Bird Communities of Contrasting Secondary Habitats of Bonaire, in the Arid South-Eastern Caribbean

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Bird communities of contrasting secondary habitats of Bonaire, in the arid South-eastern Caribbean

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Abstract.—We studied the bird communities of five contrasting semi-natural habitats of Lac Bay, Bonaire, South-eastern Caribbean, during the fall of 2011. A total of 420 point counts were conducted in five different habitats and 63 species were detected. Of these, 31 (49%) were migrants, 24 (38%) were residents, 6 (10%) occurred both as residents and migrants and 2 (3%) were migrants that possibly or irregularly breed. Most migratory species were shorebirds and waders (76%). The bird communities of the five habitats studied showed significant differences in species composition and associated community parameters. Mangrove thicket and salt flat habitats had roughly a two-fold higher total species richness and a four-fold higher migratory species richness compared to woodland habitats. In woodland habitats, breeding residents dominated, whereas migratory shore and waterbirds dominated in salt flat habitat. The Northern Waterthrush, Parkesia noveboracensis, 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. Our results suggest that the relatively expansive hypersaline wetlands of Bonaire (of which Lac is only a small part) may be of special significance to migratory shore and waterbirds. In contrast to other areas of the Caribbean, invasive exotic birds so far play a minor role in the communities studied.

Keywords.—Southern Caribbean, avian community, mangrove, migration, invasive species, tropical dry forest

Introduction

Insight into bird community structure and composition, and how this differs among habitats and changes over time, is particularly valuable because of the rapid declines in biodiversity occurring worldwide. The effects of human-mediated land-cover and land-use change, leading to alteration, degradation and fragmentation of natural habitats play a key role in this (Acevedo and Restrepo 2008). Island bird communities typically have lower species richness compared to similar systems on the continents but also have much higher proportions of endemism. Island bird communities further appear to be particularly vulnerable to human-mediated habitat change, which is also typically compounded by the introduction of exotic species. Not surprisingly, 90% of global bird extinctions involve island endemics (Johnson and Stattersfield 1990).

Bonaire’s avifauna is comprised of 55 resident or breeding species and 167 migratory species (Prins et al. 2009). Of the resident species, 15 are Southern Caribbean endemic subspecies, of which two are found only on Bonaire, and five are established exotic species. Only a few studies have examined how avian species and communities are affected by differences in habitat and landscape (Latta 2012) on Caribbean islands. As most tropical avifaunal research has focussed on the wet tropical forests, bird communities of tropical dry forests remain poorly known (Toms et al. 2012). Whereas in the past, many casual and incidental observations have been made on the bird fauna of Bonaire, almost no quantitative assessments have been conducted with which to assess how bird communities differ among habitats or from which to document potential shifts in bird community structure in the future. While the avifauna of the three leeward Dutch Caribbean islands of Aruba, Bonaire and Curaçao show strong similarities, Prins et al. (2009) show that they remain in flux and that the number of newly documented species shows no signs of gradual decline. In this study we conducted point counts in contrasting habitats of Lac Bay, Bonaire, as representative tropical dry forest and littoral habitat in the arid southern Caribbean, during the fall migration season. These were used to provide preliminary insights into the current bird
community structure, composition and species use of those habitats. The study was conducted in the hinterlands and around the shores of the Lac Bay in Bonaire. The bay covers an area of roughly 700 ha and contains the principal concentration of mangroves and seagrass habitat of the island. Based on its natural beauty and ecological values this 7-km² bay has been designated as a legally protected RAMSAR site and is identified as a Birdlife International IBA (Important Bird Area) (Wells and Debrot 2008). One of the identified information gaps for Lac was information pertaining to the value of Lac and its adjacent semi-natural vegetation as bird habitat, particularly with respect to fall migrants. Although Voor (1983) provides historical bird sighting records for the bay, for several years the only source available documenting more recent records was an unpublished report by van Moorsel and Meijer, which listed 30 bird species observed in February and March 1992. Therefore the bay and its surroundings offered an excellent setting for a study of avian community structure. This work forms part of a series of descriptive baseline ecological studies commissioned by the Dutch Ministry of Economic Affairs for Lac Bay and a preliminary version of this work is also available as part of an unpublished IMARES agency report (Debrot et al. 2013).

