



LOS ROQUES AND LAS AVES ARCHIPELAGOS, VENEZUELA:

A MARINE ECOLOGICAL AND CONSERVATION
RECONNAISSANCE OF TWO LITTLE-KNOWN SOUTHEASTERN
CARIBBEAN OCEANIC ARCHIPELAGOS

*Adolphe O. Debrot, Anaurora Yranzo,
and Dulce Arocha*



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LOS ROQUES AND LAS AVES ARCHIPELAGOS, VENEZUELA: A MARINE ECOLOGICAL AND CONSERVATION RECONNAISSANCE OF TWO LITTLE-KNOWN SOUTHEASTERN CARIBBEAN OCEANIC ARCHIPELAGOS

ADOLPHE O. DEBROT¹, ANAURORA YRANZO², and DULCE AROCHA³

ABSTRACT

The Los Roques and Las Aves oceanic coral reef archipelagos of Venezuela lie in a biogeographically unique and biologically diverse area of the Caribbean and possess extensive coral reefs, seagrass beds, mangroves and shallow macroalgae meadows. The geographic location of these archipelagos safeguards them from most Western Atlantic hurricane damage as well as the most severe Caribbean coral bleaching episodes. While the Aves islands remain uninhabited and are an area of low accessibility, Los Roques has been a managed national park since 1972. We here present an updated synthesis of recent research for these archipelagos as an aid to scientists and conservationists interested in these island groups for which no recent ecological reviews are available.

Los Roques has been much better documented than Las Aves and is the largest coral reef marine protected area of Venezuela. It has about 1,500 inhabitants living principally from tourism and fisheries. Studies show that Los Roques possesses fish populations that suffer comparatively less fishing pressure and may serve as a rare benchmark for pristine fish communities elsewhere in the Caribbean. It has also successfully maintained its importance to seabird colonies for the last five decades, notwithstanding serious marine park funding and staffing shortages. A new baseline biological inventory for Las Aves is particularly critical considering the fragmentary information available for this archipelago. The relatively intact and resilient oceanic coral reef systems of Los Roques and Las Aves are of regionally significant conservation value and deserve much more conservation and biodiversity attention than so far accorded.

INTRODUCTION

We here provide an updated synthesis of recent research for the Los Roques and Las Aves southeastern Caribbean island groups as an aid to scientists and conservationists interested in the unique biodiversity values of these archipelagos. The most recent conservation overview for these areas dates from 2002 and only includes information from the Los Roques archipelago (ParksWatch 2002). While the scientific research on these island groups remains scattered throughout the literature, several new works show that these areas deserve more conservation and biodiversity attention than they have so far been accorded. An updated bibliography and formal ecological review are clearly in order.

The two island groups we discuss here are located along a line stretching east from Bonaire. Los Roques is a designated “wetland” of exceptional importance as a reservoir of food resources and biodiversity. In 1996 it was included in the list of wetlands protected by the Ramsar Convention (Convention on Wetlands of International Importance- rsis.ramsar.org), a treaty which had earlier been

¹Wageningen Marine Research, Wageningen University and Research, P.O. Box 57, 1780 AB, Den Helder, and Marine Animal Ecology, Wageningen University & Research Centre, P.O. Box 3700 AH Wageningen, The Netherlands: dolfi.debrot@wur.nl

² Instituto de Zoología y Ecología Tropical, Facultad de Ciencias, Universidad Central de Venezuela

³ Gerencia de Ordenación Pesquera, Instituto Socialista de la Pesca y Acuicultura

ratified by Venezuela in 1988. This Venezuelan national park was founded in 1972 (Decree N° 1.061- Creation of Los Roques National Park) (Figure 1). It is about 157 km from Venezuela's mainland coast and covers about 225.153 ha. The park, including its internal and surrounding waters (Rodriguez 2003), lie in the so-called “Ecoregion Southern Caribbean Sea” (wwf.panda.org). The total surface area of the atoll-like formation is about 894 km² (Weil 2003). Los Roques’ (11°51'27"N 66°45'27"W) highest point is 130 m and the deepest waters of the park are up to 1700 m. The existence of numerous keys (42) and two large coral barriers, one from north to south (24 km) and the other from east to west (32 km) allow for a variety of marine environments ranging from sandy beaches, rocky beaches, calm bays, coastal or barrier reefs, mangrove areas, seagrass beds, lagoons and salt ponds (Rodriguez 2003). Most islands have well-established names and numerous publications provide maps of this archipelago.

The Aves islands are distributed in two atoll-shaped clusters at about 150 km from the coast of Venezuela; Aves de Barlovento (12°01'00"N 67°14'00"W) and Aves de Sotavento (11°58'48"N 67°39'23"W), which lie between Bonaire and Los Roques (Figures 2, 3) and consist of small, low-lying sandy or mangrove-vegetated islands. Most islands and islets have names given them by the fishermen but there is considerable confusion regarding the names. For our maps we used the names given on the map by Antczak & Antczak (2015) but there are many older names reported as well. For Las Aves de Sotavento these include the names “Isla Aves de Sotavento”, “Isla Larga”, “Cayo Tirra”, “Isla Saqui-saqui”, “Cayos de La Colonia”, “Isla Maceta” and “Cayo Sterna”. Of these names the only one used on the map of Antczak & Antczak (2015) is “Saqui-saqui” (though spelled as Saki-saki) which is the common name for the bush *Suriana maritima* (Ginés & Yepez 1960). It is often not clear which name corresponds to which island and most early accounts fail to provide a map. For Las Aves de Barlovento the following names can be found in the literature and on informal maps: “Isla Aves de Barlovento”, “Isla Tesoro”, “Cayo Bubi” and “Cayo de Las Bobas” “Isla Sur”, “Isla Pirata” and “Isla Oeste”. Establishing authentic and consistent names for the islands, islets and keys of the Aves islands would be useful to both science and conservation purposes.

