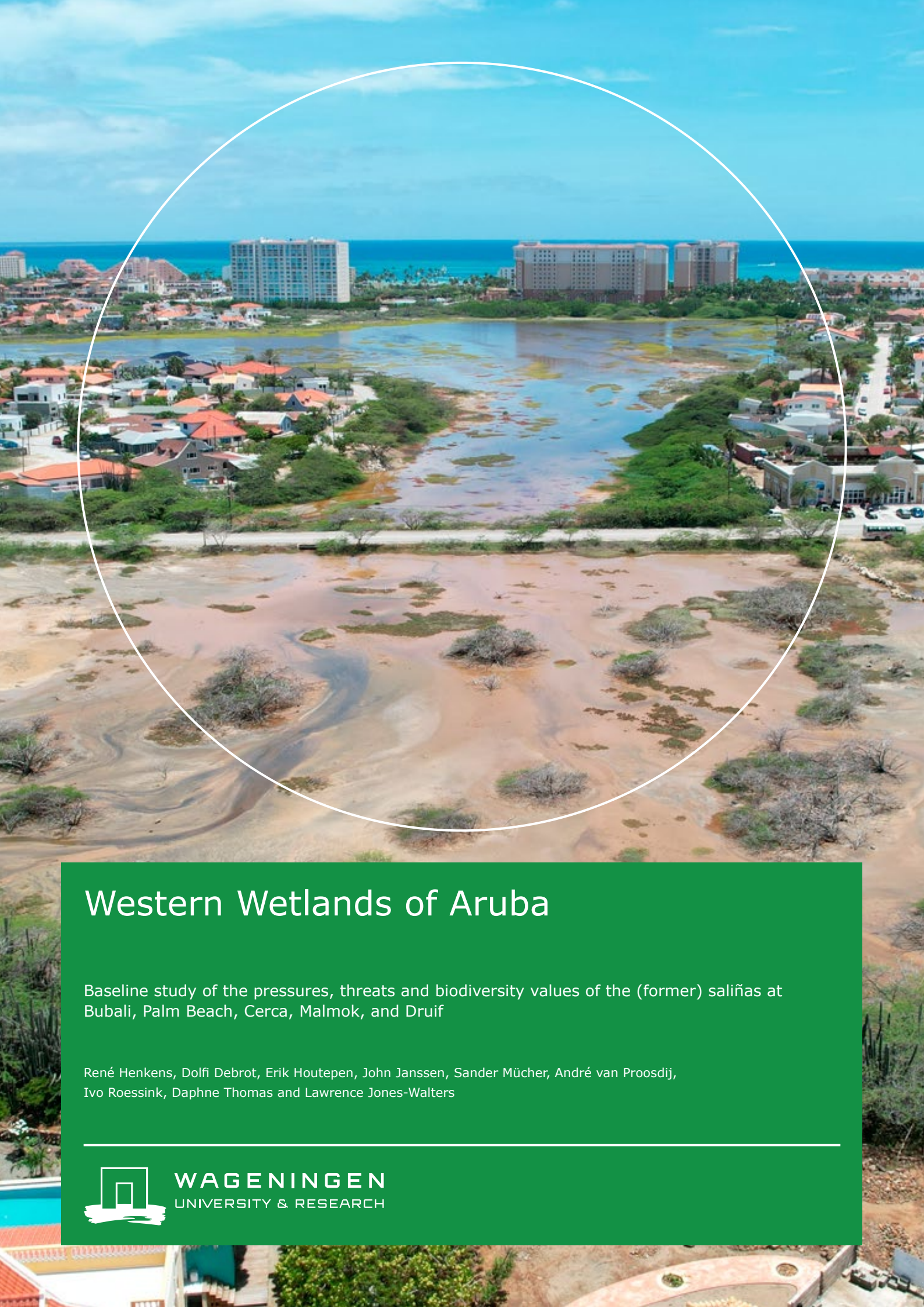

Western Wetlands of Aruba

Baseline study of the pressures, threats and biodiversity values of the (former) saliñas at Bubali, Palm Beach, Cerca, Malmok, and Druif

René Henkens, Dolfi Debrot, Erik Houtepen, John Janssen, Sander Mücher, André van Proosdij, Ivo Roessink, Daphne Thomas and Lawrence Jones-Walters

WAGENINGEN
UNIVERSITY & RESEARCH

Western Wetlands of Aruba

Baseline study of the pressures, threats and biodiversity values of the (former) saliñas at Bubali, Palm Beach, Cerca, Malmok, and Druif

René Henkens[1], Dolfi Debrot[2], Erik Houtepen[3], John Janssen[1], Sander Mücher[1], André van Proosdij[1], Ivo Roessink[1], Daphne Thomas[1] and Lawrence Jones-Walters[4]

1 Wageningen Environmental Research
2 Wageningen Marine Research
3 Carmabi Foundation
4 Wageningen Corporate Strategy & Accounts

This research was funded by the Tourism Product Enhancement Fund (TEPF), a fund specifically designated for enhancing the tourism product in Aruba (project number 5200048135).

Wageningen Environmental Research
Wageningen, November 2024

Reviewed by:
Lian Grabijn, Researcher (Wageningen Environmental Research)

Approved for publication:
Joke de Jong, teamleader of Biodiversity & Policy

Report 3380
ISSN 1566-7197

WAGENINGEN
UNIVERSITY & RESEARCH

Henkens, René, Dolfi Debrot, Erik Houtepen, John Janssen, Sander Mücher, André van Proosdij, Ivo Roessink, Daphne Thomas, Lawrence Jones-Walters, 2024. *Western Wetlands of Aruba; Baseline study of the pressures, threats and biodiversity values of the (former) saliñas at Bubali, Palm Beach, Cerca, Malmok, and Druif.* Wageningen, Wageningen Environmental Research, Report 3380. 66 pp.; 25 fig.; 3 tab.; 42 ref.

De Western Wetlands (392 ha) bestaan uit vijf (voormalige) saliñas langs de noordwestkust van Aruba, beheerd door de Aruba Conservation Foundation. Drie saliñas worden gevoed met (nog steeds vervuild) zoet water van een rioolwaterzuiveringsinstallatie, terwijl twee andere relatief natuurlijk zijn. Deze nulmeting beoordeelde de belangrijkste bedreigingen voor de saliñas, waaronder vervuiling, erosie, sedimentatie, versnippering, impact van bezoekers en invasieve soorten. Ondanks deze druk zijn er nog steeds 178 plantensoorten en meer dan 200 trekvogel- en broedvogelsoorten waargenomen. De saliñas spelen een cruciale rol bij het beschermen van de natuurlijke waarden van het eiland. Dit rapport vormt de basis voor de ontwikkeling van een beheerplan.

The Western Wetlands (392 ha) consist of five (former) saliñas along the northwest coast of Aruba, managed by the Aruba Conservation Foundation. Three saliñas are effluent-fed with still polluted fresh water from a wastewater treatment plant, while two others are relatively natural. This baseline study assessed the main threats to the saliñas among which pollution, erosion, sedimentation, fragmentation, visitor impacts and invasive species. Despite these pressures still 178 plant species and over 200 migratory and breeding bird species have been recorded. The sites play a crucial role in safeguarding the natural values of the island. This report gives way to the development of a management plan.

Keywords: origins, vegetation, watershed, water quality, sediment, connectivity, birds, saliñas

The pdf file is free of charge and can be downloaded at https://doi.org/10.18174/676469 or via the website www.wur.nl/environmental-research (scroll down to Publications – Wageningen Environmental Research reports). Wageningen Environmental Research does not deliver printed versions of the Wageningen Environmental Research reports.

Wageningen Environmental Research Report 3380 | ISSN 1566-7197

Photo cover: Aruba Conservation Foundation (29-06-2023)

Contents

Verification

Report: 3380
Project number: 5200048135

Wageningen Environmental Research (WENR) values the quality of our end products greatly. A review of the reports on scientific quality by a reviewer is a standard part of our quality policy.

Approved reviewer who stated the appraisal,

position: Researcher

name: Lian Grabijn

date: 25-10-2024

Approved team leader responsible for the contents,

name: Joke de Jong

date: 24-10-2024

Preface

In 2020, an important wetland system in Aruba, consisting of 4 brackish 'saliñas' or salt marsh areas (saliñas Druif, Malmok, Cerca, and Palm Beach) and a former saliña that was converted decades ago into a constructed permanent freshwater marsh as part of the wastewater treatment plant (WWTP) Bubali, commonly known as the Bubaliplas, was legally designated as a nature reserve and brought under the management of the Aruba Conservation Foundation (ACF). Two of these five wetlands are internationally recognized as Important Bird and Biodiversity Areas (IBAs), namely: Bubaliplas and Saliña Druif. In 2023 the five saliñas, collectively called the Western Wetlands, were designated as Ramsar site #2528 and formally recognized as wetlands of international importance, bringing with it a new level of conservation management requirements.

Conversely, the Western Wetlands are increasingly impacted by anthropogenic activities, and hence protecting and enhancing the integrity of the natural values of the Western Wetlands and regulating human activities in accordance with the ecological sensitivity and carrying capacity will be crucial for rehabilitating these areas of high natural value. ACF aims to restore the watershed, and health and connectivity of these saliñas in the coming decades - within the context of climate change and adaptation - and in the process of enhancing biodiversity, including through species specific restoration efforts.

In 2022 a ministerially initiated, multi-disciplinary steering group was launched to develop a project document and management plan to safeguard the protected wetland areas and adjoining marine environment, through prudent visitor, wetland and water(shed) management – safeguarding, conserving and enhancing the integrity, health and resilience of native biodiversity and wetland ecosystem, and increasing the value of the tourist product through sustainable nature experiences - thereby contributing to the sustainable future of Aruba. In the coming years, attention will also be given to the additional supportive strategies such as community engagement, creating awareness, developing sustainable nature experiences, and developing a (financial) base of support as part of ACF's Cycle of Business for Sustained Value Creation and Sustained Conservation, keeping its focus and management attention firmly on the primary task of nature conservation and consequently on value creation for Aruba's nature, environment, residents, communities, visitors and economy, in order to generate their stewardship and support for sustained conservation of Aruba's natural assets.

Carrying out a baseline study is a crucial element of conservation best practices for several reasons. It provides objective, scientifically backed information about the state of the ecosystem and lays the foundation for effective planning, implementation, and monitoring of conservation efforts. It allows us to understand the current state of the ecosystem, including species diversity, population sizes, habitat conditions, and existing threats. This data provides a clear picture of the ecosystem's health before any conservation actions are taken or visitor products and infrastructure is developed.

By documenting the initial conditions, a baseline study creates reference points against which future changes – either natural or through intended interventions- can be measured. This allows ACF, fellow conservationists, and researchers to assess the effectiveness of their interventions over time.

Baseline studies help identify which species or habitats are most at risk and prioritize conservation actions accordingly. With a thorough understanding of the baseline conditions, ACF can design strategies that are tailored to the specific needs and challenges of the Western Wetlands. By understanding the baseline conditions, conservationists can better anticipate and mitigate potential unintended consequences of their interventions, such as habitat disruption or impacts on non-target species. This reduces the risk of implementing ineffective or even harmful interventions and ensures that resources are allocated efficiently to areas where it can have the best potential for conservation success.

Moving forward, regular monitoring against this baseline data will allow for the tracking of progress of the conservation interventions against the starting conditions. This enables ACF and others to determine whether the executed actions are leading to the desired outcomes or whether it is necessary to adjust strategies, also as conditions change. Sharing this information with stakeholders and the community at large enhances transparency and accountability of ACF's conservation work.

Hence, this baseline study is a fundamental step in the conservation process that ensures actions are informed, targeted, and adaptable. It supports best practices by enabling data-driven decision-making, fostering transparency, and providing the foundation for long-term ecological health and sustainability.

This baseline study was funded by the Tourist Product Enhancement Fund (TPEF), whose scope includes nature related projects, thereby recognizing nature's significance and value for tourism and, by extension, the economy of Aruba. This baseline will also provide the necessary information for modest future tourism related product development in the Western Wetlands Nature Reserve, in accordance with sustainable recreation best practices, carrying capacity studies, and impact assessments.

Tyson O. Lopez
Chief Executive Officer
Aruba Conservation Foundation

Natasha J. Silva
Chief Conservation Officer
Aruba Conservation Foundation

Summary

The Western Wetlands refer to a set of five (former) saliñas near the northwest coast and northern tip of Aruba, listed from south to north: Saliña Bubali, Saliña Palm Beach, Saliña Cerca, Saliña Malmok and Saliña Druif. They cover a total area of 392 hectares and have enjoyed legal protection since 5 May 2020 (Nature conservation ordinance AB 2020 no. 67) and were designated as Wetlands of International Importance under the Ramsar Convention on 10 November 2023 (Ramsar site no. 2528). This baseline concerns an assessment of the wetlands biodiversity values and the pressures and threats affecting them. It is a crucial step for the development of a conservation plan.

Biodiversity values

The saliñas of Bubali, and to a lesser extent Palm Beach and Druif, have undergone significant human alteration. These sites are fed by effluent from the Bubali wastewater treatment plant, which has faced capacity issues for several decades. These areas are characterised by freshwater conditions, high nutrient loads and, particularly at Bubali, extensive year-round water coverage. In contrast, the relatively unaltered saliñas of Cerca and Malmok still experience natural seasonal cycles of fluctuating salinity and water levels typical of the arid southern Caribbean's wetlands. Due to these differing environmental conditions, the two categories of water bodies support distinctly different flora and fauna.

Natural saliñas exhibit a dynamic seasonal turnover in plant and animal communities based on their adaptations to varying salinity levels. This includes seasonal growth and coverage by the native seagrass *Ruppia maritima* and the presence of amphidromous native freshwater fish such as the range restricted Molly *Poecilia vandepolli*. In contrast, the modified effluent-fed saliñas support flora and fauna that are largely foreign to the island's natural ecosystems. Aquatic vegetation in these areas is dominated by dense stands of the reed *Typha dominguensis* and the invasive Water hyacinth (*Eichhornia crassipes*). The aquatic macrofauna is dominated by invasive species, such as the Nile tilapia (*Oreochromis mossambicus*) and the Red-eared slider turtle (*Trachemys scripta*). Despite their altered conditions, these man-made freshwater systems serve as valuable habitats for migratory and breeding bird species.

To date citizen-science[1] data reveal the (ir)regular presence of 216 native migratory and resident bird species in the Western Wetlands. Recent scientific research also reveals the presence of 21 vegetation types, 146 native flora species and 32 new species for Aruba (probably non-native species escaped from gardens). No less than 23 of these bird and plant species are registered on the protected species list of Aruba (Landsbesluit AB 2017 no. 48). Future inventories and monitoring research on other species groups (e.g. butterflies, dragonflies, spiders) will undoubtedly reveal the presence of further species to be included on the protected species list. Many of these species will be largely restricted to the wetland and terrestrial habitat of the saliñas. It can therefore be concluded that the conservation and restoration of the Western Wetlands is crucial for safeguarding the biodiversity values of Aruba.

Pressures and threats

The distinct ecological characteristics of these two wetland types (Bubali, Palm Beach and Druif on one side and Cerca and Malmok on the other), present different management challenges. However, both wetland types face six overarching pressures and threats:

1. **Water pollution**
   The Bubali wastewater treatment plant (WWTP) has had capacity problems for many decades now. The nutrient-rich effluent has affected Bubali, and subsequently Palm Beach and Druif. Besides nutrients the water and sediment may also be contaminated with heavy metals, agricultural and industrial chemicals, hydrocarbon fuels, pharmaceutical drugs or biological agents such as bacteria, parasites and viruses. Assessment of these contaminants warrants separate studies.

[1] Involving citizens in scientific research is called Citizen Science. Citizen Science has been evolving rapidly in recent years supported by the increasing digitisation of science.

Restoration measures in the saliñas Bubali, Palm Beach and Druif should be taken after the problems with the WWTP have been solved and the effluent is clean. At all times it should be prevented that the WWTP-effluent reaches the still quite natural saliñas of Malmok and Cerca.

2. **Urbanisation, soil erosion and sedimentation**
   The saliñas belong to three watersheds or water catchment areas: saliña Druif lies within the smallest watershed of only 256.1 hectares, the saliñas Malmok and Cerca are part of a watershed of 767.8 hectares, while Bubali and Palm Beach lie in a watershed of 1292.4 hectares. Less than half of each of these watersheds is covered with (natural) vegetation. Siltation[2] has been accelerated due to poor land-use practices and urbanization, which increases erosional runoff to the saliñas. This decreases the water absorption capacity and increases the risk of flooding during heavy down pours. Restoration of the water absorption capacity of the saliñas will require the removal and appropriate disposal of accumulated sediment. Restoration of the water retention capacity of the watershed will require a combination of measures like restoration of the (natural) vegetation, improvement of land-use practices and halting of the ongoing urbanisation.
3. **Ecological fragmentation**
   Historically, all of the saliñas with the exception of Druif, were interconnected to some extent. Today, restoring and maintaining any remaining connectivity is a high priority as the saliñas are becoming increasingly isolated from each other. Ecological corridors should interconnect the saliñas and the roois so that the Western Wetlands can truly be considered one protected area, where flora and fauna can freely move between the five saliñas.
4. **Visitor impacts: disturbance and trampling**
   All five (former) saliñas offer unique recreational and tourism potential. It is important to connect the natural values of the Western Wetlands and visitors with each other and not to see these as separate. The visitor-use of each saliña must be carefully tailored to its ecological vulnerability. A visitor centre, board walks and bird hides are some of the recommended control measures that can direct visitors in the preferred (non impacting) direction, without the need for too many high visibility rules and regulations (although they will be in place to be employed if necessary).
5. **Invasive species**
   The Western Wetlands are severely affected by invasive species, some of which have been present for many decades, among which the Water hyacinth (*Eichhornia crassipes*), the Red-eared slider (*Trachemys scripta subsp. elegans*), the Yellow-bellied slider (*Trachemys scripta subsp. Scripta)*, the Cane toad (*Rhinella marina*), the *Boa constrictor* and the Tilapia (*Oreochromis mossambicus*). A plan should be developed to manage these invasive species, localize and remove (potentially invasive) exotic species and raise awareness.
6. **Climate change.**
   Aruba is increasingly vulnerable to climate change impacts. Temperatures are predicted to rise 1 to 3.5 degrees Celsius; average windspeed will increase; precipitation will decrease 0 to 40%, especially in the dry season; precipitation events will become heavier; storm surge associated with the hurricane season will become more frequent and sea-level is expected to rise roughly between 30 and 130 cm in 2100. These combined climate change impacts are likely to decrease the resilience of the saliñas. Without adaptive management and protection measures (i.e. management of the entire watershed and protection and restoration of coastal habitats e.g. coral reefs, reef islands, seagrass beds and mangrove forests), climate change could drastically alter or even lead to the loss of a number of Aruba's saliñas.

The governmentally appointed Western Wetlands Working Group in Aruba has determined eight conservation targets that a conservation plan will have to focus on: 1) Wetlands Connectivity, 2) Wetland Ecology, 3) Water Quality, 4) Native Flora, 5) Land Birds, 6) Water birds, 7) Buffer Zone Management and 8) Sustainable Recreation. The main recommendations from this baseline study have been described above, while the final chapter of this report lists more specific recommendations for each of these eight conservation targets.

[2] Siltation is a natural process leading to the transformation of wetlands into dry land over geological timescales.

1 Introduction

1.1 Context

The Western Wetlands refer to a set of five (former) saliñas near the northwest coast and northern tip of Aruba. Roughly from southwest to northeast these are the wetlands known as Bubali, Palm Beach, Cerca, Malmok and Druif (figure 1.1). They have enjoyed legal protection since 5 May 2020 (Nature conservation ordinance AB 2020 no. 67) and were designated as Wetlands of International Importance under the Ramsar Convention on 10 November 2023 (Ramsar site no. 2528). Parts of Bubali and Druif have also been recognised as Key Biodiversity Areas (KBA site no. 20856 and no. 20855 respectively) and as Important Bird Areas (IBA site no. AW001 and no. AW002 respectively; Birdlife International 2008). Altogether, 392 hectares of the Western Wetlands are protected under one or more of these protection categories.

As well as being fed by rainwater, Bubali and, to a lesser extent, Palm Beach and Druif receive fresh water from the Bubali wastewater treatment plant (WWTP) and have turned into man-made semi-permanent fresh or brackish water wetlands. Malmok and Cerca are still relatively natural saliñas where the salinity changes from brackish to hypersaline, depending on the season.

Figure 1.1 *Map of the Western Wetlands which has been legally designated as wetlands of international importance under the Ramsar Convention on 13 November 2023 (the Ramsar-delineation covers 392 hectares).*

All five saliñas of the Western Wetlands still possess high biodiversity values, which explains why this composite site has recently been designated as a wetland of international importance under the Ramsar Convention. At the same time, the (former) saliñas are threatened by pollution, sedimentation, fragmentation, disturbance, invasive species and climate change, among others. ACF needs recommendations on how to improve the health and resilience of the wetlands ecosystems and to ensure that residents and tourists can enjoy the wildlife in a sustainable way.

1.2 Project purpose

The purpose of this assignment was to do a baseline study of the biology and ecology of the Western Wetlands Nature Reserve, and to use this to provide recommendations on how to increase and restore ecosystem health, resilience, and biodiversity, while at the same time enabling sustainable nature experiences in specifically designated zones and also reducing anthropogenic threats and impacts on the Western Wetlands Nature Reserve.

1.3 Research questions

The governmentally appointed Western Wetlands Working Group in Aruba determined eight conservation targets that the protected area conservation management plan (PACMP) will have to focus on: 1) Wetlands Connectivity, 2) Wetland Ecology, 3) Water Quality, 4) Native Flora, 5) Land Birds, 6) Water birds, 7) Bufferzone Management and 8) Sustainable Recreation. The conclusions and recommendation in chapter 6 have therefore been formulated around these eight conservation targets.

This report provides the baseline information for these conservation topics and aims to address the following research goals:

- Chart a baseline of biotic, abiotic, ecological, hydrological and geomorphological factors;
- Conduct a quickscan of the pressures and threats of the Western Wetlands and a general assessment of its current state of biodiversity and ecosystem health;
- Provide recommendations on how to increase and/or restore to regain ecological functionality;
- Provide recommendations on how to integrate sustainable recreation within saliñas Bubali and Palm Beach.

Cultural heritage was not included as a topic within this assignment. However, local experts were contacted with the aim to find opportunities to merge cultural heritage values into the recommendations concerning sustainable recreation and tourism development.

1.4 Research approach

Stakeholder interviews were held in September 2023 with relevant representatives from the government, conservation and tourism sectors in Aruba. These interviews were aimed at developing an understanding of the ‘unpublished’ knowledge and visions regarding development of the Western Wetlands. A baseline study on the water quality and wetland ecology was carried out in February-March 2024. Vegetation maps and watershed maps were developed as part of a larger study carried out by Wageningen Environmental Research since 2021.

