in recent decades, which also probably offer the Yellow-shouldered Amazon a wider range of habitat options.

Notably absent from the salt flat habitat at Lac was the Caribbean Coot. The species is an important species for the island but prefers a number of freshwater locations, such as those at Playa Grandi and Washikemba and Onima (Nijman et al. 2008). At Lac, the wetland habitat is largely hypersaline (Debrot

et al. 2012) and will probably only be used as a last-resort by this species. Interesting was the absence in our counts of the Pearly-eyed Thrasher, *Margarops fuscatus*, listed by Prins et al. (2009) as a relatively common breeding resident for Bonaire. Six sighting records for the Carib Grackle, *Quiscalus lugubris*, document the further spread and establishment of this introduced species.

Our results show the highest concentration of migrant birds to be in the mangrove thickets and salt flat habitats studied. Most migrant species detected were shore birds and waders. For both migratory and resident shorebirds and waders, shallow wading habitat on Bonaire is very abundant and to be found at many other locations aside from Lac. The same is true for terrestrial resident bird species which can find a similar range of habitats all across the island. Based on our results we cannot conclude that Lac carries special local significance for the bird communities studied.

Two other studies have documented a valuable habitat function for birds in a few isolated areas of Lac. Debrot et al. (2009) identified breeding habitat for the Antillean tern at Lac, while Harms and Eberhardt (2003) documented important communal roosting sites for parakeets and pigeons at Lac. However, both studies also show that such habitat value is likely not ecologically limiting, or in any way restricted to Lac. So while other studies highlight the special habitat-value of Lac in terms of seagrass and mangrove ecosystems (Debrot et al. 2012), the fish nursery function (Nagelkerken et al. 2000), as well as for specific species such as the endangered Rainbow Parrotfish, *Scarus guacamaia*, the Queen Conch, *Strombus gigas*, and the Green Turtle, *Chelonia midas*, the question still remains whether Lac carries any special habitat values with respect to avifauna.

Lac bay has been documented as a breeding location for the endangered Reddish Egret (Voous 1983; Van Moorsel and Meijer 1993) but recent breeding observations remain lacking. Three other species of egret that commonly nest (or nested) in Lac are Green Heron *Butorides striatus* and Tricolored Heron *Egretta tricolor*, and Snowy Egret *Egretta thula* (Voous 1983). In our study, Reddish Egret, Tricolored Heron and Green Heron were also among the ten most abundant species in either the mangrove thickets or the Lac salt flats (Figure 6, Figure 7). Further observations directed to document potential egret breeding activity at Lac is recommended. The mangroves further seem to be of importance in southern Bonaire as a main nesting and roosting habitat for the Scaly-naped Pigeon, *Patagioenas squamosa*. Whereas Van Moorsel and Meijer (1993) noted the absence of this species in 1993, in our study the species was among second-most abundant species in the *Rhizophora* forests. This pigeon, which was extirpated in the middle of the 20<sup>th</sup> century on Aruba, has always been quite rare on Curaçao and common on Bonaire (Prins et al. 2009). The increased abundance of this species at Lac might reflect a recent change in habitat use or a more general increase in abundance of this species on the island. Lac is also the only large and consistent roosting site for frigate birds on Bonaire (Voous 1983, Moorsel and Meijer 1993), which it remains to this date.

From old maps (Wagenaar Hummelink and Roos 1970) it is clear that saline waters were formerly a minor part of the Lac system. Today, stagnant backwaters and salt flats behind the mangroves have grown in importance inside Lac. It is therefore not surprising that the abundance of the West Indian flamingo, *Phoenicopterus ruber*, in Lac has grown from average daily counts of 10-35 birds prior to the early 1990s, to numbers typically exceeding a 100 birds since the early 1990s (Moorsel and Meijer 1993). The most important hypersaline habitat areas for the flamingo on Bonaire, lie outside of Lac (Boer 1979, Voous 1983, Smith et al. 2012), and the increasing 'value' of Lac to this species, is likely not a good development. The growing importance of this species in the salt flat habitat of Lac signals a wider ecological shift taking place within the bay which is threatening its premier values as a mangrove and seagrass nursery area.