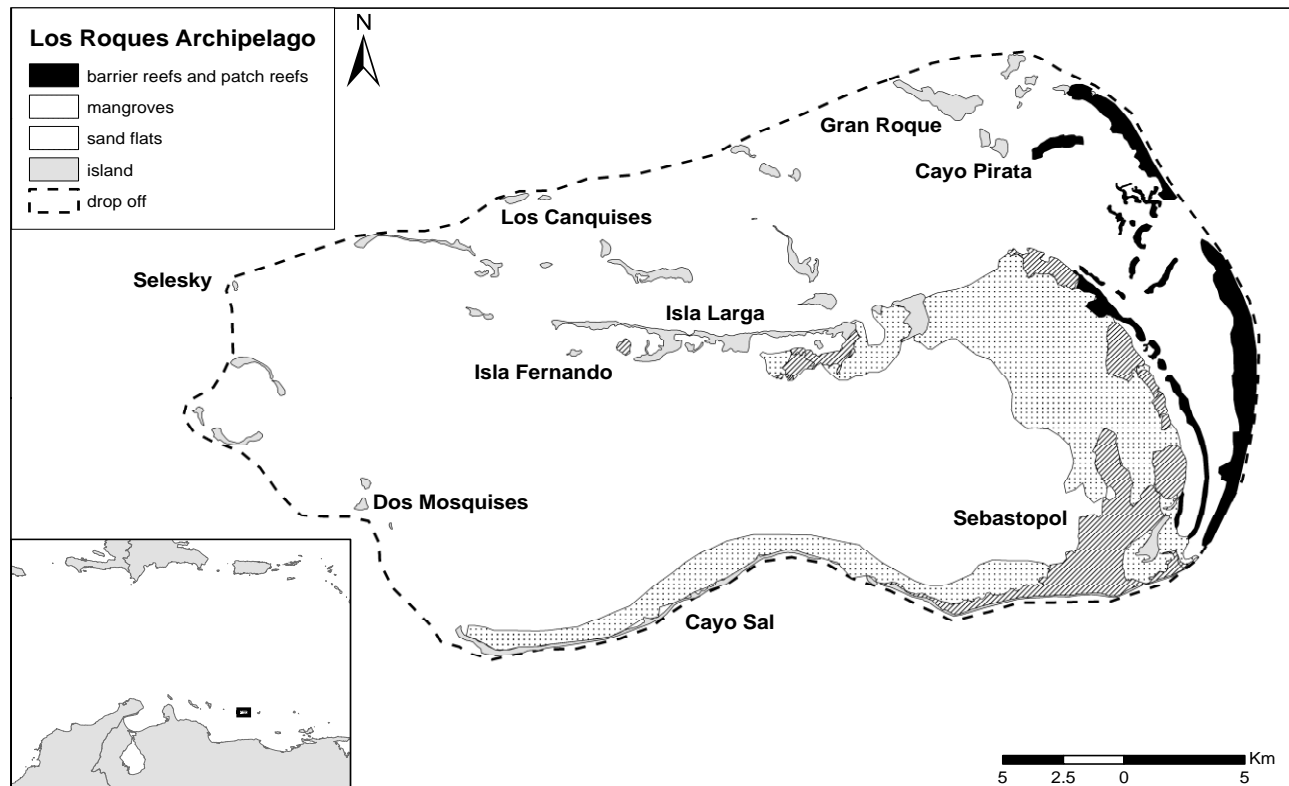


Figure 1. Map showing the main features of the Los Roques archipelago, Venezuela.

Aves de Barlovento is located 51 km west northwest from the Los Roques archipelago and 72 km due east due east from Bonaire. (Figures 2, 4). It is a circular island cluster with an average diameter of about 8.25 km and its surface area is roughly 80 km². Aves de Sotavento is located 15 km due west from Aves de Barlovento (Figure 3). It is a chevron-shaped island cluster with a maximum length along the north to south axis of about 9.25 km and a maximum width of about 8.75 km. Its total surface area is about 50 km².

Bathymetric measurements from 1939 show that both island clusters peak on a rise at depths of about 400 m connecting the islands along the north side. In contrast, on the south side of the islands, water depths of the Bonaire Trench go down to more than 1000 m. Both island clusters possess a central lagoon. In Aves de Barlovento the average depth of the lagoon is 18–20 m, whereas in Aves de Sotavento the lagoon averages only 3–4 m in depth. This difference translates into a significant difference in benthic communities. For instance, the much shallower Aves de Sotavento had more than 130 lagoonal patch reefs while the deeper Aves de Barlovento had less than 40 mapped lagoonal patch reefs in 1939 (Figures 2 and 3). Both groups have small islands on the southern and western margins and shallow barrier reefs on the wind-exposed eastern and northern margins.

Together with the islands of Los Monjes, and the ABC islands (Aruba, Curaçao and Bonaire), these archipelagos are all part of the Lesser Antilles Ridge that lies in a band off the coast of Venezuela. This ridge was formed by subduction of the Caribbean plate under the South American continental plate (Silver et al. 1975), a process that began at least 75 Ma years ago, long before closure of the Central American isthmus (Iturralde-Vinent 2006, Neill et al. 2011). Underwater terraces at depths of 20 and 45 m (Weil 2003) are indicative of lower sea levels at several times in the past, during which these archipelagos would at one time have been larger emerged islands, possible more able to support and develop endemic biodiversity (Clark et al. 2009).

In the scientific literature, both the Los Roques and Las Aves archipelagos are sometimes referred to as atolls (e.g. Ginés & Yepez 1960, Hudec and Sonnefeld 1980, Petuch 2013a). They are certainly not classical atolls formed by reef growth on the edges of subsiding oceanic volcanos or seamounts but are atolls in the morphological sense of the definition (Fairbridge 1950). Nevertheless, they were not included as atolls in the the most recent worldwide review by Goldberg (2016) as too little is yet known of their growth history and their antecedent platform since the last interglacial (Goldberg, pers. comm.). These archipelagos lie on Early Cretaceous to early Paleogene granitic and sedimentary rocks that were orogenically uplifted about 50 Ma when Gran Roque collided with the South American Plate shortly after or simultaneously with Bonaire (Ave Lallemand 1977, Levander et al. 2006, Van der Lelij et al. 2010, Garmon et al. 2017). Both archipelagos are “oceanic” in nature in that they are separated from the nearest Venezuelan mainland by a minimum of 120 km and the 1000-m deep Bonaire Trench (Silver et al. 1975). Consequently, they also possess oligotrophic tropical oceanic water quality and typically oceanic reef fish faunas which lack many continental shelf species.

Their geographic position off the northeast coast of South America has remained unchanged since the Upper Miocene, 7–9 Ma years ago (Iturralde-Vinent 2006). Both Los Roques and Las Aves form part of the climatic subzone lying in a band from Cumaná in Venezuela to Santa Marta in Colombia, along the Caribbean Coast Range. These include the Lesser Antilles from Margarita Island to Aruba (Ginés & Yepez 1960). These areas share oceanographic and climatic characteristics such as low rainfall, clear oligotrophic oceanic waters and sea surface temperatures that fluctuate between 25 °C and 29 °C during the course of the year (Cervigón 1992).