2 Origin and history

2.1 Geological origin

There have been several studies on the geology of Aruba. The most recent, and possibly the most comprehensive, is that by Derix (2016) *A review of the geology, climate and hydrology in Aruba*. He describes how the Aruban geological development has undergone a variety of changes due to tectonic displacement, uplifting, sea level rise and deformation activities. Furthermore, subterranean temperature and pressure regimes during the formation of the island caused differences between rocks in morphology and mineral composition.

These differences caused the rocks to have different levels of resistance against the erosional forces from the sea, sand, wind and rain which shaped the topographic and soil patterns of the Aruban landscape as it is seen today and, resulted in the landforms that shaped the formation of the saliñas. This is important as it gives us clues to the possible age of the saliñas and the extent to which they are naturally occurring phenomena (as opposed to being man-made or seminatural). This could have implications for the future management of the saliñas.

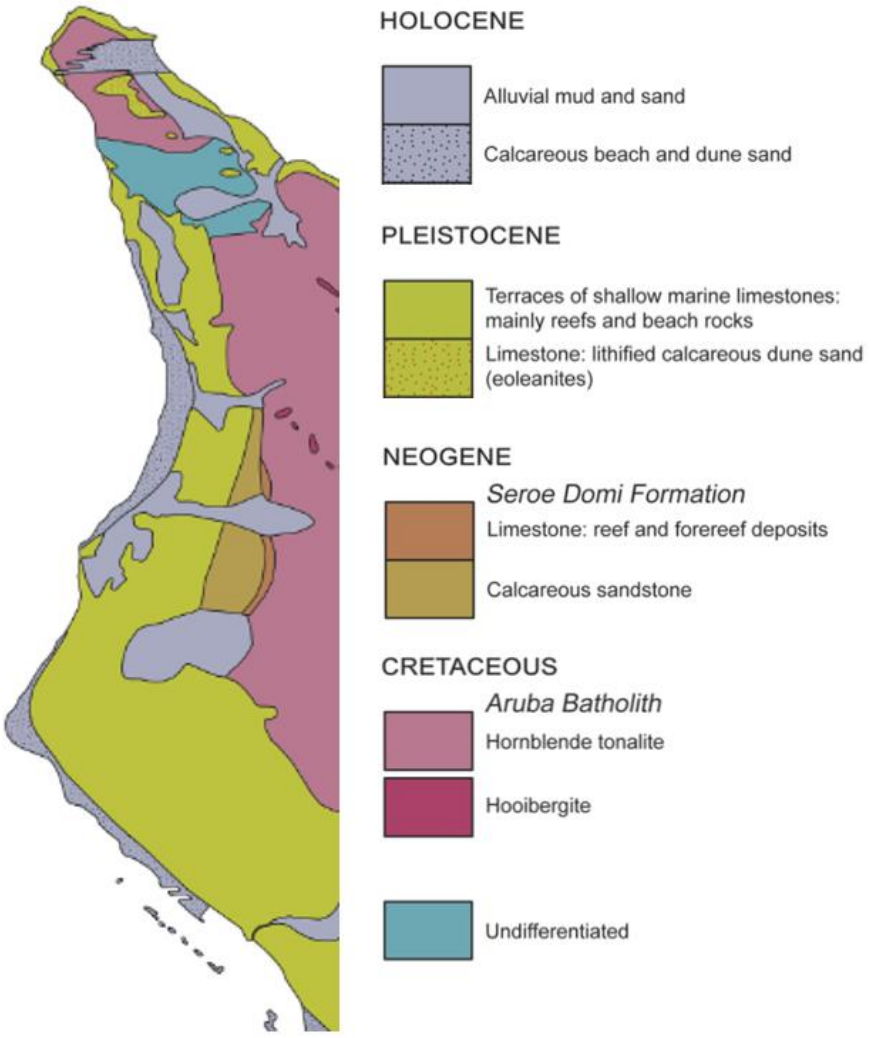

Figure 2.1 *Geology of the north-western part of Aruba (adapted to RGD, 1996).*

Figure 2.1 shows the current geology of the north-western part of the island (RGD, 1996). The saliñas are largely shown as the 'grey' areas of alluvial mud and sand. Quaternary marine limestone terraces in the form of (fossilized) reefs and beach rock fringe the island and created a raised, rocky defence or natural revetment. Behind these, on the landward side, the saliñas formed in the natural 'depressions' that established due to the slow, but gradual uplift resulting from geological processes. Derix (2016) describes some of these topographic patterns and explains how processes of erosion, weathering and sedimentation created new opportunities for soil development and vegetation.

The combination of hydrogeology, soil formation and climatic conditions ultimately resulted in the accumulation over time of mud and sand within the saliñas, shaping the Western Wetlands. Historically, during periods of rain, several of the dry rivers (locally called "rooi") feed directly into the saliñas, bringing alluvial mud and sandy sediments. However, because of the prevailing salt-laden winds and the brackish composition of the groundwater, even at some distance from the coast salt accumulation has occurred in the topsoil. When the soil is washed into the saliñas it therefore brings salt that precipitates on the surface of the sediment when the water evaporates. In several of the saliñas this was and continues to be a natural process. However, in the present day, the run-off into the saliñas is not only brackish water full of sediment. The use of fertilisers, herbicides and pesticides in garden soils and agriculture, contamination from the disposal of oils, detergents and other potentially toxic substances and discharges from hotels and the nearby hospital, and the effluent from household sewage in shallow surface cesspools means that seasonal rainwater run-off into the saliñas (and the marine environment) is potentially deleterious to man and wildlife.

2.2 Development since the early 1900s

The origin of the saliñas is a factor in decision-making over their present and future management. The island topographic map of 1912 (figure 2.2) provides us with the first comprehensive illustrated depiction of these areas. From the map it is clear to see that on the western coast there are two main saliñas, a northern area that comprises the modern saliñas of Malmok and Cerca (the whole area then called 'Salinja Cerká') and a southern area comprising Palm Beach and Bubali (at that time referred to as Keitoe). At that time, Druif is depicted as what appears to be a boca, with a small, raised sandbar in its mouth.

Both of the western saliñas have a brief legend stating 'Na regen onder water' – under water when it rains. At the southern end of Keitoe (meaning "quiet") there is a small area of 'zoutpannen' - salt pans, man-made areas set aside for salt production. The next meaningful representation of the Western Wetlands is provided by the aerial photographs of 1948 (figure 2.3). By then, Druif had a more obvious sandbar blocking its entrance to the sea; (in one conversation with a local stakeholder it was suggested that this entrance was more permanently blocked with the construction of a road that crossed the entrance in the 1960s). However, combined with the 1912 map, the implication is that the entrance was slowly closing due to sand deposition that was most likely a result of the prevailing currents.

The western saliñas were then (1948) still fully intact. They all seemed inundated with water shortly before the pictures were taken and are clearly visible in the aerial photograph. In 1948, these low-lying areas likely contained much less accumulated sediment from erosional run-off and may have permanently had shallow water of fluctuating salinity throughout most of the year, similar to such habitats currently on Curaçao and Bonaire. The salt pans were still visible at the southern end of what is now known as 'Bubaliplas', and the water treatment works there today had not yet been constructed. There was still very little urban development and roads all appear to be dirt tracks.

Based on the historical maps and aerial photograph, it appears that Cerca and Malmok are natural saliñas that sit within a protective curtain provided by the fossilised coral revetment. There may be one area through which seawater could enter (for instance at surge tides between Hadikoerari and Basiroeti, figure 2.2) but it is likely that most of the water feeding them at that time came in the form of saline groundwater as is common in low-lying coastal lands in Curaçao and Bonaire. Such areas would have become seasonally inundated with freshwater run-off and may have been filled from the sea during hurricane events due to wash-over from the sea.

Bubali and Palm Beach were probably more frequently inundated by seawater, as evidenced by the salt pans which were most likely fed by the gap and the coral revetment of what was identified on the map as 'Poos Chikitoe'. Druif was certainly behaving as a more 'natural' saliña by 1948 and, with the exception of the small areas affected by the landscaping around the golf course, it has remained largely the same shape and area since then.

Figure 2.2 *Historic topographic map of Aruba (Werbata-Jonckheer, 1912).*

If we contrast that with the current situation, we can see massive urbanisation and infrastructure development (figure 2.4; see also figure 3.4 in chapter 3). Druif has housing development and a golf course along its western edge, and based on the image from Google Earth[3], its bright green colour indicates that it is full of water, but that high nutrient content is causing algal blooms and massive growth of aquatic plants. This is probably the result of water pumped directly from Bubali by pipeline into Druif and which is known to be high in nutrient concentrations (see also § 3.2). The entrance to the sea appears to be even more permanently blocked.

[3] Accessed 04-06-2024.

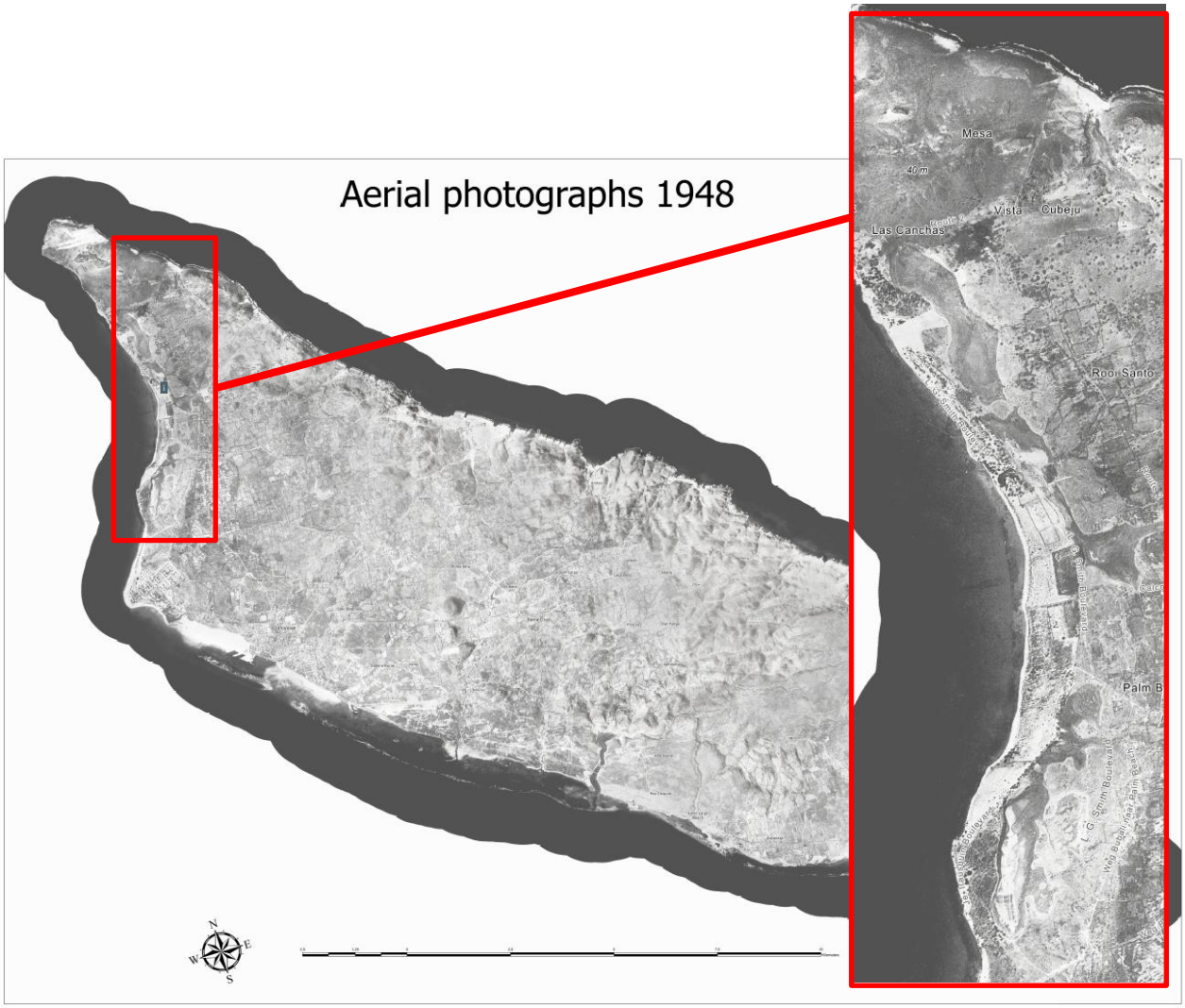

Figure 2.3 *Aerial photograph of Aruba in 1948 (Anonymous).*

Of the western saliñas, Malmok has retained some of its previous area but is almost completely closed-in by development along the eastern edge. Cerca has been most affected by development and is hemmed in on all sides. The dry rivers are still visible and, are still feeding water during the periods of rainfall. However, they are impeded by roads and in some cases housing development. The coastal strip has a major road and linear housing development along most of its length.

Bubali and Palm Beach have been massively modified, by the wastewater treatment plant, infrastructure and built development. Bubali is no longer a saliña in the true sense, since it has permanent fresh water and extensive reed beds. Palm Beach has also lost most of its previous characteristics and is heavily vegetated with less area that could be termed 'saliña'.

Figure 2.4 *The current extent of urbanization along Aruba's west coast (image from Google Earth).*

3 Pressures and threats

3.1 Introduction

The biodiversity values of the Western Wetlands largely depend on the ecological condition of the saliñas and the different pressures and threats. In this report we present and describe obvious pressures and threats from water pollution, urbanisation, soil erosion and sedimentation, ecological fragmentation, visitor impacts, invasive species, and climate change - a snapshot of what is known to date. Monitoring should be carried out to demonstrate the seriousness of the pressures and threats so that targeted action can be implemented.

3.2 Water pollution

On 8 May 2024, the government of Aruba was once again ordered through a court case verdict to take immediate measures to tackle the nuisance caused by the wastewater treatment plant (WWTP) in Bubali[4]. This verdict centred on the ongoing problems with the WWTP. The plant has capacity problems for several decades now (see also Van Halewijn et al., 1992): it is designed to treat approximately 4,500 m³ of wastewater daily, but currently (May 2024) it processes 8,000 to 9,000 m³ per day, and on rainy days even up to 12,000 m³.

Bubali is permanently fed by effluent from the Bubali WWTP. Palm Beach is more elevated than Bubali. When Bubali is in danger of overflowing, its water is actively pumped into Palm Beach. Druif receives effluent from the Bubali WWTP through a pipeline for irrigation of the golf course Tierra del Sol (see Stimaruba, 1992). These three saliñas are therefore quite different from the more natural saliñas Cerca and Malmok, which are mainly fed by run-off rainwater.

Table 3.1 *Overview of the measurement results of dissolved oxygen, temperature, acidity, salinity and alkalinity of the sampled saliñas in early March 2024. For water sample locations see figure 3.1. Colours: red = inadequate, green = adequate. Indicative goals refer to water quality criteria for slightly brackish waters in the European Water Framework Directive.*

Location		DO (mg/L)[1]	DO (%)[1]	T (°C)[1]	pH[1]	Salinity[1]	Alkalinity[2]
	Indicative goal	**> 5**	**60-120**		**6.0-9.0**		
A	Bubali – outlet channel	2.18	26.8	25.61	7.54	1.12	258
B	Bubali – lookout point	0.62	7.7	26.49	7.66	1.09	205
C	Bubali – roadside	1.29	16.3	26.87	7.7	0.79	208
D	Palm Beach	2.6	32.8	27.05	8.26	1.53	314
E	Cerca 1	3.85	48.7	27.12	9.38	44.3	1095
F	Cerca 2	7.52	99.3	29.55	8.38	48.5	365
G	Malmok 1	5.1	67.8	30.05	8.14	96	138
H	Malmok 2	0.76	10.0	28.97	7.18	364.8	1055
I	Druif 1	2.59	31.7	25.05	9.57	4.29	160
J	Druif 2	0.45	5.5	24.98	8.69	4.38	299

[1] Measured using a HANNA Instruments HI98199 multimeter.

[2] Measured using a HANNA Instruments HI83399 multiparameter photometer.

[4] Verdict in court case 8 May 2024 belonging to AUA202400787 KG.

Table 3.2 *Overview of the measurement results of the nutrient concentrations in the sampled saliñas in early March 2024. For water sample locations see figure 3.1. Colours: red = inadequate, green = adequate. Indicative goals refer to water quality criteria for slightly brackish waters in the European Water Framework Directive.*

Location		Phosphate PO_4 (mg/L)[1]	Ammonia NH_3-N (mg/L)[1]	Nitrite NO_2-N (ug/L)[1]	Nitrate NO_3-N (mg/L)[1]
	Indicative goal	**< 0,14**	**< 0.6**	**< 0**	**< 2.2**
A	Bubali – outlet channel	22.5	47.06	7	0.6
B	Bubali – lookout point	34.1	22.56	43	1.6
C	Bubali – roadside	10.5	0.76	52	5.4
D	Palm Beach	11.7	0.51	0	0.3
E	Cerca 1	0	1.44	0	0
F	Cerca 2	0	0.72	0	0.6
G	Malmok 1	0	1.66	0	0
H	Malmok 2	0.38	45.56	11	11.2
I	Druif 1	0.52	0.29	0	0
J	Druif 2	6.1	0.34	0	0

[1] Measured using a HANNA Instruments HI83399 multiparameter photometer.

Figure 3.1 *Locations A-J where the water samples were taken in early March 2024.*

For this baseline study, the following water quality parameters of each saliña were assessed: temperature (T), dissolved oxygen (DO), oxygen saturation (DO%), acidity (pH), alkalinity, salinity, phosphate (PO_4), ammonia (NH_3-N), nitrite (NO_2-N) and nitrate (NO_3-N). Temperature, pH, salinity and oxygen-parameters were measured on the spot using a HANNA Instruments HI98199 multimeter. Water samples were taken, collected in a coolbox, stored in a fridge and analysed in the lab within 24 hours. HANNA Instruments HI83399 multiparameter photometer was used to analyse alkalinity, phosphate and nitrogen-parameters.

This results in a first snapshot overview of the water quality in each saliña at the onset of the dry season (figure 3.1, table 3.1 and 3.2). It is considered a snapshot as this baseline study did not allow for the assessment of other water or sediment contaminants such as heavy metals, agricultural and industrial chemicals, hydrocarbon fuels, pharmaceutical drugs or biologic agents such as bacteria, parasites and viruses – these warrant separate studies.

Nevertheless a recent study (Vermeij et al. 2019) indicates that the abundances of faecal bacteria (*Escherichia coli* and especially *Enterococci*) in sewage water that enters Aruba's coastal waters appears significant and locally exceeds limits for safe use by humans. The same water also enters from Bubali into the saliñas Palm Beach and Druif.

Untreated wastewater can contain high concentrations of nutrients such as phosphates and ammonia. In the water column ammonia is converted by *Nitrosomonas* bacteria to the very poisonous nitrite, which is then converted by *Nitrobacter* bacteria into nitrate. This may (or may not) be followed by denitrification which is a microbially facilitated process where nitrate is reduced and ultimately produces molecular nitrogen gas through a series of intermediate steps. This typically occurs in anoxic pondwater sediments.

Saliñas are dynamic systems. They increase in size and have reduced salinity in the rainy season or after heavy downpours and they decline in size and have higher salinity due to evaporation in the dry season. As a result, water quality parameters reflect these natural dynamics. These natural dynamics are disturbed in the effluent-fed salina Bubali and to a lesser extent Palm Beach and Druif. The receival of sewage water explains why the salinity in these saliñas was much lower compared to Cerca and Malmok and also why, especially Bubali, had much higher nutrient concentrations.

Figure 3.2 *The last remaining puddle of hypersaline water in Salina Cerca, just before it temporarily dried up completely mid-May, 2024. Evaporation of water results in increasing levels of contaminants as they simply become more concentrated.*

Malmok (location H) also had remarkable high nutrient concentrations, but this was mainly due to the fact that it had almost dried up, as can be deduced from its hypersalinity. Evaporation of water had resulted in a very concentrated value for the remaining contaminants (see also figure 3.2). To a lesser extent this was also observed for the other locations in Malmok and Cerca. Higher nutrients in these more natural saliñas may be explained by the presence of large numbers of (roosting) birds and contaminated run-off water coming from the urbanized areas. The water quality of these two saliñas in terms of nutrient concentrations was considered good at the time of the sampling. The processes of nitrification (a natural process where ammonia is converted to nitrate) appear to function in these wetlands but the process of denitrification remains largely hidden (in the sediments) and was difficult to register in the water samples. In productive

systems, it can indeed be observed that nutrients are rapidly removed from the water and are instead being stored in the primary producers (algae and vascular plants) and/or consumers (small invertebrates and/or fish).

Phosphate dynamics seem much simpler and suggests that most phosphate contamination in the semi-natural Malmok and Cerca is resolved due to mineralization before it reaches the wetlands. The effluent-fed wetlands Bubali, Palm Beach and Druif on the other hand show much higher concentrations of phosphate which is associated with the influx of raw sewage water.

Water quality standards depend on climate and location and for these reasons "universal water quality standards" do not exist (Vermeij et al, 2019). In Europe, phosphate levels such as those measured in Bubali would exceed the water quality criteria of the European Water Framework Directive (threshold at 0.14 mg/L; Van der Molen et al. 2006) with a factor 75 to 244[5]. As no water quality criteria for saliñas are available, the results of the monitoring were compared to small slightly brackish waters in the European Water Framework Directive (type M30; STOWA, 2018) in order to get a first indication of the water quality status of the saliñas.

Indirectly, the high nutrient concentration values for Bubali show that the capacity of the WTTP is insufficient for nutrient removal. Although the European Water Framework Directive is derived for European freshwaters, it nevertheless provides a first indication of the poor ecological status of Bubali surface water caused by excess nutrients. The dissolved oxygen levels corroborate the previous finding as DO levels are very low (range 60-120%; Van der Molen et al., 2006) and are indicative of a large oxygen demand due to breakdown processes of organic matter originating from the effluent.

All in all, and not surprisingly, the results indicate that in terms of nutrient overload the saliñas of Malmok and Cerca, which do not directly receive sewage effluent are the two remaining most natural saliñas.

3.3 Urbanisation, soil erosion and sedimentation

The extent of vegetation in the watersheds[6] can give an indication about the risk of soil erosion and sedimentation of the saliñas. The Western Wetlands watersheds have been assessed with the elevation-model of the ArcGis Hydrology toolbox. A land cover map (figure 3.4, Mücher et al., 2024) shows that the Western Wetlands are part of three separate watersheds (or water catchments, water basins). Saliña Druif lies within the smallest watershed of only 256.2 hectares (table 3.3). The saliña's Malmok and Cerca are part of a watershed of 767.8 hectares, while Bubali and Palm Beach lie in a watershed of 1292.4 hectares.