Methods

Study sites

Bonaire is located in the Southern Caribbean Sea, about 87 km north of the coast of Venezuela and 40 km east of Curacao (Fig 1), within the so-called ‘Caribbean dry region’ (Sarmiento 1976). Average rainfall is 463 mm/y, most of which falls in the last three months. 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 km² and its highest point is the 241m high hill of Brandaris, situated on the north-west side of the island (de Freitas et al. 2005).

The southeastern 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 cacti, intermixed with low scrub and large expanses of land largely devoid of vegetation. This is characteristic for the eastern shoreline, which receives slightly less rainfall on average than the western side of the island. While destructive land-use practices such as woodcutting for charcoal production have all but ceased, free roaming goats and donkeys continue to impact native vegetation throughout the island (de Freitas et al. 2005).

Five representative habitats in and around the Lac area as based on vegetation (de Freitas et al. 2005) were selected for sampling (Figure 1). These were: 1) Rhizophora salina and Conocarpus beach (mangrove thickets: ~ 370 ha); 2) Sesuvium salina (Lac salt flats: ~ 72 ha); 3) Coccoloba-Melocactus and Conocarpus middle terrace (dry evergreen woodland: ~ 236 ha); 4) Prosopis-Euphorbia, Haematoxylon – Caesalpinia and Acacia-Croton middle terrace (dry deciduous woodland: ~ 106 ha); and 5) Lithophila-Euphorbia lower terrace including four other barren coastal vegetation types (coastal barrens: ~ 308 ha) (de Freitas et al. 2005).

Mangrove thickets (Rhizophora salina and Conocarpus beach) (vegetation heights: 1.5—5.0 m) were concentrated along the western and northern shores of Lac and were dominated by the mangroves Rhizophora mangle and Avicennia germinans, whereas Laguncularia racemosa and Conocarpus erectus were also commonly found in the thickets. The salt flat (Sesuvium salina) habitat (vegetation heights up to 0.5 m) was concentrated in areas along the hypersaline backwater shores and mud pools of Lac (Fig 1) and was dominated by a low herbaceous vegetation of the halophytes Sesuvium portulacastrum, Lithophyla muscoides and Salicornia perennis. Dry evergreen woodland habitat (Coccoloba-Melocactus and Conocarpus middle terrace) sub-landscape is a mix of two evergreen woodland formations 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 low shrubs and the trees Coccoloba swartzii,
Haematoxylon brasiletto and Metopium brownei (heights: 0.5—2.5 m). Dry deciduous woodland (principally Prosopis-Euphorbia, Haematoxylon-Caesalpinia and Acacia-Croton middle terrace was found principally along the north-western shores of Lac towards Warahama (de Freitas et al. 2005). The vegetation was dominated by grasses (*Sporobolus pyramidatus, Eragostis urbaniana, Anthephora hermaphroditia*) and scattered trees (especially *Prosopis juliflora*, followed by *Casearia tremula, Randia aculeata, Haematoxylon brasiletto* and *Caesalpinia coriaria*) and shrubs and prickly-pear cacti (*Opuntia wentiana, Croton flavens* and *Phyllanthus botryanthus*). The tree cover (heights 0.5—5.0 m) was less well-developed than in the *Coccoloba-Melocactus* landscape and more deciduous in nature. This vegetation was additionally characterized by the importance of large manchineel trees, *Hippomane mancinella* (≤7.0 m high). These trees are intensively used as roosting sites by mixed flocks of parakeets and native columbids (Harms and Eberhardt 2003). The coastal barrens habitat (principally *Lithophila-Euphorbia* lower terrace, but including four other barren coastal vegetation types) was a barren, windblown saline sub-landscape typical of the coralline rocky east coast of the island. This vegetation was additionally characterized by scattered *Conocarpus* bushes interspersed with grasses, grass-like *Cyperaceae*, *Lithophila muscoides* and *Jatropha gossypiiifolia* (heights: 0.0—1.5 m). This habitat was sampled both on the north side of Lac and on the south side (Fig 1). De Freitas et al. (2005) give further details about these vegetation types.
Field sampling and analysis

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 fall migration peak (Prins et al. 2009). All counts were done by J. Ligon, who is a recognized and experienced birder with many first records and rare sightings for Bonaire (Prins et al. 2009). On any given day, separate sites were no less than 100 meters apart. With the aid of Zeiss Victory FL 10 x 32 binoculars, fixed-radius (100 m) point counts (Wunderle 1994) were done in the morning hours before 10:00 h. After arriving at the census point and waiting for 6 minutes, all birds detected within a period of 6 minutes up to the cut-off distance of 100 m, were noted and counted. 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 also at greater distances 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 m, while smaller passerines in thick vegetation were effectively recorded out to no more than about 30 m. The technique of ‘distance sampling’ (Buckland et al. 2001) is often used to account for such imperfect detection, but the number of detections was not sufficient for robust estimates of detection curves. Rather, we used relative encounter rates (presence/absence per point count) for comparison between habitats. In total, 420 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.