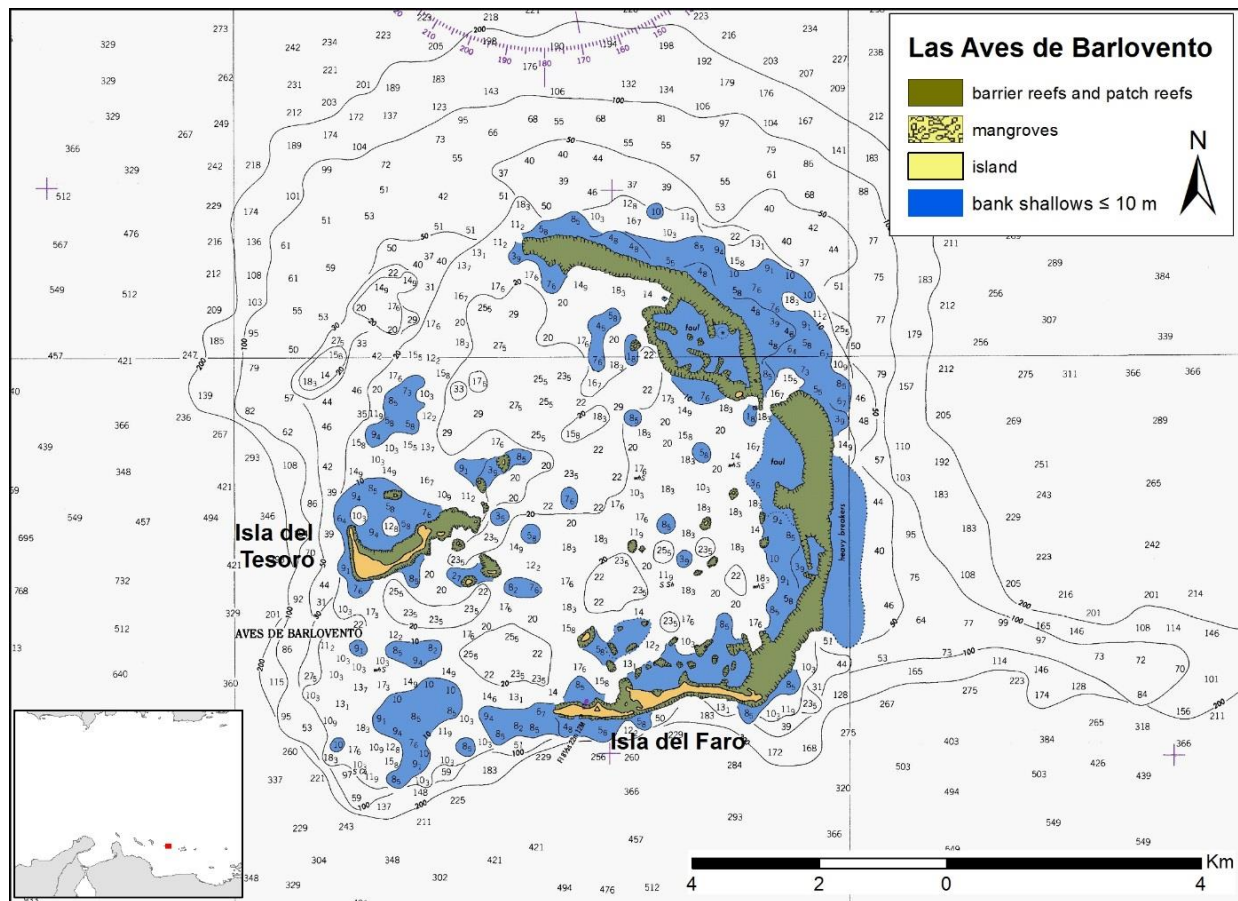


Figure 2. Bathymetric map showing the main features of the Barlovento group of the Las Aves archipelago, Venezuela. Source map: U.S. Navy Survey 1939.

Both island groups lie in an area affected by seasonal, wind-driven upwelling which is most concentrated directly upstream in the vicinity of Margarita Island (Sturm 1991). One effect of this upwelling is that the southern continental margin of the Caribbean shows lower than average annual sea surface temperatures compared to surrounding waters (Rueda-Roa & Muller-Karger 2013), which provides partial protection from regional coral bleaching events. For example, high ocean temperatures in 2005 caused the most severe bleaching event in the Caribbean Basin, yet the thermal stress was lower off Venezuela, including Los Roques, Aruba, Bonaire and Curaçao (Eakin et al. 2010). Hetzinger et al. (2008) show how sea surface temperature and precipitation signals deposited in the coral skeletons at Los Roques provide a multidecadal record of hurricane activity which may help elucidate mechanisms underlying the patterns seen in North Atlantic sea surface temperatures and associated climate change.