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## Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

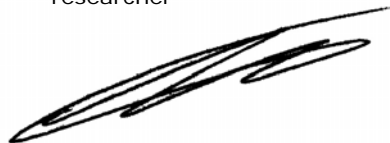
## Justification

Report C165/12  
Project Number: 430.87010.03

The scientific quality of this report has been peer reviewed by a colleague scientist and the head of the department of IMARES.

Approved: Dr. M.J. Baptist  
researcher

Signature:



Date: January, 2013

Approved: F.C. Groenendijk, MSc.  
Head of Department

Signature:



Date: January, 2013

## Appendix A: Number of sightings per habitat type and total number of sightings and individuals per species.

Species	status	n sightings per habitat type					sightings	Individuals
		1	2	3	4	5		
Tropical Mockingbird ( <i>Mimus gilvus</i> )	res	11	6	25	35	14	91	107
Bananaquit ( <i>Coereba flaveola</i> )	res	25	3	16	31	5	80	104
Scaly-naped Pigeon ( <i>Patagioenas squamosa</i> )	res	25	4	17	20	0	66	147
Yellow Warbler ( <i>Dendroica petechia</i> )	res	23	4	14	22	0	63	80
Brown-throated Parakeet ( <i>Aratinga pertinax</i> )	res	10	1	25	16	0	52	134
Barn Swallow ( <i>Hirundo rustica</i> )	migr	8	13	7	11	10	49	91
Common Ground Dove ( <i>Columbina passerina</i> )	res	5	2	16	10	10	43	72
Grey Kingbird ( <i>Tyrannus dominicensis</i> )	res & migr	13	11	3	12	2	41	52
Black-faced Grassquit ( <i>Tiaris bicolor</i> )	res	2	0	11	17	6	36	54
Greater Flamingo ( <i>Phoenicopterus ruber</i> )	res	1	34	0	0	0	35	1512
Ruby Topaz ( <i>Chrysolampis mosquitus</i> )	res & migr	2	1	12	4	0	19	19
Western Sandpiper ( <i>Calidris mauri</i> )	migr	2	14	0	0	0	16	47
Black-winged Stilt ( <i>Himantopus himantopus</i> )	res & migr	3	11	0	0	1	15	32
Lesser Yellowlegs ( <i>Tringa flavipes</i> )	migr	6	7	1	0	1	15	31
Tricolored Heron ( <i>Egretta tricolor</i> )	res	4	11	0	0	0	15	18
Least Sandpiper ( <i>Calidris minutilla</i> )	migr	4	8	0	0	1	13	28
Northern Waterthrush ( <i>Seiurus noveboracensis</i> )	migr	8	3	1	1	0	13	15
Osprey ( <i>Pandion haliaetus</i> )	migr	1	10	0	1	1	13	15
Green Heron ( <i>Butorides virescens</i> )	res & migr	7	5	1	0	0	13	14
Ruddy Turnstone ( <i>Arenaria interpres</i> )	migr	8	3	0	0	0	11	27
Semipalmated Sandpiper ( <i>Calidris pusilla</i> )	migr	2	9	0	0	0	11	21
Greater Yellowlegs ( <i>Tringa melanoleuca</i> )	migr	4	6	0	0	1	11	20
Spotted Sandpiper ( <i>Actitis macularius</i> )	migr	6	5	0	0	0	11	12
Reddish Egret ( <i>Egretta rufescens</i> )	res	3	7	0	0	0	10	13
Eared Dove ( <i>Zenaida auriculata</i> )	res	0	0	7	1	0	8	10
Grey Plover ( <i>Pluvialis squatarola</i> )	migr	2	5	0	0	0	7	18
Caribbean Eleania ( <i>Elaenia martinica</i> )	res	0	0	2	5	0	7	8
Semipalmated Plover ( <i>Charadrius semipalmatus</i> )	migr	1	6	0	0	0	7	8
Northern Scrub Flycatcher ( <i>Sublegatus arenarum</i> )	res	2	0	1	4	0	7	7
Blue-winged Teal ( <i>Anas discors</i> )	migr	0	4	1	0	1	6	42
Carib Grackle ( <i>Quiscalus lugubris</i> )	res	1	4	0	1	0	6	16
Yellow-crowned Night Heron ( <i>Nyctanassa violacea</i> )	res and	3	2	1	0	0	6	6
Bare-eyed Pigeon ( <i>Patagioenas corensis</i> )	res	2	0	0	3	0	5	6
Crested Caracara ( <i>Caracara cheriway</i> )	res	0	3	0	2	0	5	6
Whimbrel ( <i>Numenius phaeopus</i> )	migr	2	3	0	0	0	5	6
Wilson's Plover ( <i>Charadrius wilsonia</i> )	migr	1	4	0	0	0	5	6
Brown-crested Flycatcher ( <i>Myiarchus tyrannulus</i> )	res	2	0	1	1	0	4	4
Great Blue Heron ( <i>Ardea herodias</i> )	migr	0	4	0	0	0	4	4
Yellow Oriole ( <i>Icterus nigrogularis</i> )	res	3	1	0	0	0	4	4
Stilt-Sandpiper ( <i>Calidris himantopus</i> )	migr	0	3	0	0	0	3	12
Snowy Egret ( <i>Egretta thula</i> )	res	0	3	0	0	0	3	4
Sora Rail ( <i>Porzana carolina</i> )	migr	3	0	0	0	0	3	4
Troupial ( <i>Icterus icterus</i> )	res	0	0	3	0	0	3	4
American Golden Plover ( <i>Pluvialis dominica</i> )	migr	1	2	0	0	0	3	3
Great Egret ( <i>Ardea alba</i> )	migr &	0	3	0	0	0	3	3
Belted Kingfisher ( <i>Megasceryle alcyon</i> )	migr	0	2	0	0	0	2	2
Black-whiskered Vireo ( <i>Vireo altiloquus</i> )	res	2	0	0	0	0	2	2
Merlin ( <i>Falco columbarius</i> )	migr	1	0	1	0	0	2	2
Peregrine Falcon ( <i>Falco peregrinus</i> )	migr	1	1	0	0	0	2	2
Willet ( <i>Catoptrophorus semipalmatus</i> )	migr	1	1	0	0	0	2	2