Higher-order community analysis was done by clustering the species into the following feeding functional groups: frugivores and nectarivores, granivores, arboREAL insectivores, aerial insectivores, shorebirds, waders, generalists and ‘others’ (raptors, fishers, and water fowl). Species richness per habitat was assessed using species accumulation curves using bootstrapping methods as implemented in the R-package ‘vegan’ (Oksanen et al. 2012). Per habitat type, the number of species was 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 $H'$ (Margalef 1958; Shannon and Weaver 1949), the Chao diversity index and an evenness index as Pielou Evenness $J$ (Pielou 1966). For the only two migratory species for which sufficient data were available (Barn Swallow, Hirundo rustica and Northern Waterthrush, Parkesia noveboracensis), seasonality of encounter rate was inspected by modelling days with and without records as a binary response variable in a logistic Generalized Linear Model (R Development Core team 2011).

Results

Community structure

During 71 (17%) of the counts, no birds were detected. In the remaining 349 counts, 815 species sightings were made. More than half (53%) of the birds counted ($n = 2890$) were the American Flamingo, Phoenicopterus ruber, recorded in 35 sightings (39%) from the salt flat habitat.

Most species ($n = 39$, 62%) were recorded on fewer than ten occasions. Of the 63 species recorded, 24 (38%) were resident; 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, such as the Brown Pelican, Pelecanus occidentalis, gulls and terns, American Oystercatcher, Haematopus palliatus and Magnificent Frigatebird, Fregata
magnificens, were not recorded due to our restricted choice of habitats and restrictions of the method used (circular point counts with restricted radius).

Among waterbirds, (herons, flamingo, waders) migratory species made up significantly more than half of the species (74%, Fisher’s Exact Test with non-waterbirds and non-migratory species pooled, \( p = 0.044 \)), whereas among non-waterbirds species, they made up significantly less than half of the species (43%, Fisher’s Exact Test with non-waterbirds and non-migrants pooled, \( p < 0.001 \)).

Bootstrapping showed that the chosen level of sampling (i.e., 76—89 samples per habitat type) was sufficient to reliably detect community differences. The leveling 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 (Fig 2).

While due to the range of habitats sampled, community differences were to be expected, the dry-evergreen and the dry-deciduous forests showed high similarity. The more detailed relative distribution of species among habitats according to feeding functional groups is evident in Figure 3. The Lac salt flats showed the highest concentration of shorebirds and larger waders, whereas evergreen woodlands had the highest concentrations of frugivores and nectarivores. The coastal barrens characterized by low grasses and shrubs had the highest relative presence of granivores. Arboreal insectivores were absent in the Lac salt flats and the coastal barrens whereas aerial insectivores were represented in all five habitats. Mangrove thickets had a high concentration of frugivores and nectarivores.

Mangrove forests and salt flats had highest overall species richness, diversity and evenness but clearly divergent guild compositions. Community descriptors (Table 1) and guild composition were very similar between the two types of woodland habitat. The coastal barrens showed lowest species richness, diversity and evenness of all five habitats (Table 1), but showed more overlap in guild structure with the woodland bird communities than with either the mangrove thicket or salt flat habitats (Fig 3). When only migrants were considered (Table 1) the salt flats and mangrove thickets also had

![Fig. 2. Species accumulation curves for all species (A), 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.](image-url)
the highest species richness (cumulatively 24 species), whereas the remaining habitat types showed similar, low species richness (5-6 species).

Species composition

The ten most abundant species in the five sampled habitats, derived from the relative contribution to the total species’ presence as based on sighting frequency, are shown in Figure 4. For both the mangrove thickets as well as the salt flats, the ten most frequently detected species were in low abundance compared to the large number of species seen rarely (‘other’). The species’ structure represented in Figure 4, corresponds to the general community descriptors discussed above (Table 1).