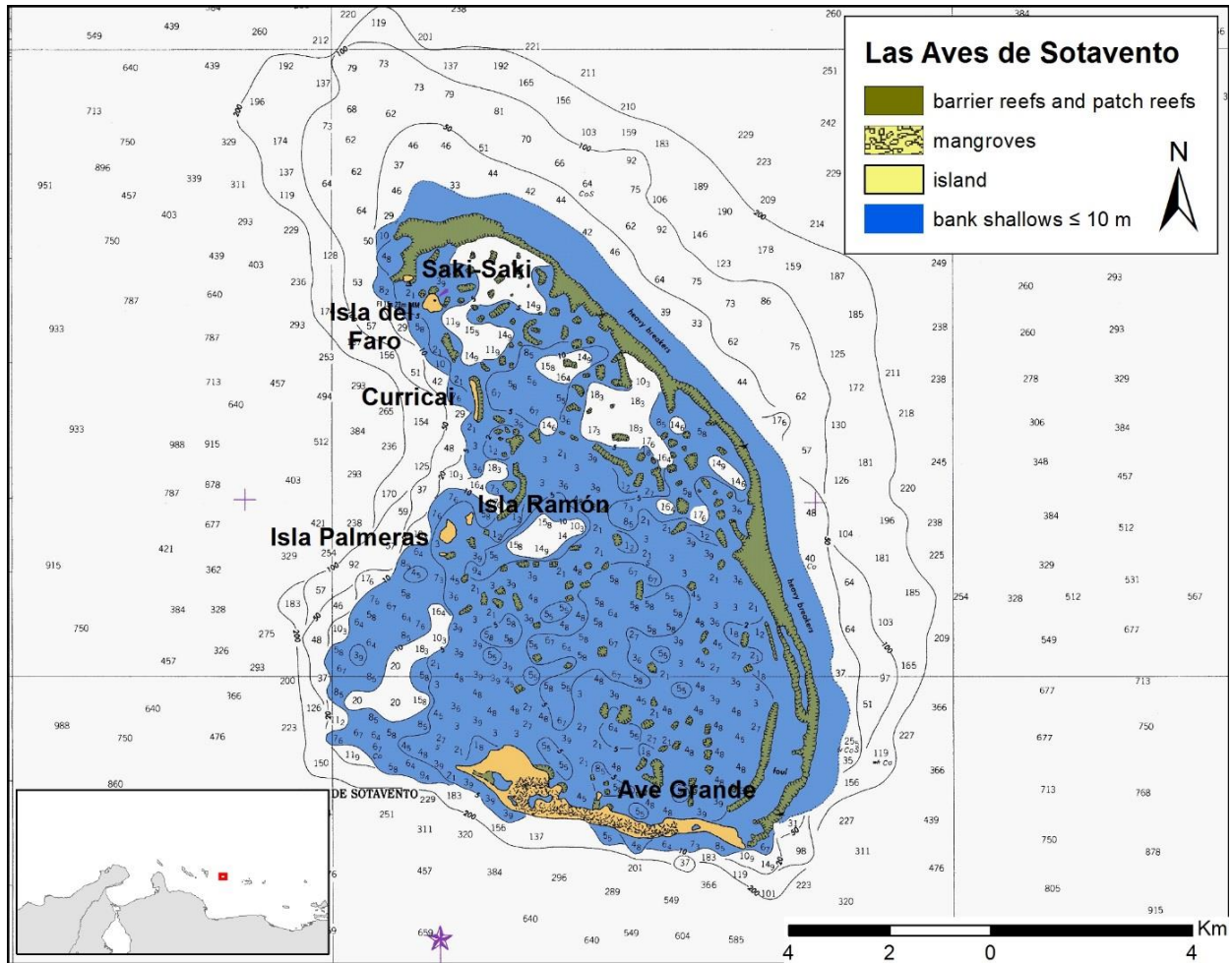


Figure 3. Bathymetric map showing the main features of the Sotavento group of the Las Aves archipelago, Venezuela. Source map: U.S. Navy Survey 1939.



Figure 4. Drone image of a section of the Aves de Barlovento islands, Venezuela, November 2016. (Photo: J. van Eenennaam).

BIODIVERSITY AND ECOLOGY

Marine biodiversity

Together with the ABC islands of the Dutch Caribbean, both archipelagos lie in an area of exceptional biodiversity (Miloslavich 2010). Bustamante (2002) and Bustamante & Paris (2008) identify the southeastern Caribbean islands (from Bonaire to Los Roques) as an ecoregion without a World Heritage Site (WHS) and thus highlight the value of designating such an area. They consider that a WHS based on one or more islands or island groups in the Southeastern Caribbean Islands ecoregion will meet the following criteria: 1) outstanding biological and geological value; 2) relatively high conservation status; 3) threatened by current or potential intensive use (tourism and fishing); 4) include no-take areas; 5) serve as a focus for local, national and international conservation efforts and organizations; and 6) located in a marine ecoregion with poor WHS representation (Bustamante & Paris 2008). Additionally, since 2003 the Venezuelan Foundation Caribe Sur (www.caribesur.org) has been actively promoting the creation of a connected marine Biosphere Reserve, including Los Roques, Las Aves and La Orchila. Moreover, the foundation supports the declaration of Las Aves as a National Park and the integration of these islands with Curaçao and Bonaire as a transboundary marine ecological corridor in the southern Caribbean. This idea is also supported by the Dutch government (Debrot et al. 2018).

Los Roques is home to about 69 species of corals (Weil 2003), 200 species of crustaceans, 140 species of molluscs, 45 species of echinoderms, 77 species of sponges (ParksWatch 2002, but see also Diaz et al. 1987 and Alvarez et al. 1990) and about 307 species of fish, including 23 species of sharks (Ramírez & Cervigón 2003, Tavares 2005). Much more information is available on the biodiversity of the ABC islands than for the Venezuelan archipelagos discussed here. This is in part reflected in a much lower documented species number per km of coastline for Venezuela, which averages 37 species per km of coastline than for the ABC islands which average 117 species per km of coastline (Miloslavich et al. 2010). However, even much less remains known about the coral reefs of the Las Aves archipelago than about those of the Los Roques archipelago. To help draw attention to the biodiversity of these areas and to serve as a primer to further initiatives, we here present a new ecological and conservation synthesis and bibliography.

Early information on the biodiversity of the Aves islands are given by Wagenaar Hummelinck (1940), Buissonjé et al. (1957), van der Werf et al. (1958) and Ginés & Yepez (1960). Weil (2003) suggested Las Aves as a good candidate for a natural sanctuary area or national coral reserve based on the exceptional state of its reefs, but was unable to add new information on this island group. According to Robertson et al. (2005), whom studied growth and longevity in the abundant reef herbivorous fish *Acanthurus bahianus*, of Las Aves, the habitats of Las Aves are directly comparable to those of Los Roques while Cervigón (1989) also emphasizes the similarity of the fishery resources of the two island groups. In 2011, 14 coral species and between 20% and 40% of coral cover was documented from a number of stations in the Aves islands by A. Yranzo and E. Villamizar (unpublished data). Alevizon & Brooks (1975) reported coral cover levels as high as 75%–85% three and a half decades earlier. The coral diversity of Los Roques is the highest documented for Venezuela and is among the highest in the Caribbean (Weil 2003). Weil (2003) lists sixty-nine species for the archipelago, including non-reef building species. Weil (2003) reported coral cover values varying from 65% for the exposed reefs of Cayo Sal and 25% for lagoonal patch reefs in well-circulated waters. The reefs are well-developed and diverse, with underwater caves and terraces at depths of 20 and 45 m (Weil 2003). Octocorals and sponges are also numerous (Alvarez et al. 1985). Schweizer et al. (2005) provide a basic habitat map of benthic habitats and submerged vegetation for Los Roques.

Of all crustaceans, lobsters have the highest economic value and tradition of fishing in Los Roques. The three species reported for Venezuela, *Panulirus argus*, *P. guttatus* and *P. laevicauda* are present. The most abundant of these species is *P. argus* and has been studied in the archipelago by many authors (Cobo et al. 1972. Ginez et al. 1978; Ginez & Rodriguez 1979; Soriano 1984; Hauschild & Laughlin 1985; González & Posada 1988). For the 1998/99 fishing season Yallonardo et al. (2001) documented Catch per

Unit of Effort in the fishery at an average of 2.3 kg/trap/month and 156 kg/diver/month and found these values stable compared to values documented back to the early 1980s. This suggested a stable lobster population even though catches were 40% lower than formerly. This decline in catches was ascribed to the lower number of fishing licences granted and lower numbers of total traps used in the fishery. Recent quantitative lobster stock assessments are lacking, so the current population status of the species remains unknown. Losada-Tosteson & Posada (2001) found artificial reefs made from used tyres to be useful as shelters for juvenile lobsters.