Strikingly, (much) less than half of the watersheds are covered with urban green or natural vegetation. More than half of each watershed is covered with built-up area or is bare or only sparsely vegetated. This lack of vegetation means that the water absorption and retention capacities are limited, and that large amounts of water and eroded sediment will drain off to the saliñas during the rainy season. The saliñas can therefore be considered sediment traps (figure 3.3).

The lack of natural vegetation within the watershed in combination with the silted saliñas, increases the chances of flooding during heavy downpours. The opposite is that the chances of flooding will decrease if the watershed is covered with more natural vegetation and sediment from the silted saliñas is being removed (and managed in the future with the placement of sediment traps). Removal of accumulated sediment can help restore former water coverage of saliñas which would be very beneficial to aquatic and avifaunal biodiversity. In addition, such measures can increase the water buffering capacity of such areas and help limit coastal flooding during the rainy season.

[5] Nutrient concentrations like these are not dangerous to human health in and of themselves.

[6] A watershed is defined as any surface area from which runoff resulting from rainfall is collected and drained through a common point, in this case a saliña. It is synonymous with a drainage basin or catchment area.

Table 3.3 *Land cover of the three Western Wetland watersheds.*

	Western Wetlands watersheds					
	Druif		Malmok/Cerca		Bubali/Palm beach	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Salina/wetland/fresh water	8.1	3.9	56.2	7.3	53.2	4.1
Built-up/road	34.4	16.6	307.6	40.1	509.0	39.4
Bare/sparsely vegetated	119.4	34.1	110.7	14.4	170.2	13.2
Urban or natural vegetation	94.2	45.4	293.3	38.2	560.0	43.3
Total	256.1	100.0	767.8	100.0	1292.4	100.0

Aruba has a rich archaeological past (Kelly and Hofman, 2019). For instance, the archaeological site of principal importance at Malmok, with over 60 archaic Amerindian burials dating from 1650-1300 BP is located ca. 200 to 300 m from the sea, on a lower terrace limestone formation covered with sandy soil and bordering the saliña. Kelly and Hofman (2019) list 33 mapped archaic sites for Aruba, of which Malmok is among the three most important[7]. Therefore, before any major soil or sediment-disturbing activities in these areas are carried out, an archaeological assessment or evaluation is recommended.

Figure 3.3 *At some places thick layers of sediment have accumulated in the saliñas. At this location in Malmok for instance a 1.75 m stick could be inserted completely into the sediment without hitting bedrock.*

[7] Aruba also has a wealth of ceramic-age prehistoric archaeological sites, the three most important of which are at Tanki Flip, Savaneta and Santa Cruz (Haviser and Hofman, 2015; Dijkhoff and Linville, 2004).

3.4 Ecological fragmentation

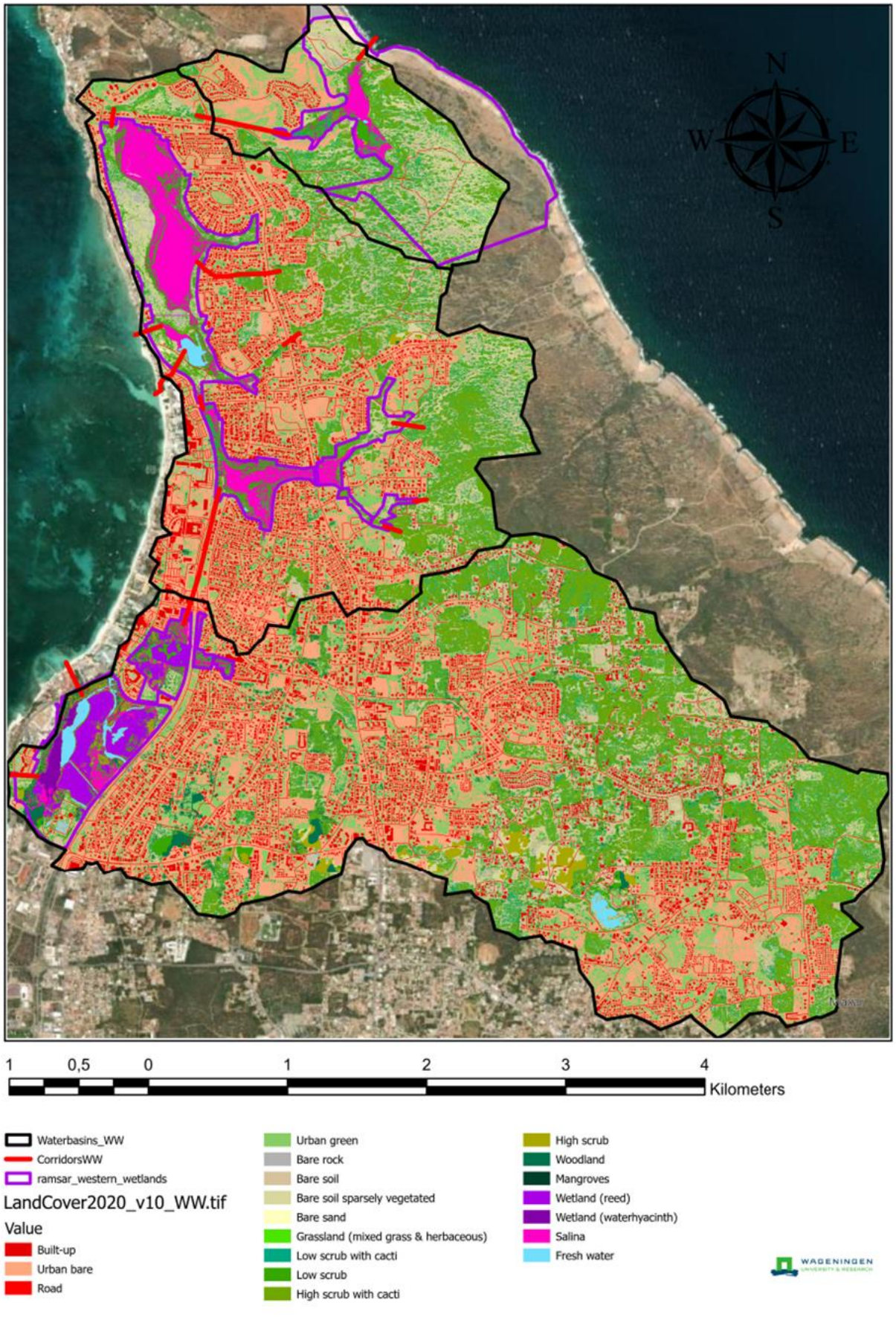

Figure 3.4 *Land cover map showing that the Western Wetlands are part of three watersheds (waterbasins).*

The Western Wetlands cover 392 hectares, which is a relatively small area to provide habitats for viable populations of all the associated species of flora and fauna. The fact that the saliñas are more or less separated from each other makes the situation for some of these species even more complicated (especially for those that cannot fly). This increases the risk of geographical isolation, also because the immediate surroundings of these saliñas are highly urbanised (figure 3.4).

The ecological fragmentation of the Western Wetlands needs further study but in the short to medium term a precautionary approach needs to be applied, based on what is known about the ecology and behaviour of certain species groups. For example, breeding passerines, such as warblers, need these ecological corridors when their young first leave the nest. They need to forage through areas of habitat that are not separated or fragmented by infrastructure, as the young at that stage in their life histories may not be able to traverse longer distances between habitats or may be vulnerable if they do, because of their poor flight or inexperience in avoiding predators.

While the autecology of specific Aruban lepidoptera is not yet known, it is well known that certain butterfly species can be confined to particular habitats by behavioural mechanisms and will not fly beyond them. The precautionary principle should therefore be applied here and, as far as possible, preserve the habitats that fringe the saliñas and seek to connect them (with similar habitat) where possible. Likewise, damselflies and dragonflies are often very habitat-specific when choosing territories and it's not known how mobile they are. Connecting habitats will potentially increase the chances of successful reproduction.

However, when doing so it is critical to avoid converting the two remaining semi-natural saliñas of Malmok and Cerca to freshwater sewage conditions. That would contaminate these saliñas with nutrients, destroy the natural dynamics and ecosystem of the saliñas.

Finally, the endangered and range-restricted Vesper Mouse (*Calomys hummelincki)* is a grassland species about which the distribution is not fully mapped (Bekker, 1996) but, again, is likely to benefit from ecosystem connectivity[8]. The grassy areas around the saliñas may serve an important function for this species.

3.5 Visitor impacts: disturbance and trampling

Visitor-use numbers of the saliñas are not available. This chapter only gives an impression of the use of the saliñas based on site visits in February and March 2024.

Present use of the saliñas by tourists or residents seems limited. Visitor facilities are limited as well. A bird watching tower is present in Bubali some 200 m from the entrance at the J.E. Irausquin Boulevard. The platform at the top of the tower offers a great view on the Bubali wetlands, though the tower might need maintenance or replacement by a newer version.

Palm Beach on the other side of the same boulevard seems a tranquil, natural area which probably does not attract many visitors. The same holds for Cerca. The site has some dirt tracks which are being used to cross the saliña between the L.G. Smith Boulevard and the residential area on the other side (figure 3.5). The irregular crossing of the saliña by visitors, whether tourists or residents, destroys vegetation and is a source of disturbance, especially for birds.

The southern point of saliña Malmok (Malmok 2, figure 3.1) seemed quite heavily trampled referring to the large amount of dirt tracks. The whole area is protected under the Nature conservation ordinance AB 2020 no. 67 and the Ramsar Convention, but approximately half of the area is dry land crisscrossed with dirt roads (figure 3.6). A shed from Skydive Aruba has been raised in the middle of the dry area. The black mangroves and shallow waters bordering the eastern edge of the wetland are often home to a substantial number of birds such as herons, spoonbills and waders. The site has the potential to become much more attractive for bird species if the 'dry area' is better protected and if nature development measures can be implemented.

[8] Pers. Comm. Gisbert Boekhoudt, 2023.

Dredging accumulated sediments to allow more coverage by the shallow groundwater table would automatically decrease present visitor use, while birding hides for bird watching might be raised to improve visitor experience and prevent disturbance.
The large northern part of Malmok still looks like a natural saliña, with a salt crust and hardly any dirt roads. Birding hides might be raised here as well to facilitate bird watching and simultaneously prevent disturbance.

Figure 3.5 *Dirt tracks are clearly visible in the approx. 70 m wide stretch of saliña Cerca between L.G. Smith Boulevard (left) and the residential area (right) (image from Google Earth).*

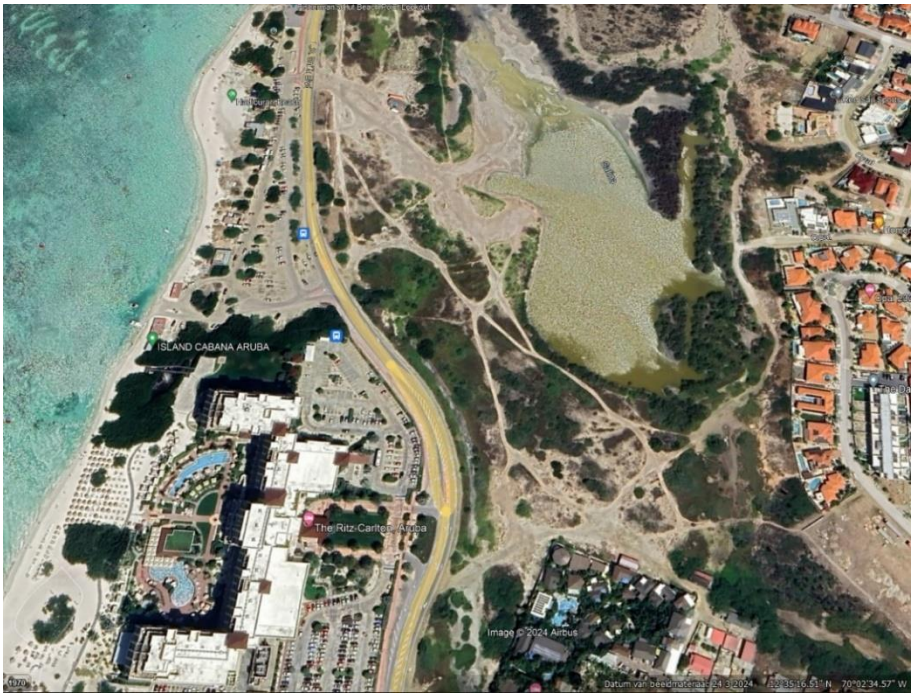

Figure 3.6 *The southern part of saliña Malmok, between the 'yellow' coloured L.G. Smith Boulevard in the middle and the residential area on the right, is crisscrossed with dirt roads (image from Google Earth).*

Druif, located in the Tierra del Sol golf course is a relatively tranquil area. Visitors to the area are nearly only golf players and green keepers. They drive around in golf carts, mainly on paved paths which is completely different from the ATVs and UTVs used by tourists on dirt roads just outside Tierra del Sol. The site seems to act as a relatively safe haven for many land and waterbird species, which are probably attracted to the lush green present due to irrigation. Many water and land birds species were observed during the visit in February and March 2024.

3.6 Invasive species

Invasive species pose a threat to native species as they may outcompete them. Small islands are particularly vulnerable to exotic species becoming invasive for multiple reasons. First of all, islands are small and harbour only small populations, resulting in a higher chance of species going extinct. Secondly, as islands are isolated, geneflow from neighbouring islands and mainland is restricted, resulting in a lower recolonization rate once a species has become extinct locally. Thirdly, Aruba, like many other small islands, imports large quantities of goods and receives many visitors from abroad, strongly increasing the risk of unwanted import of potentially invasive species. In addition, the many disturbed sites on Aruba offer niches for exotic plants to grow and establish. Lastly, knowledge on (potentially) invasive species is low and budgets to raise awareness and combat established invasives are limited, hampering a timely recognition and eradication of invasive species.
New introductions of exotic species occur frequently. Several of them are known to have become invasive in other regions, but not all become invasive on all sites. Several exotic species have become invasive on Aruba or have the potential to become so. A few are briefly discussed here to facilitate early recognition and swift mitigation. When observed and recognized early, eradication is often easy and does not require many resources.

3.6.1 Flora

A few individuals of the cacti *Cylindropuntia tunicata* were observed on the karst terrace east of saliña Cerca. Removing this handful of plants is still easy. Once establish and spread over the island, removing an invasive species completely is usually not feasible, illustrated by e.g. the Madagascar rubber vine, *Cryptostegia grandiflora*. Other species are present on several locations on Aruba, including sites in the Western Wetlands, but which have not yet formed massive stands, e.g. *Sesbania bispinosa* and *Euphorbia lactea*. Removal of such species from the Western Wetlands may still be possible.

Neem tree (*Azadirachta indica*) is native to the Indian subcontinent. It is widely planted in all (sub)tropical regions and has become invasive in many regions worldwide. It spreads rapidly and can outcompete other plant species with birds being the main vector to spread the numerous fruits. On Aruba, it grows mainly in urban areas, particularly in places that receive more water, e.g. in gardens and flower beds and along roads, where it receives extra rainwater due to run-off from the road. It can be found in the Western Wetlands occasionally, but has not formed dense stands yet. Open areas in Bubali and Palm Beach, which have a higher water table seem potential suitable areas.

Washingtonia robusta, the Mexican or Californian fan palm, is native to Mexico and the southwest of the United States. Is widely used in gardens and for public landscaping. On Aruba, similarly to neem tree, it grows mainly in moist places such as gardens, and along roads, where it receives extra rainwater due to run-off from the road. In Bubali, many large specimens of *Washingtonia robusta* are present and the presence of many seedlings and semi-adult plants illustrate the continuous spreading of this exotic species.

Ink berry (*Scaevola taccada*) is native to the coasts of Africa and Asia where it occurs in dunes. It's similar to the Caribbean native *Scaevola plumieri*, which on Aruba is only known from Boca Grandi. *S. taccada* is widely planted in gardens and public landscaping and is known from natural areas on several places on Aruba, including Savaneta coast and Boca Grandi. In the Western Wetlands, this invasive species was only observed in the dunes and adjacent terrace on the north coast around the entrance of Druif.

The true native origin of Water hyacinth (*Eichhornia crassipes*) is not exactly known. However, as this floating aquatic species requires fresh water, which naturally is not present on Aruba year-round, the species

is considered exotic for Aruba. This aquatic species prefers eutrophic conditions including (strongly) polluted waterways. The species is known to completely overgrow waterways, blocking all the light and obstructing the passage of boats. On Aruba, it's covering large surfaces in Bubali, profiting from the influx of hypertrophic, polluted wastewater. As permanent fresh water is scarce on Aruba, the risk for other areas on Aruba is limited but it has already established in some of the dams. Effective management strategies typically involve a combination of physical removal and biological control methods[9].

Eef Jansen van Stinapa:

Uniek natuurgebied loopt groot gevaar

ORANJESTAD — De plas bij de rioolzuivering te Bubali is een natuurgebied geworden dat international de aandacht trekt, aldus de heer Eef Jansen van de STINAPA Aruba in een gesprek met de Amigoe. Op de Benedenwindse eilanden is nergens een brakwaterplas te vinden van dergelijke omvang. Vele vogels vinden in dit gebied een rustige verblijfplaats. Nog onlangs bezocht een groep Duitse ornithologen dit gebied en was verbaasd op zo'n kleine oppervlakte zon grote verscheidenheid aan vogels te kunnen zien.

De steeds verder oprukkende waterhyacinth dreigt echter de plas volledig te gaan overdekken. De heer Eef Jansen zet daarbij uiteen dat we behalve het grote veld waterhyacinthen aan de zijde van Bubali momenteel langs de hele rand van de plas stukken vinden die al met waterhyacinth zijn begroeid. Binnen korte tijd - de heer Jansen schat binnen een jaar - zal de plas volledig overdekt zijn.

Reeds eerder heeft de Stinapa dit gevaar gesignaleerd en het BC besloot toen een aantal ,,werk" krachten van de tijdelijke arbeidsvoorziening in het zetten om het euvel te bestrijden. Als men wil zien wat het resultaat is van zes maanden werken moet men aan de zijde van Bubali maar eens gaan kijken. De Stinapa Aruba is van mening dat op deze wijze dit unieke Arubaanse natuurgebied zeker verloren zal gaan.

Amigoe. - (donderdag 28 december 1978), p. 5

Figure 3.7 *The invasive Water hyacinth covers large parts of Bubali and causes these problems already for some 50 years as this (Dutch language) news article from 1978 shows. Picture by Greg Peterson (Aruba Birdlife Conservation).*

In the Western Wetlands, the presence of most invasive species is still limited, being restricted to smaller patches particularly on the karst terraces. Aside from the widely spread aquatic Water hyacinth, removing most of the other invasive species from the saliñas still seems possible if carried out soon. Some species may not be fully eradicated, but their presence in the Western Wetlands may be restricted (containment), e.g. Neem tree and Madagascar rubber vine. Complete removal of Water hyacinth, some exotic grass species and herbs will not be feasible as they have become widespread and cover larger areas (figure 3.7).

3.6.2 Fauna

Buurt and Debrot (2012) stress the importance of recognising the role of the most significant alien species and eradicate or manage them. One of those species is the Red-eared slider (*Trachemys scripta* subsp. *elegans*) which is considered one of the world's worst invasive species (figure 3.8). It is a freshwater terrapin that is native to the Mississippi River Basin of North America. The species gets its name from the red stripe behind its eye, and its habit of sliding off rocks or logs into the water when it is startled. This species is highly adaptable and is able to tolerate slightly salty (brackish) conditions. Like all reptiles, Red-eared sliders are cold blooded, so they must pull themselves out of the ponds and bask in the sun to warm up their bodies so they can properly digest their food. Unfortunately, one of their preferred basking places is on top of the water level nests of wetland birds. Sliders are known to crush bird eggs in this way; they also have been

[9] https://dcnanature.org/invasive-water-hyacinth/?lang

known to eat the chicks. The precise impact of the introduction of Red-eared sliders on other pond species is not fully known. However, it is clear that with no predators to keep the population in check, the Red-eared sliders could be significantly upsetting the ecology of Aruba's saliñas[10].

The second invasive terrapin found in the saliñas in the Yellow-bellied slider (*Trachemys scripta* subsp. *scripta*), which is another opportunistic omnivore that is likely to impact a host of plant and animal species. It can hybridise with the Red-eared slider. Once established, both species are expensive to control and almost impossible to eliminate completely. This is currently the case, but in light of their likely impact, capture and control measures should be considered.

Figure 3.8 *Two invasive species from Bubali: a Boa constrictor eating a native Eared Dove (left) and Red-eared sliders (right). Pictures by Albert Peterson and Greg Peterson (Aruba Birdlife Conservation).*

The *Boa constrictor* (figure 3.8) has become an ever-present invasive species on Aruba that is particularly destructive to breeding birds such as the Aruba burrowing owl. It is also hard to control, but intensive removal of adults and sub-adults can help to control the populations.

Another invasive includes the poisonous Cane toad (*Rhinella marina*) which was introduced in Aruba in the early sixties and which feeds on almost every faunal species dead or alive which is smaller than itself (Van Buurt, 2001).

Other invasives include the Tilapia, *Oreochromis mossambicus*, a freshwater fish originally from Africa, introduced to Aruba for mosquito control, and which has managed to rapidly reproduce and dominate the local fresh- and brackish water habitats on the island. These fish can alter the local habitats, outcompete local species like several freshwater shrimp and fish species (Debrot 2003a, b) and generally disrupt the balance within these delicate ecosystems[11]. They are very difficult to control once established, electrofishing being one of the options, but they do provide food for fish predators such as the Osprey, *Pandion haliaetus.*

The impacts of feral dogs (*Canis familiaris*) and cats (*Felix domesticus*) is not known. The dog was widely present in the Caribbean during the pre-Colonial period (Masseti, 2001), and could also well have been present in small numbers on the islands centuries before discovery and settlement by Europeans. Nevertheless, today, the dogs present on the islands are numerous and fully derived from imported races. As active and roaming predators they form an important threat particularly to larger fauna (such as cottontails and land crabs on Aruba). Roaming dogs are also an important disturbance to ground-nesting birds (Debrot et al., 2009).

Feral cats are generally associated with man but can survive in the wild on their own. Cats can have major impact on endangered species. However, most cats impacting nature live in close association with man. Cats can be a key problem for ground-nesting seabirds (Madden et al. 2022, 2023). Eradication is difficult but local control is feasible and urgently needed near sensitive bird nesting areas.