Though the mangrove and salt flat habitats were similar in general community descriptors (Table 1) and had high concentrations of migratory species concentrations compared to the other three sampled habitats, their species compositions differed greatly. The most important species in the mangroves were a mix of frugivores and nectarivores (Bonaire Bananaquit, Coereba flaveola bonairiensis, Scaly-naped pigeon, Patagioenas squamosa, Bonaire Brown-throated Parakeet, Aratinga pertinax xanthogenia), insectivores (Yellow Warbler, Setophaga petechia) and waterbirds (Green Heron, Butorides virescens, and Ruddy Turnstone, Arenaria interpres). A migratory warbler, the Northern Waterthrush was also common in the mangrove thicket habitat. The most common species sighted in the salt flats were the American Flamingo, Phoenicopterus ruber, and several shorebirds and egrets such as the Western Sandpiper, Calidris mauri, Tricolored Heron, Egretta tricolor, Black-necked Stilt, Himantopus mexicanus, and a IUCN Red list species, the Reddish Egret, Egretta rufescens (Fig 4). Aerial insectivores such as the Barn Swallow and Gray Kingbird, Tyrannus dominicensis, were also common in this habitat.

The bird communities of evergreen

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Number of species recorded</th>
<th>Extrapolated species richness</th>
<th>Shannon-Weaver diversity (H’)</th>
<th>Pielou Evenness (J)</th>
<th>Chao</th>
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<tbody>
<tr>
<td>Mangrove forest</td>
<td>42</td>
<td>47.6</td>
<td>3.22</td>
<td>0.86</td>
<td>47.97</td>
</tr>
<tr>
<td>Lac salt flats</td>
<td>46</td>
<td>51.1</td>
<td>3.43</td>
<td>0.89</td>
<td>60.96</td>
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<tr>
<td>Evergreen woodland</td>
<td>22</td>
<td>25.5</td>
<td>2.54</td>
<td>0.82</td>
<td>62.04</td>
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<tr>
<td>Deciduous woodland</td>
<td>23</td>
<td>26.3</td>
<td>2.55</td>
<td>0.81</td>
<td>38.82</td>
</tr>
<tr>
<td>Coastal barrens</td>
<td>12</td>
<td>14.3</td>
<td>2.02</td>
<td>0.81</td>
<td>29.76</td>
</tr>
</tbody>
</table>

Table 1. Bird community descriptors for the five habitat types. The extrapolated species richness is based on bootstrap results (see the main text and Fig. 2).
woodland and deciduous woodland were quite similar both in community descriptors and principal species that were dominated by common resident breeding species. Most common were species such as the Tropical Mockingbird, *Mimus gilvus*, the Bonaire Bananaquit, the Scaly-naped Pigeon, Bonaire Brown-throated Parakeet and Yellow Warbler. In the woodland habitats, small granivores such as Common Ground-Dove, *Columbina passerina*, eared Dove, *Zenaida auriculata*, and Black-faced Grassquit, *Tiaris bicolor* were also among the top ranking species. In contrast, the bird community of the coastal barren was the most truncated in terms of species contributions and had lowest species richness and diversity of all. The most important species were the generalist Tropical Mockingbird, the granivorous Common Ground-Dove, and Black-faced Grassquit and the migrant insectivore, the Barn Swallow.

Though 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. Bonaire Bananaquit, Black-faced Grassquit, *Tiaris bicolor* were also among the top ranking species. In contrast, the bird community of the coastal barren was the most truncated in terms of species contributions and had lowest species richness and diversity of all. The most important species were the generalist Tropical Mockingbird, the granivorous Common Ground-Dove, and Black-faced Grassquit and the migrant insectivore, the Barn Swallow.

Passerine migrants

Of the 27 migratory paruline warblers known from Bonaire (Prins et al. 2009, de Boer et al. 2012), we documented only two species during our point counts. These were the Northern Waterthrush and the Prothonotary Warbler, *Protonotaria citrea*. Of the combined migratory passerine 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 (Figures 5a and b). Hence, these contrasting differences between

**Fig. 4.** The 10 principal bird species in a) mangrove thickets, b) salt flats, c) evergreen woodland, d) deciduous woodland and e) coastal barrens, as based on relative sighting frequency.
the two species, which have been generally known and accepted for a long time based on opportunistic sightings (e.g. Arendt 1992, citing Vouos 1983), can now be confirmed with more quantitative data. 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. However, no significant habitat differences were found (Fisher Exact Test, $p = 0.751$). Northern Waterthrushes were primarily and significantly (Fisher Exact Test, $p = 0.005$) encountered in the mangrove thicket habitat (Fig 4, 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 (Vouos 1983). 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, Vouos 1983) or to migratory birds.