The oldest major contribution on mollusks comes from Work (1969) who discusses the ecology and systematics of 125 species of molluscs of Los Roques. Los Roques is also home to the rare endemic cone shell, *Conus duffyi*, a species listed as VU by the IUCN Red List (Petuch 2013b). More recently, this species has been considered to be a subspecies of *Conus mappa* (Kohn 2014). More recently, Jimenez et al. (2014) described no less than 49 species of mollusc associated with the reef-building *Orbicella annularis*. The queen conch or pink conch (*Lobatus gigas*) is one of the largest gastropod mollusks of the Caribbean region and is a very important species for Los Roques and Las Aves (Schapira 2007). Los Roques formerly supported a large population of this species (Fernández 2002). Brownell (1977) and Weil & Laughlin (1984) studied reproduction and growth in various *Lobatus* species of Los Roques. At the regional level, there are various governmental agreements for the extraction and marketing of this mollusk in the Caribbean. *Strombus gigas* is included in the list of Endangered Species of the World Conservation Union (IUCN), and in November 1992 was included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The species was formerly common along the whole coastline of Venezuela but with highest densities in the Venezuelan Caribbean islands. In the 1980s, 98% of the total national conch production came from the Los Roques and Las Aves islands but densities plummeted by more than 95% (Posada 2015). In 1999, Sweizer & Posada (2006) conducted conch surveys for Los Roques and documented mean population densities of 19 conch per ha, which is much lower than the minimum mean density of 100 adult conch per ha required in healthy breeding populations (Stoner et al. 2012, Stoner & Ray-Culp 2000). In 2000, a general moratorium was established for capture of conch, prohibiting take throughout the year for all of Venezuela (Posada 2015). Today the illegal harvest continues, mainly from Los Testigos and Las Aves (Posada 2015). Various informal accounts of conch fishing in the Aves islands are known to us, notwithstanding the continuous presence by the Venezuelan coastguard there. Hence, enforcement remains very problematic. Some studies suggest partial recovery of conch populations in localised areas of the Los Roques national park thanks to better control and compliance (Posada 2015).

Several additional recent marine biological inventories have been conducted for Los Roques. Information on marine macroalgae and seagrass beds of Los Roques are given by Vera (1993), Garcia & Gomez (2007) and Gomes et al. (2013). Gomez et al. (2014) described no less than 53 species of macroalgae associated with reefs between 12m and 22 m. More than half of the macroalgae species found constituted new records for Los Roques (Gomes et al. 2013) and indicate that the total flora should be much larger than presently known. Ballantine et al. (1994) describe an unusual benthic assemblage of algal balls that appear to imprison small fauna. Noriega & Fuentes-Carrero (2014) recently document 45 reef-associated echinoderms, Pérez-Castresana et al. (2014) provide new information on 57 species of reef-associated phytoplankton, while Yranzo & Villamizar (2014) describe 22 species of reef-associated octocorals (Figure 5).

Lopez et al. (2008) studied cryptofauna associated with dead coral colonies. The most abundant taxonomic groups found were sipunculids (57.3%), followed by polychaetes (20.5%), and crustaceans (14.8%). Grajal & Laughlin (1984) described 30 species of decapod crustaceans inhabiting dead and live coral heads of *Acropora* species while Villamizar & Laughlin (1991) document no less than 147 species of fauna associated with the sponges *Aplysina archeri* and *A. lacunosa*. Diaz et al. (2014, 2015, 2016a, b) extensively documented the polychaetes from reef stations in Los Roques. Cavada-Blanco et al. (2016) studied microphytoplankton in relation to coral spawning and found chlorophyll a concentrations to



Figure 5. Luxurious octocoral stands at Cayo Sal, Los Roques Archipelago, 2015. (Photo: A. Yranzo).

increase during and after the spawning events. This increase correlated with changes in the phytoplankton species composition and particularly with an increase in heterotrophic and mixotrophic dinoflagellates. Hudec & Sonnefeld (1974, 1980), Sonnefeld & Hudec (1977) and Sonnefeld et al. (1976) studied temperature and salinity stratification and chemistry of the Lago Pueblo heliothermal salt ponds of Gran Roque, Venezuela (and Janthiel in Curaçao). Finally, Petrash et al. (2012) studied thrombolites created by microbial mats in the shallow waters of a restricted hypersaline lagoon at Los Roques and generated insights with which to better understand lithification in Precambrian microbialites. Gingras et al. (2011) describe how burrowing animals are able to live in oxygen-depleted hypersaline waters by association with cyanobacterial mats and suggest early mobile animals may have evolved similarly in the Ediacaran epoch (about 555 Ma).

As is also the case in the Caribbean and worldwide, diverse factors such as diseases and climate change have been causing the decline of reefs from Los Roques National Park (Villamizar 2014). The area has also been found to be vulnerable to changes in regional oceanographic processes, in particular changes in wind-induced upwelling (Villamizar & Cervigón 2017). Cróquer et al. (2016) present evidence that the coral *Acropora palmata* has lost almost 50% of its original distribution in Los Roques in recent decades. While this level of loss is much lower than most other areas of the Caribbean, it does highlight the continued vulnerability of this species to global threats such as ocean warming. Notwithstanding important outbreaks of white band disease among the acroporid corals of Los Roques (Cróquer et al. 2005), the park protects one of the few areas of the Caribbean that has retained relatively high densities of *Acropora* reefs (Zubillaga et al. 2005, Villamizar et al. 2014, Cróquer et al. 2016) since the mid-1980 when the species declined precipitously throughout the Caribbean. Zubillaga et al. (2008) found important

signs of population recovery for the species three decades after the Caribbean-wide mass mortality took place.

Coral bleaching and disease are also documented problems in various species. Bastidas et al. (2012) describe extensive coral mortalities in Los Roques after a major bleaching event in 2010. For instance, on a monitoring reef, declines in coral cover between 1999 (Villamizar et al. 2003) and 2011 amounted to an average of ~37% (Villamizar et al. 2014). Verde et al. (2016) studied Caribbean ciliate infection and white band disease in three massive reef-building coral species (*O. faveolata*, *O. annularis* and *A. cervicornis*) and documented the highest vulnerability to infection for *Acropora cervicornis* and low tissue recovery rates for all three species. Nevertheless the barrier reefs, fringing reefs, patch reefs and bank reefs of this park remain the most coral-diverse oceanic reef system of Venezuela, and one of the best conserved and most resilient in the Caribbean. Cróquer et al. (2002) document high recovery rates for *Montastrea annularis* coral tissue lesions simulating damage. Humanes & Bastidas (2015) document recent high coral settlement and post-settlement survival rates for corals in Los Roques and higher survivorship on reefs with higher live coral cover. All in all, the results indicate vulnerability of the coral communities but also encouraging degrees of resilience under the reigning abiotic and biotic conditions and current anthropogenic exploitation levels.