[10] https://environment.bm/red-eared-slider
[11] https://dcnanature.org/invasive-tilapia/

3.7 Climate change

The Intergovernmental Panel on Climate Change (IPCC) have noted that small islands in the Caribbean are increasingly vulnerable to climate change impacts (Nurse et al., 2014). Aruba is part of the ABC islands that are part of the Leeward Antilles. For nearby Bonaire, the Dutch national weather service (KNMI, 2023) projects a rising temperature (1 to 3.5 degrees Celsius), increasing average windspeed and decreasing precipitation (0 to 40%), especially in the dry season (December – April). Climate change however, amplifies the atmospheric capacity to hold moisture, meaning that when rain does occur, it can come in heavy downpours resulting in flooding risks. In addition, the sea-level is expected to rise roughly between 30 and 130 cm for 2100 (KNMI, 2023). Centimeters of sea-level rise in combination with spring-tide, or hurricane related storm surge, may result in multiple meter surges leading to flooding of the saliñas, especially the low elevated Malmok (Verweij et al., *in prep*).

These combined impacts from climate change are likely to decrease the resilience of the saliñas, reducing their ability to provide essential ecosystem services such as storing carbon[12] (Adame & Lovelock, 2011; Osland et al., 2013; Howard et al., 2014), supporting biodiversity and acting as natural flood defences. Without adaptive management and protection measures (like management of the entire watershed and protection and restoration of coastal habitats e.g. coral reefs, seagrass beds and mangrove forests), climate change could drastically alter or even lead to the loss of many of Aruba's saliñas.

[12] Salinas can accumulate carbon in their sediments due to their periodic water coverage and limited oxygen, which slows down decomposition. However, they generally store less than other coastal wetlands like mangroves or seagrass meadows.

4 Vegetation and flora

4.1 Introduction

This chapter describes the vegetation and vascular plant species present in the Western Wetlands. A detailed vegetation map of the terrestrial parts of the Western Wetlands is presented for each of the five sites. The map is part of a larger vegetation map that also includes parts of the Ramsar sites labelled Southcoast and Spanish Lagoon (Janssen et al., in prep.).

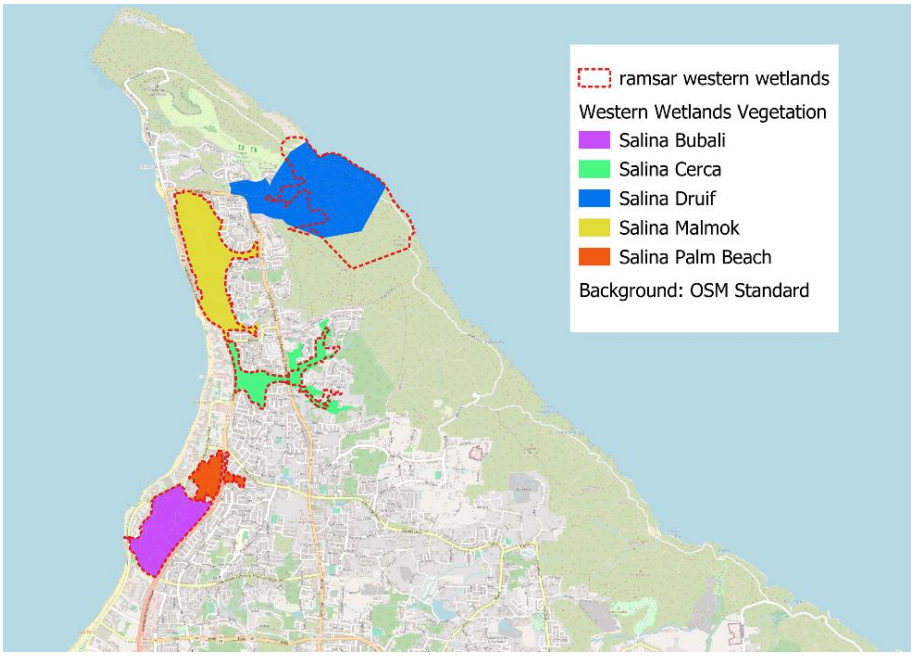

Figure 4.1 *Location of the mapped areas (colour) and the boundaries of the Western Wetlands Ramsar area (red dotted line). The boundaries of the mapped area and the Ramsar site differ slightly, as the vegetation mapping took place before the boundaries of the Ramsar site were formally established.*

Methods

The vegetation mapping took place in several stages. The basis data were a combination of (i) aerial images and (ii) field observations. A detailed false-colour satellite image was used (Pan-sharpened Worldview mosaic with 30 cm resolution, 21st of May 2020) together with World Imagery satellite images that are available in Q-GIS. Both sets of images were used to draw boundaries of the vegetation map (the spatial units of the map), based on visual interpretation of the images.

The delineated boundaries represent the borders of relatively homogeneous land units, which in the next paragraphs are described in terms of vegetation types. During field work within the delineated land units, the vegetation was described in several locations, by making standardized vegetation descriptions (relevés) in a plot. In these plots all plant species and their cover-abundance is recorded, according to the so-called Braun-Blanquet method (Westhoff & Van der Maarel, 1973). The relevés were clustered, resulting in vegetation types. These are the thematic units which are visualized on the provided map.

The vegetation types (the thematic units) were assigned to the map units (the spatial units) by visual photo interpretation. In cases of heterogeneous map units, a maximum of three vegetation types were assigned to each map unit, with a cover of at least 5%.

Throughout the field work, the presence of vascular plant species was documented. This was done by taking images and GPS coordinates of the observed plant. In the case of an observed presence of a species so far not known from the area itself or from Aruba, herbarium specimens were collected. For each of the five sites, a list of species previously documented was queried from the CACTUS database (Janssen et al., 2023). The CACTUS database contains all vegetation relevés, as well as most other plant occurrence observations from the six Dutch Caribbean islands and provides the most complete database on plant species distribution in the Dutch Caribbean.

4.2 Vegetation typology

By classification of the vegetation relevés vegetation types were constructed, which form the thematic units of the vegetation map we developed. The vegetation types were grouped into eight main groups ("formations"):

- Aquatic vegetation (A)
- Helophytic vegetation (He)
- Saliña vegetation (S)
- Mangrove (M)
- Dune vegetation (D)
- Pioneer vegetation on limestone (P)
- Grassland (G)
- Forest and high scrub (F)

The vegetation types in these groups that occur in the five saliñas are described here in detail. Vegetation types classified from the survey are given as they almost all occur within the boundaries of the Western Wetland saliñas. Note that for ease of reference, the numbering of the vegetation types aligns with the numbering used in the larger vegetation map (Janssen et al., in prep.) that includes some types not present in the Western Wetlands.

Besides these vegetation types, the following additional classes were mapped:
A0 = water (unvegetated)
D0 = bare dune
M0 = dead mangrove
X0 = bare soil
X1 = built up area (incl. gardens of houses and golf court greens)

4.2.1 Aquatic vegetation

A2. Ruppia maritima-type
This type is completely dominated by *Ruppia maritima*, which in many cases is the only plant species present. The vegetation is found in brackish water, often in places in which the salt content of the water fluctuates strongly throughout the year, from relatively fresh in periods with a lot of rain, towards strongly saline in dry periods. This species can tolerate moderate salinity fluctuations (La Peyre and Rowe, 2003), but is dependent on high salinities for proper seed germination (Strasizar et al., 2013). *Ruppia* sometimes is considered to be a seagrass, and therefore it is a protected species under the SPAW Annex III. Within the vegetation map, this type occurs mainly in saliña Cerca (figure 4.2) and a few locations in Malmok. The size and exact location of the type may fluctuate between years, depending on water table, water quality and weather. The type is not indicated in the map legend as it only covers small parts (less than 20%) of the mapped units it is only given in the GIS-file.

A3. Eichhornia crassipes-type
This is a vegetation of floating aquatic plants, completely dominated by Water hyacinth, *Eichhornia crassipes*. It is unclear whether the species is native to Aruba, but it seems unlikely. Water hyacinth grows in nutrient-rich water including polluted water, an environment originally not available on the island. It may have reached the island spontaneously (via waterbirds) or it may have escaped to nature from ponds in urban areas. The type dominates the water bodies of the heavily polluted saliña Bubali. In the past these water bodies also had a plant community dominated by Water lettuce (*Pistia stratiotes*) (see Van Proosdij, 2012, picture 018 [13]), but during field work this species was not recorded. It may be that in saliña Bubali, Water lettuce, which also depends on relatively nutrient-rich water, has been completely out-competed by Water hyacinth in the intervening years.

Figure 4.2 *Ruppia maritima vegetation in saliña Cerca. Picture by John Janssen.*

A4. Ipomoea aquatica-type
This is another community of floating non-native water plants, in this case *Ipomoea aquatica*. The species was newly recorded in nature for Aruba in 2023. *Ipomoea aquatica* is used as an ornamental plant in ponds and as a food plant. It is assumed to have escaped from cultivated sources. This vegetation type is found in small patches in saliña Druif, especially on the golf course of Tierra del Sol, but also in a small pool south of the actual saliña. Additionally, it was recorded in saliña Palm Beach. The type is not indicated in the map legend as it only covers small parts (less than 20%) of the mapped units it is only given in the GIS-file.

A5. Lemna valdiviana-type
This next species-poor water plant community is dominated by floating duck weed species, specific *Lemna valdiviana*. The Flora of Aruba, Bonaire and Curaçao (Van Proosdij, 2012) lists only one species of duck weed, namely *Lemna aequinoctialis*, but at least four species have been recorded in the last few years for these three islands, according to the identification key of Bog et al. (2020). The type is found in saliña Palm Beach and saliña Bubali in small sites that can be hardly mapped on the applied scale. As it only covers small parts (less than 20%) of the mapped units it is only given in the GIS-file.

4.2.2 Helophytic vegetation

He1. Typha domingensis-type
This is a vegetation dominated by the tall helophyte *Typha domingensis*, which grows in nutrient-rich, wet conditions. It dominates large areas of the strongly polluted saliña Bubali, where it forms dense and extremely species-poor stands (figure 4.3).

[13] Note that the plant names on that page in Van Proosdij (2012) have been mixed up: the top photo represents *Pistia stratiotes*.

He2. Eleocharis mutata-type

One of the first relatively tall helohytes that is able to grow in the brackish saliñas of Aruba is *Eleocharis mutata*. The species often forms small fields, that are relatively widespread in saliña Malmok, saliña Cerca, saliña Druif and saliña Palm Beach. In saliña Druif and Palm Beach it covers relatively large areas. The type seems to prefer brackish water (saliña Malmok, saliña Cerca, saliña Druif) but it also was found in the fresh water of saliña Bubali, but mainly in the north-east corner, where the water from saliña Palm Beach enters the area and is not yet heavily polluted.

Figure 4.3 *Typha domingensis-vegetation (H1) along a pool in saliña Palm Beach. Picture by John Janssen.*

He3. Eclipta prostrata-Stemodia maritima-type

This type consists of a mixture of tall herb communities in wetlands. In most sites the vegetation is a mixture of perennial and annual species. The exact species composition varies between sites, with both grasses and herbs as dominant species; some sites are relatively species-poor, while others are much more diverse. Some of the taller herbs and sedges that may dominate include *Neptunia plena, Cyperus ligularis, Ludwigia erecta, Ludwigia octovalvis, Phyla nodiflora* and *Stemodia maritima*, while in other places, smaller annual species have the highest cover, e.g. *Eclipta prostrata*. Other characteristic wetland-species in this type are *Urochloa reptans, Cyperus confertus, Amaranthus dubius, Cyperus oxylepis, Echinochloa colona, Cyperus surinamensis* (which was not known before from Aruba), *Eleocharis geniculata* and *Lindernia dubia* (also previously unknown from Aruba). In some plots, the tree species *Prosopis juliflora* has a high cover, but in that case the vegetation describes the edge of the wetlands, and the tree is hanging over the wetland-community. The type is found mainly in deep, sedimentary soils with strongly fluctuating water tables, ranging from deeply inundated after periods of rain, towards completely desiccated in dry periods. It has been mapped in small pools near saliña Druif. Outside the Western Wetlands this type is found in other small places all over the island, typically in tankis (man-made well) and at the bottom of dry riverbeds ("rooi").

4.2.3 Saliña vegetation

S1. Batis maritima-type

This is a low, species-poor vegetation dominated by the succulent halophyte *Batis maritima* (Saltwort or Turtleweed), which usually forms closed swards. In one site *Salicornia ambigua* is dominant in this type. This type is found on saline, wet and muddy soils, occupying the lowest zonation belt of the three salina types, listed here. On Aruba this type is widespread on brackish and saline sites in natural or slightly disturbed saliñas, including saliña Cerca, saliña Malmok and saliña Druif.

S2. Sesuvium portulacastrum-type
This is another low and species-poor vegetation of brackish conditions, in this case dominated by the succulent halophyte *Sesuvium portulacastrum* (Sea purslane). The vegetation occupies a zonation belt slightly higher than type S1. In most saliñas it occupies smaller areas than type S1. This vegetation is usually found on sandier or even (inundated) rocky sites. It is more common in other parts of the island.

S3. Sporobolus virginicus-type
The third species-poor salina-type is dominated by the spreading grass *Sporobolus virginicus* and can be represented by two subtypes. The first subtype, S3a consists of closed swards that are usually low, but under relatively eutrophic conditions may form up to one-meter-high hummocks (figure 4.4). This subtype is found higher in the zonation than the previous two salina-types and is bordered by shrubland (with *Prosopis, Vachellia* and/or *Conocarpus*) or pioneer vegetation on limestone. In this subtype S3a with closed swards, *Sporobolus virginus* typically has a cover of 75 to 100%. On the north coast, on the low limestone terraces, subtype S3b is found. This second subtype is a much more open vegetation, in which *Sporobolus virginicus* is the dominant species, but rarely has a high cover. Subtype S3b is found in places on the terrace with stagnant rainwater. The closed swards of *Sporobolus virginus* (subtype S3a) are found in all saliñas, whereas subtype S3b occurs in the coastal area of saliña Druif.

Figure 4.4 *Undulating swards of Sporobolus virginicus-vegetation in moist and brackish shores of saliña Druif, forming a mosaic with patches of Eleocharis mutata. Picture by John Janssen.*

4.2.4 Mangrove

All mangrove species are protected species under local law (AB 1995 no. 2, Art 4./AB 2017 no. 48) and of the SPAW Annex III[14]. Vegetation type *M1. Rhizophora mangle-type* can be found in the Ramsar Sites Southcoast and Spanish Lagoon but not within the Western Wetlands (Janssen et al., in prep.).

M2. Laguncularia racemosa-type
In the coastal mangroves the White mangrove *Laguncularia racemosa* (note that also *Conocarpus erectus* is sometimes referred to as White mangrove) is the thrid in the zonation belt, after the Red mangrove (*Rhizophora mangle*) and the Black mangrove (*Avicennia germinans)*. *Languncularia racemosa* forms a

[14] The SPAW protocol is a regional agreement for the protection and sustainable use of coastal and marine biodiversity in the Wider Caribbean Region and is part of the Cartagena Convention (Convention for the protection and development of marine environment in the Wider Caribbean Region). It has been ratified by the Kingdom of the Netherlands, which includes Aruba.

vegetation type in which all other mangrove species occur and incidentally may co-dominate. On relative open stands, *Batis maritima* may dominate the understory. Towards the land the type is bordered by *Conocarpus erectus* dominated mangrove or shrubland with *Coccoloba uvifera* and/or *Prosopis juliflora*. The mixed mangroves in which *Laguncularia* dominates, is mainly found along the south-coast and on the coastal islands, but a small patch is present in saliña Malmok.

M3. Avicennia germinans-type
The Black mangrove (*Avicennia germinans*) with the conspicuous air roots (pneumatophores) dominates the vegetation of relatively sheltered parts of the mangroves, where salt content of the soil may fluctuate strongly due to precipitation and evaporation. The largest area of this type is found in Spanish Lagoon (Spaans Lagoen), but smaller stands of this type are found at the south-side of saliña Malmok.

M4. Conocarpus erectus-Vachellia tortuosa-type
The fourth type of mangrove is dominated by Buttonwood (*Conocarpus erectus*), sometimes confusingly also called White mangrove. This type is the most inland and driest parts of mangroves but occurs also in other brackish sites along saliñas and in dry riverbeds ("rooi"). The species has a much broader ecological tolerance than the dominant species of the previous three mangrove types, and therefore the tree layer of this type also contains tree species of dry, inland habitats, e.g., *Vachellia tortuosa* and *Prosopis juliflora*. In the map we distinguish a variety M4a of this type, in which *Conocarpus erectus* is dominant, but forms a relatively low and open scrubland. The type is widespread in saliña Bubali and saliña Malmok, while it is rare in saliña Druif and saliña Cerca. The variety with low, open *Conocarpus*-stands is restricted to saliña Malmok.

4.2.5 Dune vegetation

D1. Mallotonia gnaphalodes-Euphorbia mesembryanthemifolia-type
This is a somewhat heterogeneous type, forming a mixture of dune grassland and low dune scrub. It is characterized by the combination of the grass *Paspalum vaginatum*, the herb *Ipomoea pes-caprae*, and the shrubs *Euphorbia mesembryanthemifolia, Suriana maritima, Scaevola taccada, Coccoloba uvifera* and *Mallotonia gnaphalodes*. Within the Western Wetlands this type is only found at the mouth (boca) of saliña Druif.

4.2.6 Pioneer vegetation on limestone

P1. Sesuvium curassavicum-type
This species-poor type resembles the next type P2, but is differentiated by the name-giving species, and the extremely low number of species. *Sesuvium curassavicum* is a species that only recently has been described as an endemic species of the islands Aruba, Bonaire and Curaçao (Sukhorukov et al., 2021). On all three islands the species is mainly found on the first limestone plateau, close to the sea, where the vegetation is strongly influenced by salt spray. In the mapped areas this type was only found at the limestone coast of saliña Druif. It is also present in other parts of the island. Note that *Sesuvium curassavicum* was not recorded within the boundaries of the Western Wetlands, although observed several times on other locations with the same vegetation type.

P2. Lithophila muscoides-Euphorbia thymifolia-type
This is a rather species-poor and open pioneer vegetation on limestone, characterized by the combination of *Lithophila muscoides, Euphorbia thymifolia* and *Sporobolus pyramidatus*. Additionally, *Sesuvium portulacastrum, Fimbristylis cymosa* and *Sporobolus virginicus* may be present, although these species are not dominant. This type is mainly found on the lowest limestone terraces of the north coast, including the terrace at saliña Druif. In the western parts of saliña Malmok it forms a transition towards the *Bouteloua repens*-grassland (type G2).

P3. Sporobolus pyramidatus-Lithophila muscoides- Fimbristylis cymosa-type
A much species-richer, and more closed vegetation containing pioneer species. Species present are those of type P2, as well as several out of the following species: *Heliotropium curassavicum, Trianthema portulacastrum, Evolvulus convolvuloides, Corchorus hirsutus, Antephora hermaphrodita, Tephrosia cinerea, Dactyloctenium aegyptium, Portulaca halimoides* and *Desmanthus virgatus*. This pioneer community was

found more inland on limestone rocks. It is widespread in the mapped area, occurring on the edges of saliña Cerca, saliña Bubali and Saliña Palm Beach, and on the north coast of saliña Druif. The vegetation development on the karst areas of the limestone bedrock is very low, especially in places where trampling or grazing takes place. Therefore, also this community may be considered a long-lasting pioneer community.

4.2.7 Grassland

G1. Bouteloua repens-Aristida adscensionis-type
This type represents relatively open swards dominated by the grass *Bouteloua repens*, in most cases accompanied by *Aristida adscensionis*. In one relevé the latter grass is the only dominant species. This type contains many rather common herb species and juvenile plants of shrub species as accompanying species, including *Vachellia tortuosa*. Characteristic is the high presence of *Melocactus* plants, mainly *Melocactus macracanthos* but also *M. stramineus*. Several small herbs are mainly found in this type, including *Marsypianthes chamaedrys, Diodella apiculata, Pectis linearis, Pectis linifolia* and *Croton ovalifolius*. This type typically was found on open volcanic rocks, often on south-exposed, sunny slopes. Succession of the vegetation into scrub and open forest is probably prevented by intensive grazing, strong winds and erosion. In the mapped areas it occurred in the hills east of saliña Druif.

G2. Cenchrus ciliaris-Chloris virgata-type
This rather species-poor type is dominated by the grass *Cenchrus ciliaris*. Few other species are found, but some shrubs may grow between the grass-dominated patches and slowly overgrow this type, including e.g. *Vachellia tortuosa* and *Prosopis juliflora*. This type represents ruderal vegetation and is found in disturbed sites, often next to urban areas and other built-up sites, for example on the edges of saliña Cerca, saliña Malmok and saliña Bubali.

4.2.8 Forest and high scrub

F1 Prosopis juliflora-type
This is a high scrub/low forest type dominated by *Prosopis juliflora*. The type has many understory and scrub species in common with the next forest type, which is dominated by *Vachellia tortuosa*, and in some places it is hard to distinguish both types. Accompanying species often present, include *Guaiacum officinale, Stenocereus griseus, Cereus repandus, Opuntia caracassana, Passiflora foetida, Rhynchosia minima, Cenchrus ciliaris* and *Lantana camara*. The type is widespread on the island, growing on less dry sites than the next type (F2). In the mapped areas it was found amongst others at saliña Druif.

F2. Vachellia tortuosa-type
This is a high scrub/low forest type with dominance of *Vachellia (Acacia) tortuosa*, distinguishing it from the previous type dominated by *Prosopis juliflora*. The understory is very similar to that of type F1. This type generally grows in more dry conditions and is widespread on the island. Within the Western Wetlands it is common along the edges of all saliñas, and it is the main type on the volcanic hills south of saliña Druif.

4.3 Vegetation maps

In this paragraph generalized vegetation maps of the different saliñas within the Western Wetlands are provided. Only the one or two most dominant type(s) in each map unit are indicated in the map. In the GIS-file of the vegetation map, more detailed information can be found. For each map unit, a maximum of three vegetation types is presented, all with percentages cover within the map unit.