**Discussion and Conclusions**

Bonaire’s bird communities were found to differ greatly among habitats. With exception of the salt flat and mangrove thicket habitats where species richness was high, the communities of arid woodlands and coastal scrub had lower species
richness but a fully native bird community. Southern Caribbean endemic subspecies played a major role in these communities and included both island bird subspecies restricted to Bonaire, namely, the Bonaire Bananaquit and the Bonaire Brown-throated Parakeet. In contrast to the large islands of the Greater Caribbean, which provide a wider range of moister and more moderate habitats and where invasive species play a major role (Avecedo and Restrepo 2008), exotic birds played only a minor role in the bird communities we studied. A recent inventory identifies invasive exotic animals as a major conservation issue for the Dutch Caribbean (van Buurt and Debrot 2012). Only one of the five established exotic species was documented in our study. We ascribe the paucity of invasive exotics in the semi-natural habitats studied to the low level of human occupation of the Lac area and to the generally harsh conditions typical of the arid Southern Caribbean. Harsh conditions clearly not only limit the inherent avifaunal richness attainable but might also protect the native bird communities by curtailing the establishment and expansion of exotic birds into the wild.

Small granivores were most important in the coastal scrublands. The coastal scrublands of Bonaire are largely the result of centuries of woodcutting and ongoing human alteration and grazing by feral livestock (de Freitas et al. 2005). Relict tree stands in remote coastal areas of nearby Curaçao show that this habitat once consisted of dense woodlands dominated by salt-tolerant evergreen, berry-producing trees, mainly *Jacquinia arborea* (Debrot, pers. obs.). Nowadays, the vegetation is dominated by annual and perennial seed-producing grasses and grass-like Cyperaceae, which explains the preference of small granivores for this habitat. The evergreen woodlands showed the highest abundance of frugivores and nectarivores. This also is not surprising as these vegetation associations are dominated by evergreen, largely berry-producing hardwood trees. Having many rare and endemic trees, the dry evergreen woodlands to the west of Lac are among the most floristically diverse of the island. The slow-growing hardwood trees, typical of this kind of vegetation, invest heavily in leaf phytochemicals and wax as protection against insect (and other) herbivory. This likely underlies the regional observation, as well as our own findings, that dry evergreen scrub is less important for native and migratory insectivores (such as warblers) compared to more disturbed early-successional vegetation (Murphy et al. 2001, Kennedy et al. 2010). Mangrove thickets were also of high importance to frugivores and nectarivores, but probably more so for shelter.

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 (Faaborg et al. 2013). 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

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Barn Swallow</th>
<th>Northern Waterthrush</th>
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</thead>
<tbody>
<tr>
<td>Mangrove forest</td>
<td>8 (10)</td>
<td>8 (10)</td>
</tr>
<tr>
<td>Lac salt flats</td>
<td>13 (15)</td>
<td>3 (3)</td>
</tr>
<tr>
<td>Evergreen woodland</td>
<td>7 (8)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Deciduous woodland</td>
<td>11 (13)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Coastal barrens</td>
<td>10 (13)</td>
<td>0 (0)</td>
</tr>
<tr>
<td><strong>P-value (Fisher-Erwin test)</strong></td>
<td><strong>0.751</strong></td>
<td><strong>0.005</strong></td>
</tr>
</tbody>
</table>
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* (Lefebre et al. 1994). This pattern is seen throughout the Caribbean (Arendt 1992, Wunderle and Waide 1993).

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 though Trinidad, whereas 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 (Prins et al. 2009). It is thought that these islands are not part of any main migration flyway (Prins et al. 2009). So, although birders have documented many species during the course of some 60 years, 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, whereas only three species can be considered relatively common; namely, Northern Waterthrush, American Redstart and Blackpoll Warbler, *Setophaga striata* (Prins et al. 2009).