Several studies have focussed on fish biodiversity. Alevizon & Brooks (1975) reported 44 species of fishes from patch reefs in the Aves islands. Croquer et al. (2010) discuss 2003 and 2004 monitoring data on the benthic and fish communities of Dos Mosquises Sur and Madrizquí at Los Roques National Park, and in Morrocoy National Park on the Venezuelan mainland coast. While as with coral communities, fish



Figure 6. Large coral formations, high coral cover and adult Schoolmaster Snapper (*Lutjanus apodus*) at Madrizquí island, Los Roques Archipelago, March 2015. (Photo: A. Yranzo).

community structure did not change over time, and fish communities were dominated by herbivores (Pomacentridae, Scaridae and Acanthuridae), large piscivores (e.g. Lutjanids and Serranids) were significantly more abundant in Los Roques than in Morrocoy (see also Posada et al. 2003). However, fish densities were especially high in protected areas; for example: 9.30 ± 3.79 ind/1,000 m² were recorded in Los Roques, where fishing is restricted (Debrot et al. 2008). Cervigón (1989) reported a fleet of 30 vessels registered in La Guaira as stationed in the Aves islands and targeting snappers and groupers by means of a combination of hook-and-line and fish traps. During a one-week visit to Aves de Barlovento, in November 2016, J. van Eenennaam observed ample Baracuda, *Sphyraena barracuda*, Bar Jacks, *Caranx ruber*, Spanish Mackerel, *Scomberomorus maculatus*, Cero Mackerel, *S. regalis*, Wahoo, *Acanthocybium solandrii*, Silk Snapper, *Lutjanus vivanus*, Queen Snapper, *Etelis oculatus*, Vermillion Snapper, *Rhomboplites aurorubens*, Red Hind, *Epinephelus guttatus*, Yellow-mouth Grouper, *Mycteroperca interstitialis*, Amberjack, *Seriola* spp., Black Jack, *Caranx lugubris*, and also large West-Indian topshell, *Cittarium pica*. This might suggest that the populations of large reef and reef-associated piscivores are still in fairly good condition in the Aves islands. For both island groups the rarity or even absence of typical continental shelf species (e.g various scianids) are characteristic of oceanic reef fish faunas, similar to the nearby oceanic reef islands of Curaçao and Bonaire (e.g. Luckhurst & Luckhurst 1978, Bruckner & Bruckner 2003, Sandin et al. 2008). Growth and longevity data are available for key reef herbivorous fishes from Los Roques (Choat et al. 2004, Robertson et al. 2005) and Las Aves (Robertson et al. 2005). Boomhouwer et al. (2010) and Romero et al. (2011) tried to predict and verify spawning aggregation sites at Los Roques based on physical reef characteristics and local fisherman knowledge. Elise et al. (2017) compared fish populations of 21 areas including Marine Protected Areas throughout the Caribbean. Of these Los Roques Archipelago, was the most isolated. They found that Los Roques displayed the highest species richness, density of piscivores, and abundance of large species of all areas studied and recommend that Los Roques may serve as a benchmark for healthy reef fish assemblages in the Caribbean (Figure 6). Lasso-Alcalá & Posada (2010) document the first arrival of the invasive Lionfish, *Pterois volitans*, to the reefs of Los Roques in December 2009. Elise et al. (2015) further find evidence to suggest that the healthy species composition of the fish assemblages of Los Roques might even help resist early impacts of the Lionfish invasion.

For Los Roques, up to a total of 23 species of sharks have been reported, some of which are resident while others are only frequent or temporary visitors because of their oceanic or migratory habits. The most common species are Blacktip sharks, *Carcharhinus limbatus*, Caribbean reef shark, *Carcharhinus perezi*, Lemon shark, *Negaprion brevirostris* and Nurse shark, *Gynglostoma cirratum*. Through studies (mark-recapture) by Tavares (2001a, 2001b, 2005 and 2007) it has been determined that Los Roques is a shark nursery area where the young are born and remain until reaching adulthood. Towards implementing its Plan de Acción Nacional (PAN) for the conservation for sharks, in June 2012 Venezuela designated Los Roques as a shark sanctuary (Official Gazette N°39.947). Additional research (e.g Tavares 2005, 2008, 2009) had also demonstrated the importance of the shallow areas of Los Roques lagoon as a shark nursery area. More recently, Tavares et al. (2016) found clear indication of partitioning of Lemon shark nursery habitat use into primary and secondary nursery areas as well as spatio-temporal partitioning of habitat use by distinct shark size classes at Los Roques.

Four sea turtle species nest in Los Roques (Guada 2003). Of particular importance are the nesting beaches for the Hawksbill turtle, *Eretmochelys imbricata* (De los Llanos 2002). Hunt (2010) recently mapped aquatic habitat use by Hawksbill turtles for Los Roques where data for the period 2002 to 2006 suggest a stable or even increasing Hawksbill population in Los Roques (de los Llanos 2002, FCLR 2007). Approximately 200 sea turtle nests annually in Los Roques of which about 70% are Hawksbills (Hunt 2010). Guada & Solé (2000) mention nesting records for the Leatherback turtle in Las Aves and the importance of Las Aves as a foraging ground for the Green turtle. In November 2016, J. van Eenennaam photographed a recently hatched Hawksbill turtles on the beach of Isla del Tesoro, Aves de Barlovento, documenting the first record of use of the extensive beaches of this island group by this critically endangered species. From the historical review of sea turtle exploitation in Venezuela by Antczak et al. (2007), it is clear that the Aves archipelago must have experienced intensive sea turtle

hunting during the Venezuelan colonial (16th – 18th century) and republican times (19th century). No recent sea turtle nesting assessments are available for the Aves islands, but this could be intensive based on what is also known for comparable beaches in nearby Bonaire (STCB 2015). Becking et al. (2016) studied post-breeding migration of sea turtles in Curaçao and Bonaire and found that adults of three species that nest in the Dutch leeward islands migrated across the Aves islands to Los Roques. Hence, Los Roques, but possibly also Las Aves, seem to offer important foraging areas for the nesting turtles of the Dutch islands. Guada & Solé (2000) point to the need for a systematic assessment of sea turtle nesting beaches for Venezuela to include the Las Aves islands. For the period spanning 1992-2005 Bjorkland (2011) documents numerous mortalities of the Leatherback turtle in long-line fisheries that take place targeting pelagic fishes around the Aves and Los Roques archipelagos. This species is the most common species of sea turtle caught as bycatch in the Venezuelan longline fishery.