4.3.1 Saliña Druif

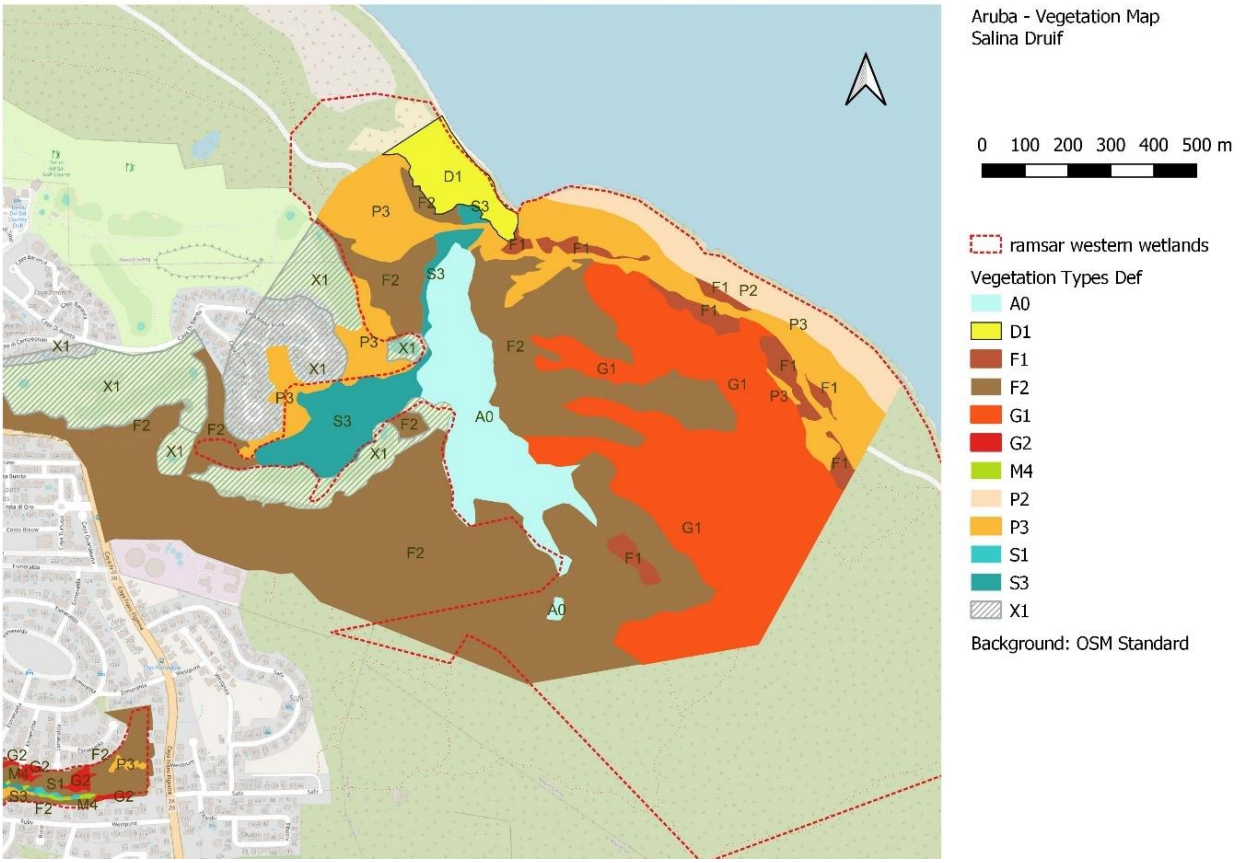

Figure 4.5 *Vegetation map of saliña Druif.*

Saliña Druif (figure 4.5) consists of a slightly degraded wetland, with indications of eutrophication (illustrated by the occurrence of the *Lemna valdiviana*-type A5), but also rather extended patches of *Sporobolus virginicus* and *Sesuvium portulacastrum* vegetation. Along the entrance of the saliña, dry coastal dune vegetation is found, which is a relatively rare ecosystem of the Leeward Islands. On Aruba larger patches of coastal dunes occur in the Westpoint Ramsar site (Arashi dunes) and at Boca Grandi. The dry parts south and east of saliña Druif are covered by a mosaic of open grassland (type G1) and shrubland (F2), with limestone pioneer communities at the coast. Most parts of saliña Druif are heavily overgrazed by free-roaming goats.

4.3.2 Saliña Malmok

Saliña Malmok (figure 4.6) is one of the two (relatively) well-preserved saline saliñas on the island and consists largely of a shallow wetland with gradual transitions towards grassland and shrubby vegetation on the shores and edges. Especially the eastern edge is relatively disturbed by human impact from the adjacent built-up area, with several constructions reaching into the saliña. The amount of well-developed, low saliña vegetation is high, also if compared to the islands Bonaire and Curaçao. *Ruppia maritima*-vegetation (type A2) is present on a few locations. As this type is rare on Aruba, it's presence on saliña Malmok is important. Also, the mangrove patches of *Avicennia germinans* (type M3) are of interest, as such mangroves are further only found at Spanish Lagoon.

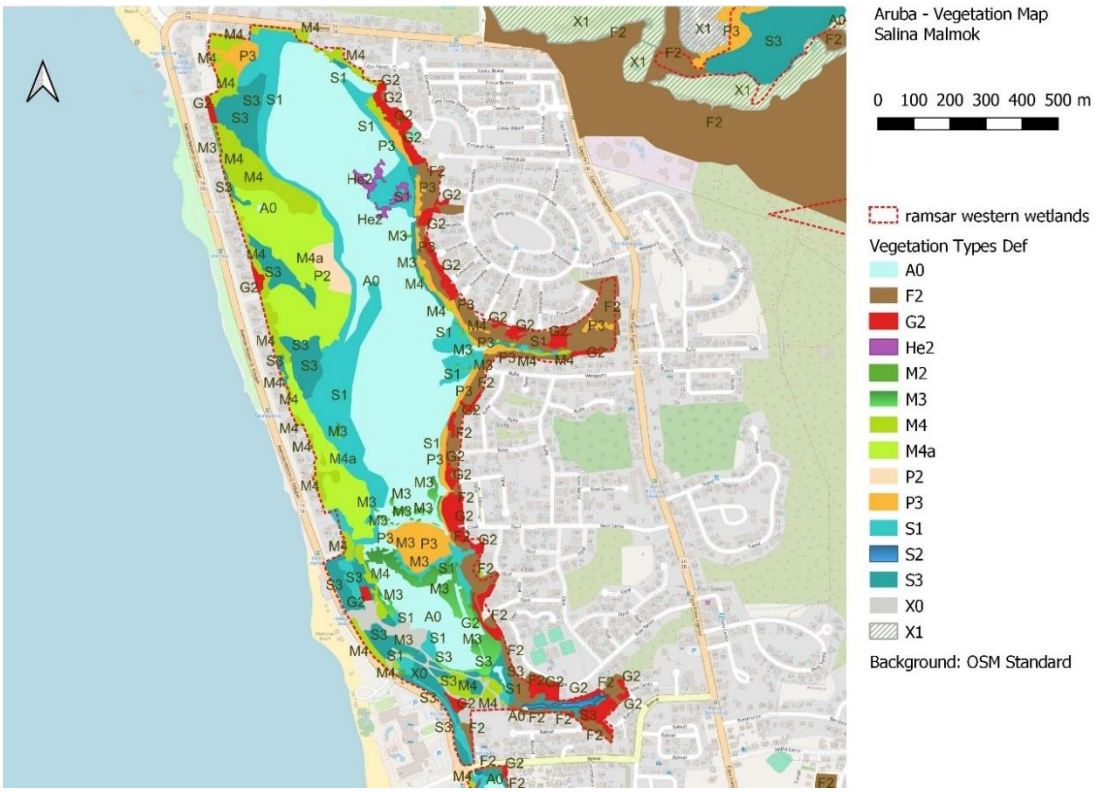

Figure 4.6 *Vegetation map of saliña Malmok.*

4.3.3 Saliña Cerca

Saliña Cerca (figure 4.7) is the second (relatively) well-preserved saline saliña on the island. Similar to saliña Malmok, it also consists largely of a shallow water body with gradual transitions from low wetland vegetation towards grassland and shrubby vegetation on the shores and edges. Also here, the eastern edge is disturbed by human impact from the adjacent built-up area and even constructions built into the saliña. Similarly, the catchment area to the east is rather disturbed, being enclosed by the surrounding buildings. The amount of well-developed low saliña vegetation is high, similar to saliña Malmok. The rare *Ruppia maritima*-vegetation (type A2) is here more widespread than in saliña Malmok.

4.3.4 Saliña Bubali and saliña Palm Beach

Saliña Bubali and saliña Palm Beach (figure 4.8) are the most disturbed saliñas of the Western Wetlands. By far the most important source of disturbance is the uncontrolled influx of large quantities of heavily nutrient-enriched and polluted water into Bubali originating from the neighbouring, malfunctioning Bubali WWTP. The result of this continuous influx of wastewater is the presence of a freshwater lake (Bubaliplas), which is atypical for a dry Caribbean island. The hyper-rich water feeds massive fields of tall helophytes and water bodies overgrown with Water hyacinth (*Eichhornia crassipes*). The edges, transitioning to the higher limestone terrace are covered mostly with high *Conocarpus* associated mangroves.

In general, saliña Palm Beach is slightly more diverse, but it is also much smaller, and more strongly disturbed by human impact from the surrounding buildings and roads. It is slightly higher elevated than Bubali and water is therefore actively pumped into Palm Beach to prevent Bubali from overflowing.

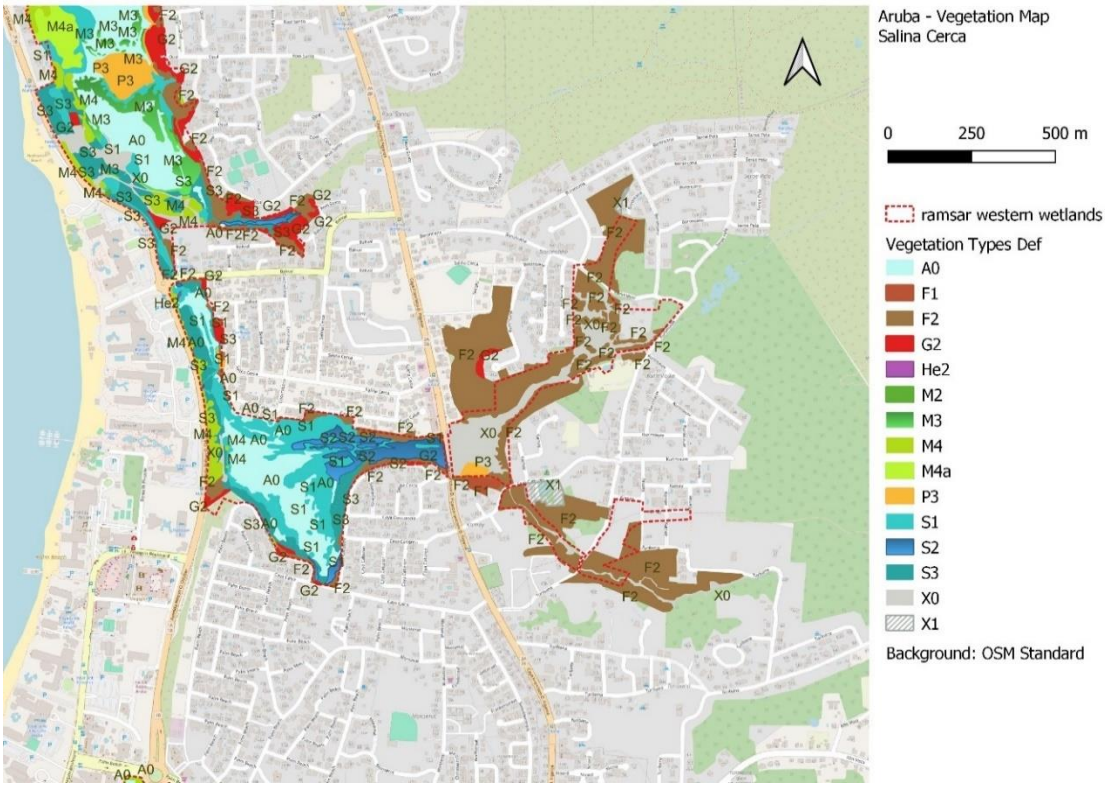

Figure 4.7 *Vegetation map of saliña Cerca.*

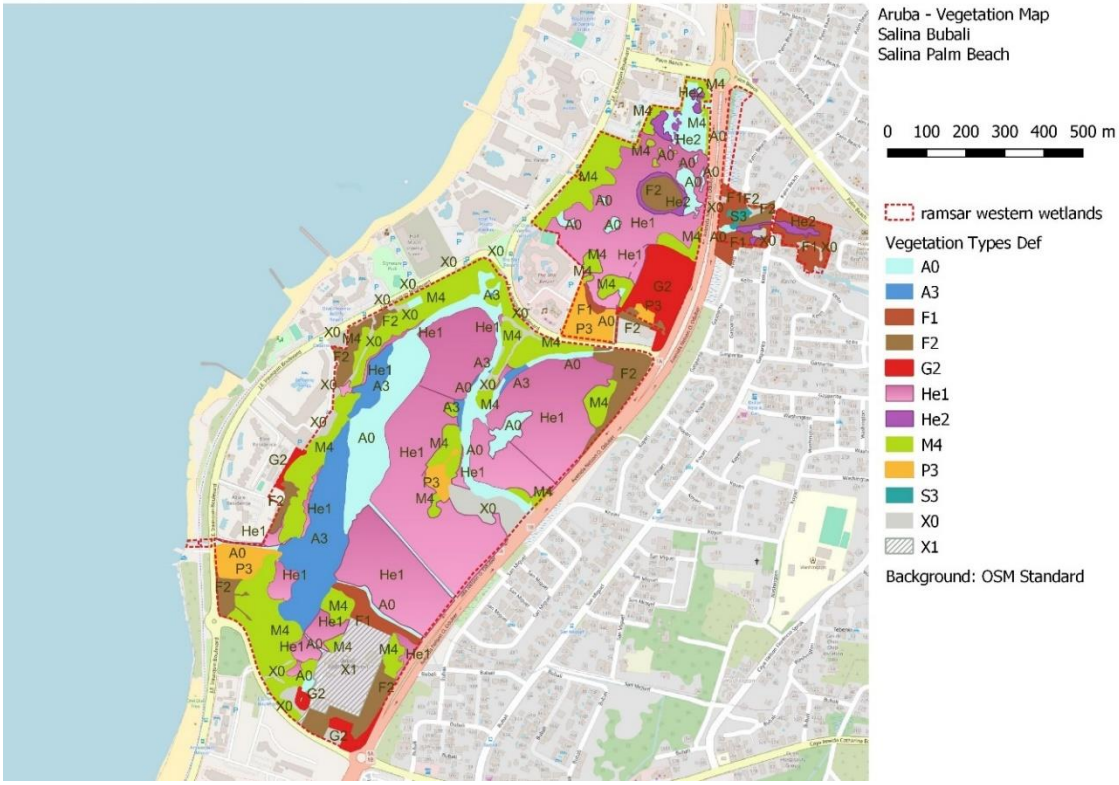

Figure 4.8 *Vegetation map of saliña Palm Beach (north) and saliña Bubali (south).*

4.4 Flora

4.4.1 Recorded plant species

A total of 178 vascular plant species was recorded for the Western Wetlands during site visits for the vegetation mapping. A full list is presented in Annex 1. Most recorded plant species were known from Aruba previously, based on records in the CACTUS database and the Flora of Aruba, Bonaire and Curaçao (Van Proosdij, 2012). Additionally, 32 species were recorded that until then were not known or documented for Aruba, although some have been cultivated in gardens for a long time. Knowledge on the distribution of plant species on Aruba is limited, particularly for the Western Wetlands as these were not included in the landscape ecological vegetation map of Aruba (De Freitas et al., 2024).

12 plant species present in the Western Wetlands are listed on the Aruban protected species list (Landsbesluit 2017 no. 48). These species are locally protected due to their rareness, endemism and/or ecological importance. In addition, a small number of species is listed on the SPAW Annex III. The SPAW protocol is a regional agreement for the protection and sustainable use of coastal and marine biodiversity in the Wider Caribbean Region and is part of the Cartagena Convention (Convention for the protection and development of marine environment in the Wider Caribbean Region). It has been ratified by the Kingdom of the Netherlands (thereby including Aruba).

Cacti form a major component of the Aruban flora and several species are present in the Western Wetlands. The columnar cacti *Cereus repandus, Stenocereus griseus* and *Pilosocereus lanuginosus* are key nectar sources for several bat species. Barrel cacti on Aruba comprise four species, all of them endemic to either Aruba alone or the ABC islands. The Western Wetlands host substantial numbers of columnar cacti and endemic barrel cacti of the species *Melocactus macracanthos* and *M. stramineus*. Two species of prickly pear cactus are listed on the Aruban list of protected species: *Opuntia caracassana* and *O. curassavica*. *O. curassavica* is a (near-)endemic species of which the distribution outside the ABC islands is limited. In sharp contrast, *O. caracassana* is the most common species of Aruba. In the Western Wetlands, all cacti are restricted to the karst terraces on the edges of saliñas Malmok, Cerca and Druif, as well as the hills east and south of Druif. Smaller numbers occur in saliña Bubali and Palm Beach. *Ruppia maritima*, one of the seagrass species, is listed on the SPAW Annex III and on the list of locally protected species. This species is present in saliña Cerca (see 4.2 type A2) and (very limited) in Malmok. *Ruppia* is rare on Aruba, which is mainly due to the lack of suitable environment for this saline aquatic species. *Sesuvium portulacastrum* is listed on the Aruban protected species list, as this species plays an important role in the coastal vegetation on coastal cliffs and terraces, as well as saliñas.

All mangrove species on Aruba are protected based on their listing on the Aruban protected species list. These are listed on the SPAW Annex III as well and include *Avicennia germinans*, *Conocarpus erectus, Laguncularia racemosa* and *Rhizophora mangle*, of which the first three are present in the Western Wetlands. These species play a key role in protecting the coast against ocean waves and erosion, preventing run-off of sediments into the ocean as well as providing a habitat for many birds, fish and terrestrial and marine invertebrate species.

In summary, the Western Wetlands harbour a large number of vascular plant species including several species that are protected by Aruban law and some listed on the SPAW Annex III. Some of these species are endemic for Aruba or the ABC islands. As such, the Western Wetlands play an important role in safeguarding the long-term survival of these species.

5 Birds and other fauna

5.1 Introduction

The diversity of habitats offered by the different saliñas is of particular value to the breeding and migratory birds of Aruba. Citizen science data available at eBird[15] provide an overview of the avian diversity per saliña (Annex 2). The bird community has never scientifically-sound been monitored however, so that year-round bird numbers are not available.

Most species have been observed in Bubali, but this is probably simply due to the fact that this site has a watch tower which facilitates bird watching. To date citizen-science data reveal that 216 native species have (ir)regularly been observed in the Western Wetlands (Annex 2) as well as 27 non-native species which are considered vagrants or escaped pets (e.g. waterfowl, parakeets, parrots).

During the assessment of the water quality §3.2, also water samples with cast nets and sweep nets were taken and the sediment was analysed on the presence of crab holes, all in order to get an indication of the presence of staple food for birds, such as crabs, fish and invertebrates. At each location, 4 to 6 throws with the cast net were deployed for fish collection. In addition, 4 to 6 sweeps per location were performed to collect the aquatic invertebrates present. Each individual sweep comprised a trajectory of approximately 4 to 6 meter. The fish collected were identified on site using a small aquarium and/or plastic tray. Invertebrate samples were deposited in the plastic tray and invertebrates were collected, identified on sight and counted manually. Crab holes were counted in a 1 m² which was bordered with a simple rope[16].

This chapter starts with a description of the presence of these staple food species and ends with 'other species'. Much more research is necessary though to get a full picture of the value of the Western Wetlands for birds and other fauna groups.

5.2 Food species for birds

All of the saliñas have value for fish and aquatic invertebrates, most of which provide food for foraging bird species (figure 5.1).

Notwithstanding the relatively high nutrient concentrations (see §3.2), Bubali is the only one of the five wetland areas that has dense permanent populations of large fishes (such as Tilapia and Tarpon) year-round. These are extremely hardy fish capable of dealing with low oxygen concentrations. In addition, the availability of huge amounts of nutrients has boosted the growth of reeds (*Typha domingensis*) and the invasive Water hyacinth (*Eichhornia crassipes*) making the saliña completely inaccessible due to excess vegetation, which also increases the chance of fire hazards during periods of drought[17]. The high concentrations of Tilapia, and large fish in Bubali, is also possible because of the low salinity of these waters and the dependable presence of water depth which is a basic requirement for fish life.

At the time of the measurements, Palm Beach only held a little water and was completely overgrown with vegetation. As a result, no further sampling could take place neither in the water or the sediment.

Salina Druif was not overgrown and was best described as a relatively large open waterbody. Although nutrient levels were much lower in saliña Druif (see §3.2) compared to Bubali, oxygen levels were still low.

[15] https://ebird.org/

[16] The assessment of aquatic fauna is part of a more detailed study across the seasons and the results will be published accordingly. Monitoring protocols have been developed for this purpose.

[17] The most recent wetlands fire took place on 10 September 2018 when 24% of the surface of Bubali burnt to the ground. https://www.visitaruba.com/news/events/aruba-left-devastated-after-bubali-bird-sanctuary-catches-fire/

Sampling of the invertebrate community showed that both chironomid larvae and water boatmen (small corixids) were abundantly present. In addition, several exuviae (cast-off outer skins of emerged dragonflies) were found in the grass and the ground was speckled with holes of small Fiddler crabs (*Uca* spec.). Neither sweep net nor cast-net sampling resulted in any fish being caught in saliña Druif. This was probably due to the fact that salina Druif has occasionally been cut off from the Bubali-effluent in the past-years due to a dispute between the property owner and the government, with the salina drying-out completely seasonally.

Figure 5.1 *Birds feeding on 'other fauna' in the Western Wetlands. From top-left 'around the clock': Pied-billed grebes with a dragonfly larvae; Black-bellied plover with a crab; Osprey with a Tilapia; Roseate spoonbill with a small fish; Purple gallinule with a frog; Great egret with a dragonfly larvae. Pictures by Albert Peterson and Greg Peterson (Aruba Birdlife Conservation).*

Malmok actually consists of two very different wetland areas: a large saliña which dries up (figure 3.1 location H) and a shallow area which consistently has water (figure 3.1 location G). Location H was already drying up rapidly during February/March 2024, resulting in a hypersaline environment. Due to its vicinity to the sea, storms can occasionally sweep seawater into the saliña, which after evaporating leaves the salt

behind. Over several years, this has resulted in the hostile brine conditions currently observed here. Remarkably, no Brine flies (*Ephydra salina*) or Brine shrimp (*Artemia salina*) were documented from Malmok. Although the banks of the saliña do contain holes of Fiddler crabs (up to 500 m²), no other invertebrates or fish have been observed here. This makes this area a rather unique location.
Water boatmen were very abundant at Malmok location G where also Tilapia, *Oreochromis mossambicus*, and the abundant and endemic Mosquito fish or Molly, *Poecilia vandepolli,* were caught.
The shallow waters of Cerca also provided abundant food species, especially location E where the last puddle of water could be found. At this site also Fiddler crabs, Boatmen, Molly and Tilapia could be found. Remarkably, like in Malmok, no Brine flies (*Ephydra salina*) or Brine shrimp (*Artemia salina*) were documented.