Species	status	n sightings per habitat type					sightings	Individuals
		1	2	3	4	5		
Yellow-billed Cuckoo ( <i>Coccyzus americanus</i> )	migr	0	0	0	2	0	2	2
White-cheeked Pintail ( <i>Anas bahamensis</i> )	res & migr	0	1	0	0	0	1	17
Pectoral Sandpiper ( <i>Calidris melanotos</i> )	migr	0	1	0	0	0	1	5
Baird's Sandpiper ( <i>Calidris bairdi</i> )	migr	0	1	0	0	0	1	1
Black-crowned Night Heron ( <i>Nycticorax nycticorax</i> )	migr &	1	0	0	0	0	1	1
Blue-tailed Emerald ( <i>Chlorostilbon mellisugus</i> )	res	0	0	0	1	0	1	1
Fork-tailed Flycatcher ( <i>Tyrannus savana</i> )	migr	0	0	0	1	0	1	1
Kentish Plover ( <i>Charadrius alexandrinus</i> )	migr	0	1	0	0	0	1	1
Mangrove Cuckoo ( <i>Coccyzus minor</i> )	migr	0	0	1	0	0	1	1
Prothonotary Warbler ( <i>Protonotaria citrea</i> )	migr	1	0	0	0	0	1	1
Red Knot ( <i>Calidris canutus</i> )	migr	0	1	0	0	0	1	1
Royal Tern ( <i>Sterna maxima</i> )	res	0	1	0	0	0	1	1
White-tipped Dove ( <i>Leptotila verreauxi</i> )	res	0	0	0	1	0	1	1