Los Roques is visited by at least eight cetaceans. Acevedo (2001) lists Bryde's whale, *Balaenoptera edeni*, Humpback whale, *Megaptera novaeangliae*, Common dolphin, *Delphinus* sp., Atlantic spotted dolphin, *Stenella frontalis*, Spinner dolphin, *Stenella longirostris*, and Bottlenose dolphin, *Tursiops truncatus*. Recent published cetacean records for these archipelagos are given by Halewijn & van Bree (1972), Romero et al. (2001), Swartz et al. (2003) and Bolaños et al. (2014), namely for *Megaptera novaeangliae* (Las Aves), Killer whale, *Orcinus orca* (Los Roques), False killer whale, *Pseudorca crassidens* (Las Aves and Los Roques) and *Stenella longirostris* (Las Aves) and effectively add two species to the list already compiled by Acevedo (2001) for these two archipelagos. Many more species, such as documented for the nearby Dutch Caribbean, can be expected (Debrot et al. 1998). Romero et al. (1991) also list a likely yet unconfirmed sighting for Sei whale, *Balaenoptera borealis* for Los Roques.

Terrestrial Biodiversity

The terrestrial flora of Los Roques amounts to 34 plant species, most prominent of which are three mangroves: the Red mangrove, *Rhizophora mangle*, Black mangrove, *Avicennia germinans*, White mangrove, *Laguncularia racemosa*, as well as the Buttonwood, *Conocarpus erectus* (Figure 7). The vegetation includes several catci such as melocacti, *Opuntia* and candelabra cacti primarily on Gran Roque (Inparques 2017). Burandt & Campins (1986) studied floral records for Gran Roque spanning a period of 107 years and conclude that colonization by new plant species was especially related to the shift from a primarily fishing economy to a tourism-dominated economy. Woody aboriginal species were found to be especially vulnerable to extinction which was especially ascribed to limited habitat availability by Burandt & Campins (1986). Suarez-Villasmil et al. (2012) give preliminary assessments of the insect and spider fauna of *Sporobolus virginica* grassland vegetation of Los Roques. Only three beetle species have so far been documented for these islands (Marcuzzi 1977, Peck 2011). For Las Aves, Ginés & Yopez (1960) produce a list of 20 terrestrial plants documented for the archipelago and various natural strand vegetation communities based on pioneer species and hardy salt-tolerant species. All three species of true mangroves are present, as well as the Buttonwood, *Conocarpus erectus*. On populated islands, strand vegetation is often threatened due to coastal development and recreational activity and has often become rare or strongly degraded, such as is generally the case in the nearby islands of Bonaire and Curaçao (Beers et al. 1997, Freitas et al. 2005). Due to their low levels of human presence and with the descriptions by Ginés & Yopez (1960) it appears evident that the Aves islands must still possess some of the least-disturbed and best-conserved strand vegetations of the southern Caribbean. However, no recent vegetation assessments are available.



Figure 7. Black mangrove stand (*Avicennia germinans*) on Isla del Tesoro, Aves de Barlovento islands, Venezuela, November 2016. (Photo: J. van Eenennaam).

Bisbal (2008) discusses the terrestrial vertebrates of these island groups, most of which are birds. In total he lists eight endemic terrestrial taxa for Los Roques and two for Las Aves. In 1973, LeCroy (1978) documented 37 species of birds during six weeks on Francisquí, Los Roques. Since then, 104 bird species, more than half of which are migratory, have been documented from the archipelago (Bisbal 2008) and new species continue to be added (e.g. Fernández-Ordóñez et al. 2015). Important nesting colonies can be found of the Brown pelican, *Pelecanus occidentalis*, the Red-footed booby and Brown booby (respectively, *Sula sula* and *S. leucogaster*), the Laughing gull, *Larus atricilla*, the Common, American least, and Bridled terns (respectively, *Sterna hirundo*, *Sternula antillarum*, *Onychoprion anaethetus*), the Brown noddy, *Anous stolidus* and the Lesser noddy, *A. minutus* (Luy 1997, Lentino & Rodner 2002, Bosque et al. 2002, Esclasans 2003, Esclasans et al. 2009). At least 50 breeding pairs of the Lesser noddy, a species critically endangered in the Caribbean have been recorded in Los Roques National Park (Lentino & Esclasans 2009, Esclasans 2003). Los Roques also possesses the second-largest breeding colony of Brown pelicans of the Caribbean (Lentino & Esclasans 2009). Halewijn (1972) indicated that the offshore waters north of Los Roques and east to Los Hermanos (Venezuelan islands) was an important feeding area for Audubon's shearwater, *Puffinus lherminieri*. The robbing of eggs remains a major problem in Los Roques (Lentino & Esclasans 2009). A black-colored subspecies of the Bananquit (*Coereba flaverola lowii*) is endemic to Los Roques while the local Yellow warbler, *Dendroica petechia obscura* and Common ground-dove, *Columbina passerina tortugensis*, are only found in the Venezuelan Caribbean islands (Lentino et al. 1994). Four other southeastern Caribbean endemics shared with the nearby Dutch islands are the White-tailed nightjar, *Caprimulgus cayennensis insularis*, the Black-whiskered vireo, *Vireo altiloquus bonairiensis*, the Scrub flycatcher, *Sublegatus modestus pallens*, and the Brown-crested flycatcher, *Myarchus tyrannulus brevipennis* (de Schauensee & Phelps 1978, Voous 1983). Because of its exceptional value as a seabird breeding area, Birdlife International recognizes the Parque Nacional Archipiélago Los Roques as one of Venezuela's 72 Important Bird Areas (IBA's) (Lentino & Esclasans 2009, Denevish et al. 2009). Based on recent surveys, Bosque et al. (2015) conclude that, in contrast to many other areas in the Caribbean where seabird nesting populations have been in decline, all the major

seabird nesting colonies of Los Roques National Park as documented 45 years earlier, were still active in 2001 and maintained comparable breeding populations.