5.3 Breeding birds

Annex 2 shows that 64 bird species are observed in the Western Wetlands, which are considered breeding birds of Aruba. Specifically vulnerable are the non-migratory resident species that are considered rare on Aruba (Article 1 Landsbesluit Flora and Fauna AB 2017 no. 48). These are the Crested caracara and the four bird species shown in figure 5.2, locally known as Patrishi (Crested bobwhite), Shoco (Burrowing owl), Prikichi (Brown-throated parakeet) and Lora (Yellow-shouldered amazon). The terrestrial area around saliña Druif (more specifically the Tierra del Sol golf course), is the Shoco hotspot on Aruba, while the area is also one of the last strongholds for the Patrishi on the island.

Figure 5.2 *From top-left 'around the clock': Crested Bobwhite (Patrishi), Burrowing Owl (Shoco), Brown-throated Parakeet (Prikichi) and Yellow-shouldered Amazon (Lora). All are rare resident bird species, whose populations receive virtually no recruitment from elsewhere and therefore almost entirely depend on the remaining (declining) habitat in Aruba, among which the Western Wetlands. All four species are listed as rare and protected under Article 1 of the Landsbesluit AB 2017 no. 48. Pictures by Albert Peterson and Greg Peterson (Aruba Birdlife Conservation).*

The Lora was observed in December 2019 in Bubali, probably escaped from a cage as the species got extinct in the wild in Aruba in 1947. In January 2024 however, it was reintroduced in the wild again after 25 Lora, confiscated from smugglers, were released in the Arikok National Park. These birds will hopefully reproduce in the wild and repopulate the Western Wetlands.

Despite these efforts the Lora, but also the Patrishi, Shoco, Prikichi and the Crested caracara will remain particularly vulnerable to extinction on Aruba. Their populations receive virtually no recruitment from elsewhere so that their numbers almost entirely depend on the remaining declining habitat. It is no wonder that they are all protected under national legislation and listed as rare in Article 1 of the Landsbesluit flora and fauna (AB 2017 no. 48). Prevention of habitat loss is urgently needed to ensure the conservation of these species in Aruba.

The remaining habitats also need to be of sufficient ecological quality. This requires management of environmental pressures. For the Tierra del Sol golf course for instance this provides a great opportunity to become a sustainable GEO Certified golf course[18] that favours sustainability, limits pesticide use, reduces runoff (including of fertilizers) and safeguards and improves its present unique value for birds and other wildlife in Aruba.

5.4 Migratory birds

The Western Wetlands act as a magnet for migratory birds, particularly shorebirds, waterfowl and North American warblers. No less than 167 migratory species have been observed since 2000 that visit the wetlands for resting, sheltering and feeding (figure 5.3). Several species can number hundreds or thousands during peak migration periods.

Figure 5.3 *Migratory bird species observed in the Western Wetlands. From top-left 'around the clock': Blue-winged teals, Black-bellied whistling ducks, Least sandpipers and Black-necked stilts. (Pictures by Albert Peterson and Greg Peterson, Aruba Birdlife Conservation).*

[18] GEO Foundation for Sustainable Golf: https://sustainable.golf/

The saliñas differ in their attraction to migratory birds. Bubali is the only one of the five wetland areas that has permanent deeper water with large fishes year-round. This makes Bubali a good hunting ground for large egrets as well as other large piscivorous birds like the Neotropical cormorant and visiting Osprey. The area is also of relative high importance to true freshwater birds like ducks, gallinules and grebes. Palm Beach has relatively mature fringing vegetation which makes it particularly attractive for warblers and flycatchers. It has standing reeds and other plants associated with its inundation during periods of rainfall, but it was almost dried up during the February/March field visit in 2024.
Druif, contains more water for a longer period each year, due to the influx of water piped directly from Bubali and the exit to the sea being now permanently blocked. It has fringing habitats and shallower areas, with muddy substrate that is often exposed, that provide ideal feeding habitat for waders and ducks and has high densities of food organisms. The abundant chironomid larvae and water boatmen explain why these areas are intensively visited by both resident birds and seasonally migratory shorebirds (Eldridge, 1992; Euliss et al., 1995; Cox and Kadlec, 1995). The small ponds and meandering tributaries to the main water body at the eastern side next to the golf course fairways and greens, with emergent vegetation and small humid islands, also offer valuable habitat for a range of bird and other species.

The large Malmok salina (location H, figure 3.1) provides an ideal site for roosting, but it had almost dried up during the baseline study. Location G (figure 3.1) has a band of mangroves, largely on its eastern boundary, that provides ideal roosting (and nesting) habitat for species such as Roseate spoonbill *(Ajaia ajaia)*, Night herons *(Nycticorax spp.)* and egrets. The scrub layer that is found behind the mangrove provides protection from disturbance and further habitat, whilst the water body in front of the mangrove is a further deterrent to human disturbance. It is generally at an ideal depth for feeding waders such as Black-winged stilt (*Himantopus himantopus*) which can occur in large numbers, often with flocks of over 100 birds.

Cerca lacks the band of mangroves, otherwise its bird community with egrets and stilts is quite similar to neighbouring Malmok, especially when all food species are concentrated in the last puddle of water before drying up.

5.5 Other species

All of the saliñas have value for fish and aquatic invertebrates. While some of these provide food for foraging waders and other bird species, many of them are spectacular predators in their own right, providing an important role in the food chain but also as indicators of habitat and water quality. Dragonflies are highly visible species that are indicative of a rich invertebrate fauna (on which they principally feed) and good water quality as some of them cannot breed in over-polluted water. For Aruba, Paulson et al. (2014) describe no less than 16 species of dragonflies, most of which depend on the various areas of fresh to brackish waters of the Western Wetlands.

All dragonfly larvae are aquatic, requiring water bodies with the variation in depth and vegetation architecture in which they hunt and feed. The adults rely on emergent vegetation for perching and roosting. Trees and aquatic plants which overhang the water, or which provide perching areas that can offer territorial viewpoints for the aggressive male dragonflies, are particularly important. Some species, especially the females of those species, spend a lot of time well away from water bodies. Ecological networks linking water bodies or terrestrial habitat to open water, may therefore be particularly important. The combination of aquatic and emergent plant architecture, often enhanced by habitats with a variety of plant species is a particularly important characteristic for dragonfly conservation and management.

The microclimate around water bodies, combined with flower-rich plant life, is beneficial for butterflies (figure 5.4). A number of plant species typical for the vegetation around the saliñas, provide important food and larval host plants for these important pollinators. Thus flower-bearing plant species are a valuable component to the habitat around saliñas. Miller et al. (2003), describe 29 butterflies for Aruba, many of which can be found in the Western Wetlands area. These include, the ubiquitous Gulf fritillary *Agraulis vanillae, Leptotes cassius, Strymon bubastus* and *Leroda eufala*, as well as the tiniest butterfly of the Western Hemisphere *Brephidium exilis sp*. Which only occurs in coastal settings.

Another group that relies on plant architecture is the spiders (figure 5.4). Orb-weaving spiders in particular require emergent vegetation with suitable structures for making their webs. As well as being important predators, which can have human health benefits as certain species prey on flies and mosquitoes, they also are indicative of a good environmental quality.

Data on mammals, reptiles, amphibians and other species for the Western Wetlands are not available at this stage.

Figure 5.4 *One of the several blue butterfly species, Hemiargus hanno, (left) and Argiope argentata (right). Pictures by Lawrence Jones-Walters, Bubali, 2024.*

6 Conclusions and management recommendations

The Western Wetlands Working Group in Aruba has determined eight conservation targets that a conservation plan will have to focus on: 1) Wetlands Connectivity, 2) Wetland Ecology, 3) Water Quality, 4) Native Flora, 5) Land Birds, 6) Water birds, 7) Buffer Zone Management and 8) Sustainable Recreation. This chapter will therefore refer to each of these conservation targets.

6.1 Wetlands connectivity

Conclusion
The five saliñas are located in an urbanised surrounding. This increases the risk of ecological isolation which will result in the local extinction of flora and fauna, especially for less mobile, ground dwelling species.

It is extremely important that all saliñas are part of an ecological network with the green hinterland in the northeast and the Caribbean Sea in the west. Green corridors can be the dry river beds (rooi), but also verges such as the (approx.) 40 m wide verge east of the L.G. Smith Boulevard between Bubali, Palm Beach and Cerca.

These corridors should remain and could even be designed for specific species. Especially less mobile ground dwelling species will benefit from these green connections, but also birds, butterflies, dragonflies and bats are known to use green corridors for orientation and daily migration from roosting to foraging areas. Ecological bottlenecks for ground dwelling species, like roads and roundabouts, might be tackled with wildlife passages under the road.

Recommendations
- Integrate saliñas into an ecological network with green corridors (e.g., rooi, roadsides, central reservations of main roads, pipes and drains - wildlife passages under roads). However, prevent contaminated water from the Bubali WWTP from ending up in the relatively natural Cerca and Malmok saliñas at all times.
- Design specific corridors for less mobile species and address ecological bottlenecks. This requires further study and tailor made measures.

6.2 Wetland ecology

Conclusion
The saliñas are still important habitat for a wide range of flora and fauna species, both breeding and migratory (bird) species. The saliñas are especially recognised for their values for wader and waterbird species. Thousands of birds visit the saliñas during the spring and autumn migration periods. Food seems abundant and the birds feed on fish, crabs and invertebrates among others. The ongoing influx of untreated, highly enriched wastewater into Bubali with overspill to Palm Beach and Druif is the largest concern, not only for the water quality and species present in the saliñas but also for public health (see 6.3).

Much about the flora and fauna remains to be understood. Several species groups, especially the invertebrates, have hardly been studied and many species new for Aruba are still 'waiting' to be discovered. Exotic species, some of which are invasive, are a concern, such as the *Boa constrictor*, freshwater turtles (terrapins) and several plant species among which the Water hyacinth which covers vast areas in Bubali.

In 2024, studies began on the ecology of the saliñas (with the help of students from Wageningen University and the University of Aruba). These inventories and monitoring should continue, across the seasons and years, so that there is a good understanding of the ecological value of the saliñas. To date, knowledge on the

presence of bird species mainly relies on citizen science data. The inventory of birds in particular needs further attention to have a good understanding about numbers and trends. Cooperation with ornithological organisations should be explored.

Recommendations

- Stop the influx of large quantities of heavily enriched, polluted water originating from the neighbouring, malfunctioning Bubali WWTP (see §6.3). This should be the first step before any remediation or restoration of the Bubali, Palm Beach or Druif saliñas. Restore Druif as a permanent water body.
- Urgently restore and maintain 'natural' conditions (hydrology, sedimentation as far as possible).
- Create slow slopes and variations in water depth, while excavating sediment (see §6.7), to increase the variety in habitats and increase biodiversity values.
- Draft a plan for the monitoring, eradication and control of invasive species.
- Continue ecological studies and monitoring with universities. Monitoring of invertebrates (dragonflies, butterflies and spiders) would be desirable, specifically in relation to location, plant diversity and architecture if and where possible. These species groups are indicative for the ecological condition of the wetlands.
- The Western Wetlands have a special value for numerous resident and migratory birds, but present knowledge relies mainly on citizen-science data. Scientifically sound monitoring of bird species numbers is essential to assess the full value of the wetlands for birds and to assess the impact of any restoration measures. Bird numbers and trends are essential for national reporting under international conventions like the Ramsar Convention on wetlands, the Convention on Migratory Species (CMS) and the SPAW protocol to the Cartagena Convention.

6.3 Water quality

Conclusion

The water quality is the basis for the ecological functioning of the saliñas. During the baseline studies in February/March 2024, the values for dissolved oxygen (DO), oxygen saturation (DO%), acidity (pH), alkalinity, salinity, phosphate (PO4), nitrate (NO3-N), nitrite (NO2-N) and ammonia (NH3-N) were determined. A snapshot as in this baseline study did not allow for the assessment of other water or sediment contaminants such as heavy metals, agricultural and industrial chemicals, hydrocarbon fuels, pharmaceutical drugs or biologic agents such as bacteria, parasites and viruses.

None of the saliñas scored well for all of the parameters tested. The worst was Bubali, and to a lesser extent Palm Beach and Druif, which all receive effluent from the Bubali wastewater treatment plant (WWTP). This results in high nutrient levels and low dissolved oxygen levels.

The water quality of Malmok and Cerca, in terms of nutrient concentrations, was relatively good at the time of sampling. The processes of nitrification (ammonia to nitrate) appear to function in these wetlands. Elevated nutrient levels were also measured though. On the one hand may contamination be due to illegal discharge of septic tanks, polluted rain water run-off or large flocks of roosting birds, on the other hand will evaporation result in higher concentration of the contaminants in the remaining water.

The heavily polluted effluent from the Bubali WWTP is the largest concern, not only for the water quality, impacts on species and ecological functioning of the saliñas, but also for public health. Moreover, a nutrient-rich condition favours the growth of Water hyacinth and makes its management more challenging. Therefore, this should be solved first before any remediation or restoration action in the saliñas should take place. Illegal discharge from septic tanks has regularly been mentioned in interviews so that it is likely to happen as well. Law enforcement is the key to solving this.

Recommendation

- Address the pollution from the Bubali WWTP. The wastewater treatment capacity should always correspond with the current and foreseen levels of waste water input to the treatment facility. Caution should be taken with the implementation of innovative solutions (like biological augmentation[19]) if the impacts on the ecology of the saliñas is not clear.
- Periodically monitor the water quality parameters assessed during this baseline study to better document and understand the water quality in all seasons. Although EU water quality standards were used as an interim benchmark in this baseline study to assess conditions in the saliñas, these standards are primarily suited to more temperate climates. Therefore, it is recommended to supplement this assessment by comparing EU standards with recognized standards for xeric (dry) climates, such as those relevant to Aruba, if available. Assess and monitor the concentration of other water or sediment contaminants such as heavy metals, agricultural and industrial chemicals, hydrocarbon fuels, pharmaceutical drugs or biologic agents such as bacteria, parasites and viruses. This is also needed in case sediment excavation is considered as restoration measure.
- Enforce laws against illegal discharge from septic tanks.

6.4 Native vegetation and flora

Conclusions

The saliñas Cerca and Malmok both have well-developed, natural patterns of saline vegetation communities. Together, they form a shallow saliña-landscape which is unique for the ABC islands[20]. However, the edges of these saliñas in particular have deteriorated due to illegal building and dumping of waste. The saliñas Bubali and Palm Beach have deteriorated the most and their water bodies have large areas of vegetation types that are typical for nutrient-rich and polluted conditions. Some water bodies are dominated by the non-native Water hyacinth (*Eichhornia crassipes*), while in drier sites the exotic palm species *Washingtonia robusta* is gradually spreading. Saliña Druif has intermediate conditions: some parts have deteriorated, whilst other areas have remained less affected.

The vegetation research recorded a total of 178 vascular plant species in the Western Wetlands, 12 were listed on the Aruban protected species list (Landsbesluit 2017 no. 48), while 32 were new for Aruba. Some are listed on the SPAW Annex III, including mangroves, sea grasses and cacti. Some of these species are endemic for Aruba or the ABC islands. As such, the Western Wetlands play an important role in safeguarding the long-term survival of these species.

In the Western Wetlands, the presence of most invasive species is still limited, being restricted to smaller patches, particularly on the karst terraces. The aquatic Water hyacinth (*Eichhornia crassipes*) covers large areas in Bubali, facilitated by the hypertrophic conditions that are caused by the influx of untreated wastewater. Removing most of the other invasive species from the saliñas seems possible if carried out soon. Some species may not be fully eradicated, but their presence may be restricted (containment), e.g. Neem tree, Madagascar rubber vine. Removal of Water hyacinth, some exotic grass species and herbs will not be feasible as they have become widespread and cover larger areas. Some level of control might still be possible (e.g. controlled burning).

Recommendations

- With the highest priority, stop the influx of sewage water from the Bubali WWTP to the saliñas Bubali, Palm Beach and Druif (whilst ensuring that Druif, in particular, does not dry out completely).
- Give high priority to the protection and reduction of pressures in the relatively natural saliñas Cerca and Malmok.
- Monitor the presence of protected (rare) plant species and vegetation types, which enables an evaluation of the management of the areas and apply additional management actions based on data-driven analysis.
- Monitor water quality and physical parameters in association with aquatic fauna for a better understanding of conditions favouring native species.

[19] Biological augmentation is the addition of archaea or bacterial cultures required to speed up the rate of degradation of a contaminant.

[20] ABC-islands are the Dutch Leeward islands of Aruba, Bonaire and Curaçao.

- Give high priority to restoration of the drier parts in Druif, which are currently heavily over-grazed by free-roaming goats. Removal of goats is crucial to enable the vegetation to recover, to prevent erosion and to restore biodiversity.
- Give high priority to the protection of the dune area at the mouth of Druif.
- Give high priority to the localization and removal of exotic species. This requires a long-term focus and resources to increase awareness and documentation of the presence of exotic species as well as their potential invasiveness. Introduce ongoing monitoring for invasive species. Immediately remove newly arrived exotic species that have not yet massively spread. For established invasives, focus on local removal or restrict their spreading, like management of fast growing/shading invasives to avoid succession and domination of native vegetation.

6.5 Terrestrial birds

Conclusion

In many places the residential areas have encroached to the edge of the saliñas, which means that the habitat for terrestrial birds is under high pressure and is becoming limited. This emphasizes again the importance of wetland connectivity and highlights the special position of saliña Druif, which still has a large area of terrestrial habitat within its borders.

Conservation but also restoration of terrestrial habitat is particularly important for rare resident bird species of Aruba like the Crested bobwhite (Patrishi), Burrowing owl (Shoco[21]), Brown-throated parakeet (Prikichi), Yellow-shouldered amazon (Lora) and Crested caracara (Warawara). These species are all threatened with extinction on Aruba and protected under Article 1 of the Landsbesluit AB 2017 no. 48. Their populations receive virtually no recruitment from elsewhere and therefore almost entirely depend on the remaining (declining) habitat on the island.

Recommendations

- Collaborate with Tierra del Sol golf course, DOW and conservation organizations to maintain and restore the last remaining fringing habitats to the saliñas.
- The Tierra del Sol golf course within the area of saliña Druif has a special responsibility for conservation of flora and fauna species in Aruba. It is the only saliña with substantial terrestrial habitat. It is strongly recommended for the management to become a sustainable GEO-Certified (GEO = Golf Environment Organization) golf course[22]. This is a comprehensive modern certification, developed to the highest credibility standard, to help golf facilities, developments and tournaments demonstrate and be recognized for their environmental and social responsibility. This GEO-certification process requires good cooperation with stakeholders.

6.6 Waders and Water birds

Conclusion

Citizen science data reveal that the Western Wetlands serve as one of few resting or sheltering areas for no less than 167 migratory and 64 breeding bird species, many of which are waders (or shorebirds), waterbirds ad warblers. Bird numbers and trends per species are not yet available but they are known to often number several thousand during peak migration periods. Bird inventories and monitoring should continue, across the seasons, so that: there is a good understanding of the ecological value of the saliñas for birds; and that the management of the areas can be evaluated and, based on data-driven analysis, additional management actions can be applied.

[21] The Tierra del Sol golf course is considered the Shoco-hotspot of Aruba.
[22] See https://sustainable.golf/

Recommendations

- Reduce and/or manage sources of human induced disturbance (including dog-walking).
- The inventory on birds needs particular attention in order to develop a good understanding about bird numbers and trends. also in relation to the requirements for national reporting on biodiversity conventions (see §6.2). Therefore it's recommended to continue[23] ecological studies and bird monitoring through cooperation with universities and other key partners.
- Develop species action plans linked to monitoring outcomes. This may include the creation of habitats - like breeding and resting islands for birds- to facilitate specific species.

6.7 Buffer zone management

Conclusion

Bufferzone management suggests that a gentle transition exists from the saliñas to the urban surroundings. This is unfortunately not the reality. Houses and roads are often constructed at the borders of the saliñas. The transition zone from saliña to urban areas is very 'sharp'. "Watershed management" may therefore be considered a better concept to use, as much of the rainwater run-off from the watersheds collects in the saliñas.

The saliñas belong to three watersheds or water catchment areas: saliña Druif lies within the smallest watershed of only 256.1 hectares, the saliñas Malmok and Cerca are part of a watershed of 767.8 hectares, while Bubali and Palm Beach lie in a watershed of 1292.4 hectares. Fact that (much) less than half of the watersheds are covered with urban or natural vegetation is reason for concern. More than half of each watershed is covered with either built-up area or is bare soil or only sparsely vegetated. This lack of vegetation means that the water absorption and retention capacities of the watershed are limited and that large amounts of water and eroded sediment will drain off to the saliñas during the rainy season. The saliñas serve as large sediment traps. The lack of natural vegetation within the watershed, in combination with the silted saliñas, increases the chances of flooding during heavy downpours. Removal of accumulated sediment can help restore former water coverage of saliñas, which would be very beneficial to aquatic and avifaunal biodiversity. In addition, such measures can increase the water buffering capacity of such areas and help limit coastal flooding during the rainy season.

The converse of the above is that the chances of flooding will decrease if the watershed is covered with more natural vegetation and sediment from the silted saliñas is being removed. Nature-inclusive development of the watersheds will also support the wetland connectivity (see §6.1). Watershed management is therefore crucial due to rainwater run-off.

Recommendation

- Aruba should adapt to the increasing risks of climate change, such as the risk of flooding during heavy downpours or the risk of flooding due to sea level rise and storm surges.
- The water retention capacity of the watershed can be increased by increasing the natural vegetation within the entire watersheds and at the same time halting the ongoing urbanisation of the watersheds. Increased natural vegetation will at the same time improve the wetlands connectivity (see also §6.1).
- The water absorption capacity of the saliñas can be enhanced by carefully deepening non-sensitive areas, such as those without archaeological significance, to reduce flood risks. However, it is essential to avoid ecological impacts, as certain species, like wading birds, rely on shallow waters for feeding. Any ecological impacts from deepening should be mitigated or compensated to maintain the ecological balance of the area.
- Sediment traps may be constructed to reduce excessive siltation of the saliñas.
- Excavated sediment should be analysed for contaminant contents (see §6.3) and, subject to this analysis, could be used for other purposes (e.g. construction, agriculture).

[23] In 2024 studies on the ecology of the saliñas, also water- and shorebirds, have been started with the help of students from Wageningen University and the University of Aruba.

- Restoration of coastal and marine habitats such as mangroves, reef islands, coral reefs and sea grass beds is essential for adaptation to climate change risks like sea level rise and storm surges. Building with nature[24] will be important to prevent the future flooding of the saliñas by the sea.
- The potential ecosystem service provided by the saliñas in relation to (blue) carbon sequestration should be established via specific research.

6.8 Sustainable recreation

Conclusion

Sustainable tourism and recreation have the potential to play a pivotal role in the conservation of the Western Wetlands by fostering a deeper connection between visitors (either residents or tourists) and the natural environment. When visitors engage in recreation that is designed to be regenerative, they are not just passive observers but active participants in the preservation, enhancement and restoration of these vital ecosystems. For this reason, it is important to connect nature and visitors with each other and not to see these as separate.