Several studies have found that vegetated habitats may differ greatly in suitability and quality for migratory warblers and that food availability can strongly influence the distribution of these species among habitats (Arendt 1992, Johnson and Sherry 2001, Wunderle and Waide 1993). Kennedy et al. (2010) found that disturbed agricultural areas may support high densities of migratory warblers, while in the Bahamas, almost half of the overwintering Nearctic warblers preferred disturbed early successional vegetation to mature woodland habitat (Murphy et al. 2001). In Jamaica, Confer and Holmes (1995) demonstrated that dry limestone forests had the lowest densities of all semi-natural habitats studied. Therefore, the paucity of migratory warblers in the dry limestone habitats around Lac also may reflect in part low habitat quality and food availability for these species.

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 caribaea* (Vulnerable), the Reddish Egret (Near-Threatened), the Piping Plover, *Charadrius melodus* (Vulnerable), the Buff-breasted Sandpiper, *Calidris subruficollis*, the Chimney Swift, *Chaetura pelagica*, the Olive-sided Flycatcher, *Contopus cooperi* (Near-Threatened) the Cerulean Warbler, *Setophaga 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.

Even though the Lac mangrove thickets were formerly used by the Yellow-shouldered Amazon (Voous 1983), this no longer appears to be the case and the species was not observed in this study. In former times, humans persecuted the parrot and the surrounding woodlands suffered more extensive disturbance by agricultural activity and charcoal burning (de Freitas et al. 2005). Under such circumstances, the mangroves of Lac apparently served as a roosting area and refuge for this species. However, as public awareness of the parrot’s value has increased in recent years, its persecution has decreased, and the species apparently no longer needs the shelter and isolation provided by the mangroves of Lac. Also, the quality of the woodlands in many areas of Bonaire has improved in recent decades, undoubtedly offering the Yellow-shouldered Amazon a wider range of habitat options.

Absent from the salt flat habitat at Lac was the Caribbean Coot. The species is of great international conservation importance and is both numerous and successful on Bonaire 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., unpubl. data) and probably will be used only 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. Arendt (2006) classifies the thrasher as an avian ‘supertramp’ due to its generalized nesting and foraging strategy, plus several other biological, ecological and behavioral attributes. Until the mid-20th century this species was by and large confined to the Fontein plantation but by the 1990s the bird had expanded to arid sectors, largely proportional to urban sprawl (Arendt 2006). While this highly adaptable species may be spreading widely in the Caribbean, our results show that at the island level the species still appears dependent on urban sprawl for which the Lac area so far has largely been spared. Six sightings of the Carib Grackle, *Quiscalus lugubris*, document the further spread and establishment of this introduced species. This was the only established invasive species that was found at Lac.

Our results show the highest abundance of migratory birds is in the mangrove thickets and salt flat habitats we studied. Most migratory species detected were shorebirds and waders. For both migratory and resident shorebirds and waders, shallow wading habitat on Bonaire is very abundant and is 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. To fully assess Lac’s local significance for the bird communities studied it would be necessary to have comparable data from other parts of the island.

Two other studies have documented a valuable habitat function for birds in a few isolated areas of Lac. Debrot et al. (2009) mentions breeding habitat for the Least Tern, *Sternula antillarum*, 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.

In the past, Lac bay has also been documented as a breeding location for the endangered Reddish Egret (Voous 1983) but recent breeding observations are lacking. Three other species of egret that commonly nest (or nested) in Lac are Green Heron, Tricolored Heron 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 (Figures 6 and 7). Further studies directed to document potential egret breeding activity at Lac is recommended. The mangroves seem to be of further importance in southern Bonaire as a main nesting and roosting habitat for the Scaly-naped Pigeon. Whereas van Moorsel and Meijer (unpubl. data) noted the absence of this species in 1992, in our study the species was the second-most abundant species in the *Rhizophora* forests. This pigeon, which was extirpated in the middle of the 20th century on Aruba, has always been quite rare on Curacao but 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 its abundance on the island. Lac also harbors the only large and consistent roosting site for frigate birds on Bonaire (Voous 1983).

From historical maps (Wagenaar Hummelinck 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 American Flamingo 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 (van Moorsel and Meijer, unpubl. data). The most important hypersaline habitat areas for the flamingo on Bonaire, lie outside of Lac (de Boer 1979, Voous 1983), 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 that is threatening its premier values as a mangrove and seagrass fish nursery area.
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Literature cited