The water quality of all saliñas should be improved and degraded vegetations of the saliñas restored in order to optimize the biodiversity values and attractiveness for nature-based recreation and tourism. Above all, the influx of sewage water from the Bubali WWTP to the saliñas Bubali, Palm Beach and Druif should be halted to avoid risks for public health and safety.

A visitor centre focusing on the Western Wetlands e.g. by utilising the abandoned 'Cheng Building' and surrounding area, could be established to explain the values of the Western Wetlands. This is not only important for tourists, but also for residents to raise awareness about the values of the saliñas. This 'Cheng Building' lies in between Bubali and Palm Beach and close to the high-rise hotels and can be considered an ideal place to concentrate the majority of the visitors to these sites and keep them away from the more sensitive natural saliñas Cerca and Malmok. Druif is already relatively protected against mass tourism influences as it is part of the Tierra del Sol golf course.

Currently visitor use of the saliñas seems limited. The only tourist facility is the watch tower at Bubali, which clearly needs to be modernised, especially for safety reasons. A board walk might serve as an additional tourist attraction. Apart from these, no more tourist facilities should be established, except for a limited board walk or designated path and (simple) birding hides at Cerca and Malmok, as these will prevent disturbance of birds and other wildlife, while facilitating the opportunity for bird watching.

Recommendation

- Above all, the influx of sewage water from the Bubali WWTP to the saliñas Bubali, Palm Beach and Druif should be halted to avoid risks for public health and safety.
- Improve the water quality and restore degraded vegetations in all saliñas in order to optimize their biodiversity values and attractiveness for nature-based recreation and tourism. Restoration among others also includes the dry area around Skydive Aruba in Malmok, which is currently intensively trampled and heavily impacting that part of the saliña.
- Develop a visitor centre (Cheng Building and surrounding area) to educate the public about the origin, history, biodiversity and archaeological values of the Western Wetlands.
- Modernize the watchtower at Bubali for safety reasons. A board walk might be constructed as an additional tourist attraction. Limit further construction of tourist facilities to bird hides.
- Restrict access of the public to the saliñas Cerca and Malmok, but install a limited board walk or designated path and raise bird hides as these will prevent disturbance of birds and other wildlife, while facilitating the opportunity for bird watching.

[24] Building with nature is a concept where nature is used to cope with climate change risks, such as floods, waves and sea level rise. It is also called 'nature-based solutions' or 'eco-engineering'.

References

Adame, M. F., & Lovelock, C. E., 2011. Carbon and nutrient exchange of mangrove forests with the coastal ocean. Hydrobiologia, 663(1), 23-50.

Ángeles Alonso, M. & M.B. Crespo, 2008. Taxonomic and nomenclatural notes on South American taxa of Sarcocornia (Chenopodiaceae). Ann. Bot. Fennici 45: 241–254.

Bekker, J.P., 1996. The Mammals of Aruba (Mammalia: Chiroptera, Rodentia, Lagomorpha). 1-78. Vereniging voor Zoogdierkunde en Zoogdierbescherming (VZZ).

BirdLife International, 2008. Important Bird Areas in the Caribbean: Key sites for Conservation. Cambridge, UK: BirdLife International. (BirdLife Conservation Series No. 15).

Buurt, G. van, 2001. De amfibieën en reptielen van Aruba, Curaçao en Bonaire. 119 pp. Gerard van Buurt, Curaçao.

Buurt, G. van & Debrot, A.O., 2012. Exotic and invasive terrestrial and freshwater animal species in the Dutch Caribbean. 1-37. IMARES, Wageningen.

Cox, R.R. & Kadlec, J.A., 1995. Dynamics of potential waterfowl foods in great salt lake marshes during summer. *Wetlands* 15, 1–8.

Debrot, A.O., C. Boogerd & D. van den Broeck, 2009. Chapter 24. The Netherlands Antilles III: Curaçao and Bonaire. Pp. 207-215. In: P. E. Bradley and R. L. Norton (eds.) Breeding seabirds of the Caribbean. Univ. Press, Florida.

Debrot, A.O., 2003a. The freshwater shrimps of Curaçao, West Indies (Decapoda, Caridea). Crustaceana 76: 65-76.

Debrot, A.O., 2003b. A review of the freshwater fishes of Curaçao, with comments on those of Aruba and Bonaire. Car. J. Sci. 39: 100-108.

Derix, R.R.W.M., 2016. A review of the Geology, Climate and Hydrology in Aruba. Landscape Series 3. Central Bureau of Statistics Aruba.

Dijkhoff, R.A.C.F. & M.S. Linville, 2004. The archaeology of Aruba: The marine shell heritage. Aruba, Archaeological Museum of Aruba, no. 10.

Eldridge, J., 1992. Management of Habitat for Breeding and Migrating Shorebirds in the Midwest. Waterfowl Management Handbook. 11.

Euliss Jr, N.H., Jarvis, R.L. & Gilmer, D.S., 1991. Feeding ecology of waterfowl wintering on evaporation ponds in California. *The Condor*, *93*(3), 582-590.

Freitas, J.A. de, Rojer, A.C., Houtepen, E.A.T., & Debrot, A.O., 2024. Landscape ecological vegetation map of Aruba (Southern Caribbean). Caribbean Research and Management of Biodiversity Foundation, Curaçao & Wageningen University & Research, Netherlands. 83 pp.

Howard, J., Hoyt, S., Isensee, K., Telszewski, M., & Pidgeon, E., 2014. Coastal Blue Carbon: Methods for Assessing Carbon Stocks and Emissions Factors in Mangroves, Tidal Salt Marshes, and Seagrasses. Conservation International, Intergovernmental Oceanographic Commission of UNESCO, International Union for Conservation of Nature.

Halewijn, R. van, Higler, L.W.G. & A.L. Spaans, 1992. Ecologisch onderzoek Bubali-plas, Aruba. RIN-rapport 92/30: 146p.

Haviser, J.B. & C.L. Hofman, 2015. A review of archaeological research in the Dutch Caribbean. Pp 37-70 in: J.B. Haviser and C.L. Hoffman (eds.), Managing our past into the future in the Dutch Caribbean. Sidestone Press, Leiden.

Janssen, J.A.M., van Proosdij, A.S.J., Houtepen, E.A. & R.J.H.G. Henkens, in prep. Vegetation mapping of saliñas and mangroves on the island of Aruba (Caribbean Region).

Janssen, J.A.M., Houtepen, E.A., van Proosdij, A.S.J. & Hennekens, S., 2023. CACTUS – Vegetation database of the Dutch Caribbean Islands, Vegetation Classification and Survey 4: 69–74.

Kelly, H. & C.L. Hofman, 2019. The Archaic Age of Aruba: New evidence on the first migrations to the island. Pp. 141-161 In C.L. Hofman and A.T. Antczak (eds.), Early settlers of the insular Caribbean-Dearchaizing the Archaic. Sidestone Press, Leiden.

KNMI, 2023. KNMI'23-klimaatscenario's voor Nederland, KNMI, De Bilt, KNMI-Publicatie 23-03.

La Peyre, M.K. & Rowe, S., 2003. Effects of salinity changes on growth of Ruppia maritima L. *Aquatic Botany*, *77*(3), 235-241.

Landsbesluit 2017 no 48. LANDSBESLUIT, houdende algemene maatregelen, van 14 juli 2017 ter uitvoering van de artikelen 4, eerste en tweede lid, en 26, eerste lid, van de Na-tuurbeschermingsverordening (AB 1995 no. 2) (Landsbesluit bescherming inheemse flora en fauna).

Madden, H., H. Boehm & L. Mielke, 2023. Foraging Ecology of Red-Billed Tropicbirds on Saba, Caribbean Netherlands, during Early Chick-Rearing. Ardea 111(2), 463-475. https://doi.org/10.5253/arde.2022.a14.

Madden, H., Leopold, M., Rivera-Milán, F., Verdel, K., Eggermont, E. & Jodice, P., 2022. Reproductive Success of Red-Billed Tropicbirds (Phaethon aethereus) on St. Eustatius, Caribbean Netherlands. Waterbirds, 45(1), 39-50. https://doi.org/10.1675/063.045.0106.

Miller, J.Y., Debrot, A.O. & Miller, L.D., 2003. A survey of butterflies from Aruba and Bonaire and new records for Curaçao. *Caribbean Journal of Science*, *39*(2), 170-175.

Molen, D. van der, Boers, P. & Evers, N., 2006. KRW-normen voor algemene fysisch-chemische kwaliteitselementen in natuurlijke wateren. H2O 2006 Vol. 25/26. P. 31-33.

Mücher, C.A., Verweij, P.J.F.M., Kramer, H., Thomas, D. & Henkens, R.J.H.G., 2024. Land Cover Classification 2020 and analysis historical land cover changes since 1900 of Aruba. Wageningen, Wageningen Environmental Research, Report, 49 pp.

Nurse, L. A., McLean, R. F., Agard, J., Briguglio, L. P., Duvat-Magnan, V., Pelesikoti, N., Tompkins, E., & Webb, A., 2014. Small islands. In Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1613-1654). Cambridge University Press.

Osland, M. J., Enwright, N., Day, R. H., & Doyle, T. W., 2013. Winter climate change and coastal wetland foundation species: salt marshes vs. mangrove forests in the southeastern United States. Global Change Biology, 19(5), 1482-1494.

Paulson, D.R., de Haseth, C. & Debrot, A.O., 2014. Odonata of Curaçao, southern Caribbean, with an update to the fauna of the ABC islands. *International Journal of Odonatology*, *17*(4), 237-249.

Peterson, Gregory, M. and Annette H. Peterson-Bredle, 2016. Bird wildlife of Aruba. Aruba Birdlife Conservation. LM Publishers. 432p.

Proosdij, A.S.J. van, 2012. Arnoldo's zakflora. Wat in het wild groeit en bloeit op Aruba, Bonaire en Curaçao. 4th edition. Walburg Press.

RGD, 1996. "Geology map of Aruba | Dutch Caribbean Biodiversity Database". www.dcbd.nl. Retrieved 3-6-2024 (from Beets, D.J., Metten, R. & Hoogendoorn, R., 1996. Geological map of Aruba. Natuurwetenschappelijke Studieskring voor het Caraïbisch Gebied. Rijks Geol. Dienst, Amsterdam. Rijks Geologische Dienst).

Stimaruba, 1992. Bubali behouden. Vereniging Stimaruba. 29p.

STOWA, 2018. Referenties en maatlatten voor natuurlijke watertypen voor de kaderrichtlijn water 2021-2027. STOWA 2018 Report Number: 2018-49.

Strazisar, T., Koch, M.S., Madden, C.J., Filina, J., Lara, P.U. & Mattair, A., 2013. Salinity effects on Ruppia maritima L. seed germination and seedling survival at the Everglades-Florida Bay ecotone. *Journal of experimental marine biology and ecology*, *445*, 129-139.

Vermeij, Mark, Marhaver, Kristen, Estep, Andrew & Stuart Sandin, 2020. Coral Reefs Baseline Study for Aruba 2019. Carmabi Foundation Curaçao. 48p.

Verweij, Peter, Cormont, Anouk, Rooij, Bertram de, Soma, Katrine, Burg, Sander van den, Kramer, Henk, Post, Pim, Tromp, Seth & Lawrence Jones-Walters, (in prep). Exploring images of a future Aruba A positive future for people and nature. Wageningen Environmental Research.

Werbata & W.A. Jonckheer, 2012. Topographische Kaart van Aruba / [triangulatie J.J. Beaujon, R.J. Beaujon en L. Lens, 1904-1909, terreinopname W.A. Jonckheer 1909-1911]. - Schaal 1:20.000. - Den Haag: Lith. J. Smulders & Co., [1912]. - 1 kaartserie in 8.

Westhoff, V. & E. van der Maarel, 1973. The Braun-Blanquet approach. In: Whittaker, R.H. (ed.) Handbook of vegetation science, part 5, Classification and ordination of communities, pp. 617-726. Junk, The Hague.

Annex 1 Plant species (inventory 2021-2023)

This list of plant species per salina is the result of field inventories in the period 2021-2023. Several species are protected under the Article 1 or 2 of the Landsbesluit Fora en Fauna (Landsbesluit AB 2017 no. 48). Some species found during the field inventories were not known from Aruba before (Van Proosdij, 2012), although some have been cultivated in gardens for a long time already.

Species	Druif	Malmok	Cerca	Palm Beach	Bubali	New to Aruba*	Landsbesluit AB 2017 no. 48
Achyranthes aspera	.	.	x	.	.		
Acrostichum danaeifolium	.	.	.	.	x	x	
Aloe vera	.	x	x	.	.		
Alternanthera halimifolia	.	.	x	x	x		
Amaranthus dubius	.	x	x	.	.		
Amaranthus viridis	.	x	.	.	.		
Ammannia latifolia	.	.	.	x	.		
Ammannia species	.	.	.	.	x		
Anthephora hermaphrodita	x	.	.	.	.		
Antigonon leptopus	.	.	x	.	.		
Aristida adscensionis	x	x	x	.	.		
Arivela viscosa	.	x	x	.	x		
Avicennia germinans	x	x	.	.	.		Art. 2
Azadirachta indica	.	x	x	x	.		
Bastardia viscosa	.	.	x	x	.		
Batis maritima	.	x	x	.	.		
Bidens cynapiifolia	.	x	.	.	.		
Boerhavia coccinea	x	x	x	x	.		
Boerhavia erecta	.	.	.	x	.		
Boerhavia scandens	x	.	.	.	.		
Bothriochloa pertusa	.	.	x	.	.		
Bouteloua aristidoides	x	.	x	.	.		
Bouteloua repens	x	x	.	.	.		
Calotropis procera	.	x	.	.	x		
Capraria biflora	x	x	x	x	x		
Cardiospermum halicacabum	.	x	.	.	.	x	
Cenchrus ciliaris	x	x	x	x	x		
Cenchrus echinatus	x	x	x	.	.		
Cenchrus pilosus	.	.	.	.	x		
Cereus repandus	x	x	x	.	.		Art. 2
Chamaecrista nictitans	.	x	x	.	.		
Chara species	x	.	.	.	.	x	
Chloris barbata	x	x	x	x	x		
Chloris virgata	.	x	.	.	x		
Cienfuegosia species	.	.	.	x	.	x	
Cnidoscolus urens	x	x	x	.	.		
Coccoloba uvifera	.	x	.	.	.		
Commelina erecta	.	.	x	.	.		
Conocarpus erectus	x	x	x	x	x		Art. 2
Conocarpus erectus var. sericeus	.	x	x	.	.		
Corchorus hirsutus	x	x	.	.	.		

Species	Druif	Malmok	Cerca	Palm Beach	Bubali	New to Aruba*	Landsbesluit AB 2017 no. 48
Cordia bullata	.	.	x	.	.		
Cordia curassavica	x	x	.	.	.		
Cordia sebestena	.	.	x	.	.	x	
Crossopetalum rhacoma	.	x	.	.	x		
*Croton conduplicatus***	x	x	x	.	.		
Croton ovalifolius	x	x	x	.	.		
Cryptostegia grandiflora	.	.	.	x	.		
Cyanthillium cinereum	.	x	x	x	.		
Cylindropuntia tunicata	.	.	x	.	.	x	
Cynodon dactylon	.	.	.	x	.		
Cyperus confertus	.	x	x	.	x		
Cyperus esculentus	.	.	.	x	x		
Cyperus ligularis	x	x	x	x	x		
Cyperus odoratus	.	x	x	x	x		
Cyperus oxylepis	.	x	x	x	x		
Cyperus planifolius	.	x	.	.	x		
Cyperus rotundus	.	x	x	x	.		
Dactyloctenium aegyptium	x	x	x	.	x		
Datura inoxia	x	x	x	.	x		
Desmanthus virgatus	x	x	x	x	x		
Desmodium incanum	.	.	x	.	.	x	
Digitaria ciliaris	.	.	x	.	.		
Diodella apiculata	.	.	x	.	.		
Ditaxis argothamnoides	x	x	x	.	.		
Echinochloa colona	.	x	.	x	x		
Eclipta prostrata	x	x	.	.	.		
Egletes prostrata	x	x	.	.	.		
Eichhornia crassipes	.	.	.	x	x		
Eleocharis geniculata	.	.	.	.	x		
Eleocharis mutata	x	x	x	x	x		
Eragrostis ciliaris	.	x	x	.	.		
Eragrostis pilosa	.	.	x	x	.		
Eragrostis tenella	.	.	x	.	.	x	
Eragrostis urbaniana	.	x	.	.	.		
Eriochloa punctata	.	.	.	x	x		
Euphorbia dioeca	.	x	x	x	.		
Euphorbia hirta	.	.	x	x	.		
Euphorbia lactea	.	x	.	.	.	x	
Euphorbia mesembryanthemifolia	x	.	.	.	.		
Euphorbia prostrata	x	.	.	.	.	x	
Euphorbia serpens	x	.	.	.	.	x	
*Euphorbia thymifolia****	x	.	.	.	.		
Evolvulus convolvuloides	x	x	x	x	.		
Fimbristylis cymosa	x	x	x	x	x		
Gossypium hirsutum	x	.	.	.	.		
Guaiacum officinale	x	x	x	x	x		
Heliotropium angiospermum	.	x	x	.	.		
Heliotropium curassavicum	x	x	x	.	x		
Hymenocallis caribaea	.	x	.	.	.	x	
Ipomoea aquatica	x	.	.	x	x	x	
Ipomoea nil	.	x	x	.	.		
Ipomoea pes-caprae	x	.	.	.	.		
Ipomoea wrightii	.	x	x	x	.		

Species	Druif	Malmok	Cerca	Palm Beach	Bubali	New to Aruba*	Landsbesluit AB 2017 no. 48
Jatropha gossypiifolia	x	x	x	.	.		
Kalanchoe x houghtonii	.	x	.	.	.		
Laguncularia racemosa	.	x	.	.	.		Art. 2
Lantana camara	x	.	x	.	.		
Launaea intybacea	x	x	x	.	x		
Lemna valdiviana	.	.	.	x	x	x	
Leucaena leucocephala	x	.	x	.	.		
Lipocarpha micrantha	x	.	.	.	.		
Lithophila muscoides	x	x	x	.	x		
Ludwigia erecta	.	.	.	x	x		
Ludwigia octovalvis	.	.	.	.	x	x	
Mallotonia gnaphalodes	x	.	.	.	.		
Matelea rubra	x	x	x	.	x		
Megathyrsus maximus	.	.	.	.	x	x	
Melicoccus bijugatus	.	.	x	.	x	x	
Melocactus macracanthos	x	x	x	.	.		Art. 2
Melocactus species	x	.	x	.	.		
Melocactus stramineus	x	x	x	.	x		Art. 2
Melochia parvifolia	.	x	.	.	.	x	
Melochia tomentosa	.	.	x	x	.		
Mentzelia aspera	.	.	x	.	.		
Mollugo verticillata	.	.	x	.	.		
Neptunia plena	x	x	x	x	x		
Oldenlandia corymbosa	.	.	.	x	.	x	
Opuntia boldinghii	.	x	.	.	.	x	
Opuntia caracassana	x	x	x	x	x		Art. 2
Opuntia curassavica	.	.	x	.	.		Art. 2
Panicum species	.	.	.	x	.		
Parkinsonia aculeata	.	.	.	.	x		
Paspalidium geminatum	x	.	.	x	.		
Paspalum bakeri	x	.	.	.	.		
Paspalum species	x	.	.	.	.		
Paspalum vaginatum	x	.	.	.	.	x	
Passiflora foetida	x	x	x	.	x		
Passiflora suberosa	.	x	x	.	x		
Pennisetum species	.	x	.	x	.	x	
Phyla nodiflora	x	.	.	x	x		
Phyllanthus niruri	.	.	x	x	.	x	
Physalis pubescens	.	.	x	.	.		
Pilosocereus lanuginosus	.	.	x	.	.		Art. 2
Physostemon stenophyllum	.	.	.	x	.		
Pistia stratiotes	.	.	.	.	x		
Pithecellobium unguis-cati	.	x	.	.	.		
Portulaca elatior	.	.	x	.	.		
Portulaca halimoides	.	x	x	x	.		
Portulaca oleracea	x	x	x	x	.		
Priva lappulacea	.	.	x	.	.		
Prosopis juliflora	x	x	x	x	x		
Quadrella odoratissima	x	x	x	.	.		
Rhynchosia minima	x	x	x	x	x		
Ricinus communis	.	.	.	x	.		
Ruellia nudiflora	x	.	.	.	.	x	
Ruellia simplex	.	x	.	.	.	x	

Species	Druif	Malmok	Cerca	Palm Beach	Bubali	New to Aruba*	Landsbesluit AB 2017 no. 48
Ruellia tuberosa	.	.	x	x	.		
Ruppia maritima	.	x	x	.	.		Art. 1
Salvinia molesta	.	.	.	x	.	x	
Scaevola taccada	x	.	.	.	.	x	
Scoparia montevidensis	.	x	.	.	.		
Senna italica	x	x	x	.	.		
Sesbania bispinosa	.	x	.	.	.	x	
Sesuvium portulacastrum	x	x	x	x	x		Art. 2
Sida ciliaris	x	.	x	x	x		
Sida salviifolia	x	.	x	.	.		
Solanum agrarium	x	.	.	.	.		
Solanum americanum	.	x	x	x	x		
Sporobolus jacquemontii	.	x	.	.	x	x	
Sporobolus pyramidatus	x	x	x	x	x		
Sporobolus virginicus	x	x	x	x	x		
Stachytarpheta boldinghii	.	x	x	x	.		
Stemodia maritima	x	x	x	.	.		
Stenocereus griseus	x	x	x	.	x		Art. 2
Stylosanthes hamata	x	x	x	x	.		
Suriana maritima	x	.	.	.	.		
Tephrosia cinerea	x	.	x	.	.		
Thespesia populnea	.	.	x	.	x		
Thymophylla tenuiloba	.	.	x	.	.	x	
Tragus berteronianus	x	.	.	.	.		
Trianthema portulacastrum	.	x	x	x	x		
Tribulus cistoides	x	x	x	x	x		
Tridax procumbens	.	x	x	x	.		
Typha domingensis	.	.	.	x	x		
Urochloa reptans	x	.	x	.	.	x	
Vachellia tortuosa	x	x	x	x	x		
Washingtonia robusta	x	.	x	x	x	x	
Total: 178	**80**	**95**	**104**	**64**	**61**	**32**	**12**

* The species is not included in Van Proosdij (2012), but has been known for long from gardens.

** In Van Proosdij (2012) as *Croton flavens.*

*** In Van Proosdij (2012) as *Euphorbia maculata.*

Annex 2 Bird species

The bird list below represents citizen-science data of species observed and registered at eBird (www.eBird.org). Observation points had to be combined to complete the list per salina[25]. Some species are protected by the Landsbesluit Flora en Fauna (Landsbesluit AB 2017 no. 48). Status as breeding, migratory, resident or vagrant in Aruba has been based on Peterson & Peterson-Bredle (2016) and confirmed by Aruba Birdlife Conservation.

Species	Scientific name	Breeding	Migratory	Resident	Vagrant	Bubali	Palm Beach	Cerca	Malmok	Druif	Landsbesluit 2017
Waterfowl											
Black-bellied whistling-duck	*Dendrocygna autumnalis*	O	O	O		X	X	X	X	X	
Fulvous whistling-duck	*Dendrocygna bicolor*				O	X	.	.	.	.	
White-faced whistling-duck	*Dendrocygna viduata*		O			X	.	.	.	.	
Swan goose	*Anser cygnoides*				P	X	.	.	.	.	
Comb duck	*Sarkidiornis sylvicola*				O	X	.	.	.	.	
Muscovy duck	*Cairina moschata*				P	X	X	X	X	X	
Blue-winged teal	*Spatula discors*		O			X	X	X	X	X	
Northern shoveler	*Spatula clypeata*		O			X		X	X	X	
American wigeon	*Mareca americana*		O			X	X	X	X	X	
Mallard	*Anas platyrhynchos*				O	X	.	.	.	.	
White-cheeked pintail	*Anas bahamensis*	O	O	O		X	X	X	X	X	
Northern pintail	*Anas acuta*		O			.	.	X	.	X	
Green-winged teal	*Anas crecca*		O			X	.	X	X	X	
Ring-necked duck	*Aythya collaris*		O			X	.	X	X	X	
Greater scaup	*Aythya marila*		O			X	.	X	X	.	
Lesser scaup	*Aythya affinis*		O			X	X	X	X	X	
Masked duck	*Nomonyx dominicus*				O	X	.	.	.	.	
Grouse, Quail, and Allies											
Crested bobwhite	*Colinus cristatus*	O		O		X	.	X	X	X	Art.1
Red junglefowl	*Gallus gallus*				P	X	.	.	.	.	
Flamingos											
American flamingo	*Phoenicopterus ruber*		O			X	X	.	X	X	Art. 1
Grebes											
Least grebe	*Tachybaptus dominicus*	O	O	O		X	X	.	X	X	
Pied-billed grebe	*Podilymbus podiceps*	O	O	O		X	X	X	X	X	
Storks											
Wood stork	*Mycteria americana*				O	X	.	.	.	.	
Rails, Gallinules, and Allies											
Sora	*Porzana carolina*		O			X	X	X	X	.	
Common gallinule	*Gallinula galeata*	O	O	O		X	X	X	X	X	
American coot	*Fulica americana*	O	O	O		X	X	X	X	X	
Purple gallinule	*Porphyrio martinica*	O	O	O		X	X	.	X	X	
Limpkin											
Limpkin	*Aramus guarauna*				O	X	.	.	.	.	
Shorebirds											

[25] Combination of observation locations in eBird: Bubali = Bubali Bird Sanctuary + Aruba Butterfly Farm; Palm Beach = Mill Resort Salina; Cerca = Mariott's Salina; Malmok = Aruba Salina; Druif = Tierra del sol Golf Course + Pond east of Tierra del sol golf course.

Species	Scientific name	Breeding	Migratory	Resident	Vagrant	Bubali	Palm Beach	Cerca	Malmok	Druif	Landsbesluit 2017
Black-necked stilt	*Himantopus mexicanus*	O	O	O		X	X	X	X	X	
American oystercatcher	*Haematopus palliatus*	O		O		X	X	X	X	X	
Black-bellied plover	*Pluvialis squatarola*		O			X	X	X	X	X	
American golden-plover	*Pluvialis dominica*		O			X	X	X	X	X	
Killdeer	*Charadrius vociferus*	O	O	O		X	X	X	X	X	
Semipalmated plover	*Charadrius semipalmatus*		O			X	X	X	X	X	
Southern lapwing	*Vanellus chilensis*	O	O	O		X	X	X	X	X	
Collared plover	*Anarhynchus collaris*		O			X	X	X	X	X	
Snowy plover	*Anarhynchus nivosus*		O			.	.	.	.	X	
Wattled jacana	*Jacana jacana*		O			X	.	.	.	.	
Upland sandpiper	*Bartramia longicauda*		O			X	.	.	.	X	
Whimbrel	*Numenius phaeopus*		O			X	X	X	X	X	
Hudsonian godwit	*Limosa haemastica*		O			X	.	X	X	.	
Short-billed dowitcher	*Limnodromus griseus*		O			X	X	X	X	X	
Long-billed dowitcher	*Limnodromus scolopaceus*		O			X	.	.	X	X	
Wilson's plover	*Anarhynchus wilsonia*		O			.	.	.	.	X	
Wilson's snipe	*Gallinago delicata*		O			X	X	X	X	X	
Wilson's phalarope	*Phalaropus tricolor*		O			.	.	X	X	.	
Spotted sandpiper	*Actitis macularius*		O			X	X	X	X	X	
Solitary sandpiper	*Tringa solitaria*		O			X	X	X	X	X	
Lesser yellowlegs	*Tringa flavipes*		O			X	X	X	X	X	
Willet	*Tringa semipalmata*		O			X	X	X	X	X	
Greater yellowlegs	*Tringa melanoleuca*		O			X	X	X	X	X	
Ruddy turnstone	*Arenaria interpres*	O	O	O		X	X	X	X	X	
Baird's sandpiper	*Calidris bairdii*		O			X	.	.	.	.	
Red knot	*Calidris canutus*		O			X	.	.	X	.	
Ruff	*Calidris pugnax*		O			X	.	.	X	.	
Stilt sandpiper	*Calidris himantopus*		O			X	X	X	X	X	
Buff-breasted sandpiper	*Calidris subruficollis*		O			X	.	.	.	.	
Sanderling	*Calidris alba*		O			X	X	X	X	X	
White-rumped sandpiper	*Calidris fuscicollis*		O			X	X	X	X	X	
Least sandpiper	*Calidris minutilla*		O			X	X	X	X	X	
Pectoral sandpiper	*Calidris melanotos*		O			X	X	X	X	X	
Western sandpiper	*Calidris mauri*		O			X	X	X	X	X	
Semipalmated sandpiper	*Calidris pusilla*		O			X	X	X	X	X	
Gulls, Terns, and Skimmers											
Laughing gull	*Leucophaeus atricilla*	O	O	O		X	X	X	X	X	
Franklin's gull	*Leucophaeus pipixcan*		O			X	.	.	.	.	
Lesser black-backed gull	*Larus fuscus*		O			X	.	.	.	.	
Black skimmer	*Rynchops niger*		O			X	X	X	X	X	
Brown noddy	*Anous stolidus*	O	O			X	.	.	X	.	
Sooty tern	*Onychoprion fuscatus*	O	O			X	X	.	X	.	
Bridled tern	*Onychoprion anaethetus*	O	O			X	.	.	X	.	
Least tern	*Sternula antillarum*	O	O			X	X	X	X	X	Art. 1
Gull-billed tern	*Gelochelidon nilotica*		O			X	.	X	X	X	
Caspian tern	*Hydroprogne caspia*		O			X	.	X	X	.	
Black tern	*Chlidonias niger*		O			X	.	.	.	X	
Common tern	*Sterna hirundo*	O	O	O		X	X	X	X	X	
Roseate tern	*Sterna dougallii*	O	O			X	X	.	X	X	Art. 1
Sandwich tern	*Thalasseus sandvicensis*	O	O			X	X	X	X	X	
Elegant tern	*Thalasseus elegans*		O			.	.	.	X	.	
Royal tern	*Thalasseus maximus*	O	O	O		X	X	X	X	X	

Species	Scientific name	Breeding	Migratory	Resident	Vagrant	Bubali	Palm Beach	Cerca	Malmok	Druif	Landsbesluit 2017
Frigatebirds, Boobies, and Gannets											
Magnificent frigatebird	*Fregata magnificens*	O	O	O		X	X	X	X	X	
Red-footed booby	*Sula sula*				O	X	.	.	.	.	
Brown booby	*Sula leucogaster*		O			X	.	X	X	.	
Masked booby	*Sula dactylatra*				O	X	.	.	.	.	
Cormorants and Anhingas											
Neotropic cormorant	*Nannopterum brasilianum*	O	O	O		X	X	X	X	X	
Pelicans											
Brown pelican	*Pelecanus occidentalis*	O		O		X	X	X	X	X	
Herons, Ibis, and Allies											
Least bittern	*Ixobrychus exilis*	O	O	O		X	.	.	.	.	
Yellow-crowned night heron	*Nyctanassa violacea*	O		O		X	X	X	X	X	
Black-crowned night heron	*Nycticorax nycticorax*	O		O		X	X	X	X	X	
Whistling heron	*Syrigma sibilatrix*		O			X	X	X	.	.	
Little Blue heron	*Egretta caerulea*	O	O	O		X	X	X	X	X	
Tricolored heron	*Egretta tricolor*	O	O	O		X	X	X	X	X	
Reddish egret	*Egretta rufescens*		O			X	X	X	X	X	
Snowy egret	*Egretta thula*	O	O	O		X	X	X	X	X	
Striated heron	*Butorides striata*				O	X	.	.	.	.	
Green heron	*Butorides virescens/striata*	O		O		X	X	X	X	X	
Western cattle egret	*Bubulcus ibis*	O		O		X	X	X	X	X	
Great egret	*Ardea alba*	O	O	O		X	X	X	X	X	
Great blue heron	*Ardea herodias*		O			X	X	X	X	X	
White ibis	*Eudocimus albus*		O			X	X	X	X	.	
Scarlet ibis	*Eudocimus ruber*		O			X	X	X	.	X	
White-faced ibis	*Plegadis chihi*		O			X	.	.	.	.	
Glossy ibis	*Plegadis falcinellus*		O			X	X	X	X	X	
Roseate spoonbill	*Platalea ajaja*		O			X	X	X	X	X	
Kingfishers											
Ringed kingfisher	*Megaceryle torquata*		O			X	.	.	.	.	
Belted kingfisher	*Megaceryle alcyon*		O			X	X	X	X	X	
Amazon kingfisher	*Chloroceryle amazona*		O			X	.	X	.	.	
Vultures, Hawks, and Allies											
Osprey	*Pandion haliaetus*		O			X	X	X	X	X	
Northern harrier	*Circus hudsonius*				O	X	.	.	.	.	
Owls											
Burrowing owl	*Athene cunicularia arubensis*	O		O		X	X	X	X	X	Art. 1
Falcons and Caracaras											
Crested caracara	*Caracara plancus*	O		O		X	X	X	X	X	Art. 1
Yellow-headed caracara	*Daptrius chimachima*	O		O		X	.	.	.	.	
American kestrel	*Falco sparverius*	O		O		X	X	X	X	X	
Merlin	*Falco columbarius*		O			X	.	X	X	X	
Peregrine falcon	*Falco peregrinus*		O			X	X	X	X	X	Art. 1
White-tailed hawk	*Geranoaetus albicaudatus*		O			.	.	.	.	X	
Parrots, Parakeets, and Allies											
Rose-ringed parakeet	*Psittacula krameri*				P	X	X	X	.	X	
Orange-winged parrot	*Amazona amazonica*				P	.	.	X	.	.	
Budgerigar	*Melopsittacus undulatus*				P	X	.	.	.	.	
Rosy-faced lovebird	*Agapornis roseicollis*				P	X	.	.	.	.	
Yellow-shouldered parrot	*Amazona barbadensis*	O		O		X	.	.	.	.	Art. 1
Green-rumped parrotlet	*Forpus passerinus*				P	X	.	.	.	.	
Brown-throated parakeet	*Aratinga pertinax arubensis*	O		O		X	X	X	X	X	Art. 1

Species	Scientific name	Breeding	Migratory	Resident	Vagrant	Bubali	Palm Beach	Cerca	Malmok	Druif	Landsbe-sluit 2017
Scarlet-fronted parakeet	*Psittacara wagleri*				P	X	.	.	.	.	
Tyrant Flycatchers: Elaenias, Tyrannulets, and Allies											
Small-billed elaenia	*Elaenia parvirostris*	O		O		X	.	.	.	.	
Caribbean elaenia	*Elaenia martinica*	O		O		X	.	.	X	.	
Tyrant Flycatchers: Pewees, Kingbirds, and Allies											
Olive-sided flycatcher	*Contopus cooperi*				O	X	.	.	.	.	
Eastern wood-pewee	*Contopus virens*				O	X	.	.	.	.	
Willow flycatcher	*Empidonax traillii*				O	X	.	.	.	.	
Northern scrub-flycatcher	*Sublegatus arenarum*	O		O		X	X	X	X	X	
Brown-crested flycatcher	*Myiarchus tyrannulus*	O		O		.	.	.	.	X	
Swainson's flycatcher	*Myiarchus swainsoni*		O			.	.	.	.	X	
Vermilion flycatcher	*Pyrocephalus rubinus*		O			X	.	.	.	.	
Piratic flycatcher	*Legatus leucophaius*				O	X	.	.	.	.	
Variegated flycatcher	*Empidonomus varius*				O	X	.	.	.	.	
Crowned Slaty flycatcher	*Empidonomus aurantioatrocristatus*				O	X	.	.	.	.	
Tropical kingbird	*Tyrannus melancholicus*		O			X	.	.	.	.	
Cattle tyrant	*Machetornis rixosa*		O			.	.	.	X	X	
Gray kingbird	*Tyrannus dominicensis*	O		O		X	X	X	X	X	
Fork-tailed flycatcher	*Tyrannus savana*		O			X	X	X	X	.	
Vireos											
Yellow-throated vireo	*Vireo flavifrons*		O			X	.	.	.	.	
Philadelphia vireo	*Vireo philadelphicus*		O			X	.	.	.	.	
Red-eyed vireo	*Vireo olivaceus*		O			X	.	.	.	.	
Chivi vireo	*Vireo chivi*		O			X	.	.	.	.	
Black-whiskered vireo	*Vireo altiloquus*		O			X	.	.	.	.	
Martins and Swallows											
Bank swallow	*Riparia riparia*		O			X	X	X	X	X	
Purple martin	*Progne subis*		O			X	.	X	.	.	
Cuban martin	*Progne cryptoleuca*		O			X	.	.	.	.	
Caribbean martin	*Progne dominicensis*		O			X	.	X	X	X	
Gray-breasted martin	*Progne chalybea*		O			X	.	.	.	.	
Brown-chested martin	*Progne tapera*		O			X	.	.	.	.	
Southern rough-winged swallow	*Stelgidopteryx ruficollis*		O			X	X	.	.	.	
Barn swallow	*Hirundo rustica*		O			X	X	X	X	X	
Cliff swallow	*Petrochelidon pyrrhonota*		O			X	X	X	X	X	
Cave swallow	*Petrochelidon fulva*		O			X	.	.	.	.	
Starlings and Mynas											
Common myna (exotic)	*Acridotheres tristis*				P	X	.	.	.	.	
European starling	*Sturnus vulgaris*				O	X	.	.	.	.	
Catbirds, Mockingbirds, and Thrashers											
Tropical mockingbird	*Mimus gilvus*	O		O		X	X	X	X	X	
Thrushes											
Veery	*Catharus fuscescens*		O			X	.	.	.	.	
Gray-cheeked thrush	*Catharus minimus*		O			X	.	.	.	.	
Wood thrush	*Hylocichla mustelina*		O			X	.	.	.	.	
Old World Sparrows											
House sparrow	*Passer domesticus*	O		O		X	X	X	X	X	
New World Sparrows											
Rufous-collared sparrow	*Zonotrichia capensis*	O		O		X	.	.	.	.	
Blackbirds											
Bobolink	*Dolichonyx oryzivorus*		O			X	.	X	X	X	
Oriole blackbird	*Gymnomystax mexicanus*		O			X	.	.	.	.	

Species	Scientific name	Breeding	Migratory	Resident	Vagrant	Bubali	Palm Beach	Cerca	Malmok	Druif	Landsbe-sluit 2017
Venezuelan troupial	*Icterus icterus*	O		O		X	X	X	X	X	
Yellow oriole	*Icterus nigrogularis*	O		O		X	X	X	X	.	
Baltimore oriole	*Icterus galbula*		O			X	.	.	.	.	
Shiny cowbird	*Molothrus bonariensis*	O		O		X	X	X	X	X	
Great-tailed grackle	*Quiscalus mexicanus*		O			X	.	X	X	.	
Carib grackle	*Quiscalus lugubris*		O			X	X	X	X	X	
Yellow-hooded blackbird	*Chrysomus icterocephalus*		O			X	.	X	.	.	
Wood-Warblers											
Ovenbird	*Seiurus aurocapilla*		O			X	.	.	.	.	
Worm-eating warbler	*Helmitheros vermivorum*		O			X	.	.	.	.	
Louisiana waterthrush	*Parkesia motacilla*		O			X	.	.	.	.	
Northern waterthrush	*Parkesia noveboracensis*		O			X	X	X	X	X	
Black-and-white warbler	*Mniotilta varia*		O			X	.	.	.	.	
Prothonotary warbler	*Protonotaria citrea*		O			X	.	.	.	.	
Tennessee warbler	*Leiothlypis peregrina*		O			X	.	.	.	.	
Connecticut warbler	*Oporornis agilis*		O			X	.	.	.	.	
Mourning warbler	*Geothlypis philadelphia*		O			X	.	.	.	.	
Common yellowthroat	*Geothlypis trichas*		O			X	.	.	.	X	
Hooded warbler	*Setophaga citrina*		O			X	.	.	.	.	
American redstart	*Setophaga ruticilla*		O			X	X	X	X	X	
Cape may warbler	*Setophaga tigrina*		O			X	.	.	.	.	
Northern parula	*Setophaga americana*		O			X	.	X	.	X	
Magnolia warbler	*Setophaga magnolia*		O			X	.	.	.	.	
Bay-breasted warbler	*Setophaga castanea*		O			X	.	.	.	.	
Blackburnian warbler	*Setophaga fusca*		O			X	.	.	.	.	
Yellow warbler	*Setophaga petechia*	O	O	O		X	X	X	X	X	
Chestnut-sided warbler	*Setophaga pensylvanica*		O			X	.	.	.	.	
Blackpoll warbler	*Setophaga striata*		O			X	X	X	X	.	
Black-throated blue warbler	*Setophaga caerulescens*		O			X	.	.	.	.	
Palm warbler	*Setophaga palmarum*		O			X	.	.	.	X	
Yellow-rumped warbler	*Setophaga coronata*		O			X	.	.	.	.	
Prairie warbler	*Setophaga discolor*		O			X	.	.	.	.	
Black-throated green warbler	*Setophaga virens*		O			X	.	.	.	.	
Canada warbler	*Cardellina canadensis*		O			X	.	.	.	.	
Cardinals, Grosbeaks, and Allies											
Summer tanager	*Piranga rubra*		O			X	.	.	.	.	
Scarlet tanager	*Piranga olivacea*		O			X	.	.	.	.	
Rose-breasted grosbeak	*Pheucticus ludovicianus*		O			X	.	.	.	.	
Blue grosbeak	*Passerina caerulea*		O			X	.	.	.	.	
Indigo bunting	*Passerina cyanea*		O			X	.	.	.	.	
Dickcissel	*Spiza americana*		O			X	.	.	.	.	
Tanagers and Allies											
Saffron finch	*Sicalis flaveola*	O		O		X	X	.	.	.	
Yellow-bellied seedeater	*Sporophila nigricollis*		O			X	.	.	.	.	
Bananaquit	*Coereba flaveola*		O			X	X	X	X	X	
Black-faced grassquit	*Melanospiza bicolor*		O			X	X	X	X	X	
Pigeons and Doves											
Rock pigeon	*Columba livia*	O		O		X	X	X	X	X	
Bare-eyed pigeon	*Patagioenas corensis*	O		O		X	X	X	X	X	
Common ground dove	*Columbina passerina*	O		O		X	X	X	X	X	
White-tipped dove	*Leptotila verreauxi*	O		O		X	X	X	X	.	
Eared dove	*Zenaida auriculata*	O		O		X	X	X	X	X	

Species	Scientific name	Breeding	Migratory	Resident	Vagrant	Bubali	Palm Beach	Cerca	Malmok	Druif	Landsbesluit 2017
Skuas and Jaegers											
Pomarine jaeger	*Stercorarius pomarinus*		O			X	.	.	.	.	
Cuckoos											
Greater ani	*Crotophaga major*		O			X	.	.	X	X	
Smooth-billed ani	*Crotophaga ani*		O			X	X	.	X	X	
Groove-billed ani	*Crotophaga sulcirostris*	O		O		X	X	X	X	X	
Yellow-billed cuckoo	*Coccyzus americanus*		O			X	.	X	X	X	
Mangrove cuckoo	*Coccyzus minor*		O			X	.	.	.	X	
Nightjars											
Common nighthawk	*Chordeiles minor*	O		O		X	.	.	.	.	
Antillean nighthawk	*Chordeiles gundlachii*	O		O		X	.	.	.	.	
White-tailed nightjar	*Hydropsalis cayennensis*	O		O		X	.	X	X	X	
Swifts											
Black swift	*Cypseloides niger*		O			X	.	.	.	.	
White-collared swift	*Streptoprocne zonaris*		O			X	.	.	.	.	
Gray-rumped swift	*Chaetura cinereiventris*		O			X	.	.	.	.	
Chimney swift	*Chaetura pelagica*		O			X	.	.	.	.	
Vaux's swift	*Chaetura vauxi*		O			X	.	.	.	.	
Chapman's swift	*Chaetura chapmani*		O			X	.	.	.	.	
Fork-tailed palm swift	Tachornis squamata		O			.	.	.	X	.	
Hummingbirds											
Ruby-topaz hummingbird	*Chrysolampis mosquitus*	O		O		X	X	X	X	X	Art. 2
Blue-tailed emerald	*Chlorostilbon mellisugus*	O		O		X	X	X	X	X	Art. 2
Total	**243**	**64**	**167**	**58**	**27**						**11**

Wageningen Environmental Research
P.O. Box 47
6700 AA Wageningen
The Netherlands
T 0317 48 07 00
wur.eu/environmental-research

Report 3380
ISSN 1566-7197

To explore the potential of nature to improve the quality of life

Wageningen Environmental Research
P.O. Box 47
6700 AB Wageningen
The Netherlands
T +31 (0) 317 48 07 00
wur.eu/environmental-research

Report 3380
ISSN 1566-7197

The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,700 employees (7,000 fte), 2,500 PhD and EngD candidates, 13,100 students and over 150,000 participants to WUR's Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.