For the Aves islands, Ginés & Yepez (1960) listed 46 species of birds, of which only two could be confirmed as breeding land birds (the Yellow warbler and the Brown-crested flycatcher). Bisbal (2008) expands the bird list to 58 species and adds the Grey kingbird, *Tyrannus dominicensis*, which might possibly be a breeding species. During a brief visit to the main island Aves de Barlovento on 19 November, 1971, several of the bird species reported before by Ginés & Yepez (1960) were observed, including Great egret, *Ardea alba*, Sanderling, *Calidris alba*, Yellow warbler, *Dendroica petechia* and many Barn swallows, *Hirundo rustica*. (R. van Halewijn, pers. comm., based on field notes). The following eleven seabirds can be confirmed as breeding on the Aves islands: Brown pelican, Brown booby, Red-footed booby, Laughing gull, Common tern, American least tern, Bridled tern, Sooty tern, Sandwich tern, *Thalasseus sandvicensis eurygnatha*, Royal tern, *Thalasseus maximus*, and Brown noddy, *Anous stolidus*. However, quantitative estimates are rare. On a small key, Ginés & Yepez (1960) observed 700–800 Brown booby nests and 1,800–2,000 birds, about half of which were chicks. For Isla del Tesoro they reported seeing about 200 nests of the Red-footed booby up to 7 meters up in the Black mangroves, no less than 300 nests of the Brown noddy, about 2,000 nesting individuals of the Bridled tern and 40 nests of the Laughing gull. The Brown noddy was found breeding on many other islands and keys in the group including Saki-saki and Ave Grande (Ginés & Yepez 1960). The Laughing gull was found nesting on at least three other islands while the Bridled tern was found by nesting by the thousands on Saki-saki, especially in association with the prickly pear, *Opuntia wentiana* (Ginés & Yepez 1960). On a tiny key next to Saki-Saki, Ginés & Yepez (1960) further found 200 nesting Royal terns and between 1,500 to 2,000 nesting Sandwich terns. According to Ginés & Yepez (1960) the Royal tern nested most numerous on another island they referred to as the Islote de Tirras. Although not confirmed by Ginés & Yepez (1960), the threatened Lesser noddy was seen by them to be numerous on both Aves de Sotavento and Barlovento and considered to be likely breeding. In 1972, the number of breeding Red-footed boobies on Isla del Faro were at well above 1,000 birds (Halewijn, pers. comm.). In 1973 in the Aves Islands, there was extensive breeding by both Brown boobies (on the ground) and Red-footed boobies (in the mangroves) at the westernmost anchorage of Isla del Faro, Aves de Barlovento (A. Debrot, pers. obs.). At that time fishermen robbed booby nestlings to use as bait in fish traps (pers. comm., A. Debrot). According to Halewijn (1972) the Sandwich tern nests each year in the Aves and Los Roques islands. During pelagic cruises in the southeastern Caribbean, Halewijn (1972) reported large numbers of Brown noddies feeding offshore around the Las Aves and Los Roques, while Murphy (2000) indicated Jaeger species (*Stercorarius* spp.; principally *S. pomarinus*, but also *S. parasitica* and *S. longicaudus*) to be numerous off Aves de Barlovento and off Los Roques where they were seen harrassing boobies. When departing Aves de Barlovento on 20 November 1972, a single Red-billed tropicbird, *Phaethon aethereus*, was further seen over deep waters (Halewijn, pers. comm., based on field notes). In conclusion, today, according to various reports, both Aves de Sotavento and Barlovento remain major seabird rookeries for both boobies and various species of tern (Figure 8). Unfortunately no recent quantitative assessments are available.

Terrestrial reptiles of the Los Roques and Aves islands include the endemic lizard subspecies *Gonatodes vitattus roquensis*, *Cnemidophorus nigricolor* (SCNLS 1956) and *Gymnodactylus antillensis*, a species also found in Bonaire, Curaçao and La Orchila. Bisbal (2008) lists nine reptile species for Las Aves and six species for Los Roques. Rivas et al. (2012) document the presence of *Anolis bonairensis* for Las Aves. Most recently, Ugueto et al. (2013) also established the presence of *Gymnophthalmus lineatus* and *Thecadactylus rapicauda* for the Aves archipelago. The only native land mammals of the islands appear to be the fishing bat, *Noctilio leporinus* (Gondelles 1997) and the Big Free-tailed bat, *Nyctinomops macrotis* (Bisbal 2008), both reported for Los Roques. Ginés & Yepez (1960) mention seeing a rodent on Las Aves. Most likely this is an introduced rat (*Rattus rattus* or *R. norvegicus*, see also Bisbal 2008) but it might also be a relic surviving native species like as existed on Curaçao prior to colonization (McFarlane & Debrot 2001).



Figure 8. One of about 50 nests of the Brown Booby, *Sula leucogaster*, on Isla del Tesoro, Aves de Barlovento, November 2016. (Photo: J. van Eenennaam).

HISTORY AND ECONOMY

The pre-colonial archaeology of Los Roques and Las Aves has been rather extensively reported (Antczak 1991, 1993; Antczak & Antczak 1991, 1999, 2005; Antczak & Antczak 2015; and Antczak et al. 2017). These islands were regularly visited by Amerindian peoples especially to harvest conch, sea turtles (probably for oil) and seabirds (especially boobies). Antczak et al. (2017) document clear differences in prehistoric harvesting practices for different bird species and suggest that because of human hunting, bird distribution and even nesting habits may have differentiated between species. Hence, the greater isolation of the Aves islands from human exploitation and their restricted suitability for human habitation may underlie their special importance as seabird rookeries and, according to Cervigón (1989), is even the basis for their name. Prehistoric use of the Aves islands seem to especially have focussed on the Aves de Sotavento group as only the island of Ave Grande (also known as Isla Larga), has potable brackish water throughout the year (Antczak & Antczak 2015). Antczak & Antczak (2015) find evidence that the Aves islands were a late preColumbian meeting place between mainland Valencioid and western insular Dabajuroid cultures. However, during the colonial epoch the Valencioid peoples no longer used these islands. Antczak & Antczak (2015) suggest that this may have been due to the fact that the Valencioid groups continued to be at war with the Spanish until the early 16th century and were much more vulnerable to the Spanish during their long-distance (150 km) crossings to the islands. In contrast, the Dabajuroid peoples were at peace with the Spanish and accessed Aves from the nearby (57 km) island of

Bonaire. They continued using these islands well into the early colonial period and even expanded their use to the Barlovento cluster (Antczak & Antczak 2015).

In 1866, the Dutch began extraction of guano from Los Roques. Many current names of keys in the archipelago originated during this period when these islands still had no permanent habitation (e.g. Northeast Key: Nordisquí, Sails Key: Selesquí) (ParksWatch 2002). Las Aves also possess 19th century ruins relating to guano extraction. While the archipelagos have further been used by man since prehistoric times as a conch fishing area (e.g. Schapira et al. 2009), permanent habitation only began about the middle of the 20th century and has remained limited to the Los Roques archipelago (ParksWatch 2002). Human impact on the flora and fauna from 19th century phosphate mining can be expected to have been large. Phosphate mining not only removed much vegetation but lowered the level of the affected islands, exacerbating vulnerability of the vegetation to storm surge, salt spray exposure and likely even impacted subterranean freshwater availability. All this, as well as possibly directed hunting and harvest for consumption has undoubtedly impacted larger terrestrial vertebrates. One example is the green iguana, *Iguana iguana*, for which Wagenaar Hummelinck (1940) lists a single early record for the Aves de Sotavento group but which is likely no longer present. An early record, but likely subsequent extirpation, of Boddaert's tropical racer snake *Mastigodryas boddaerti* from Aves, also suggests a once more resilient terrestrial ecosystem than the current situation. Hence, the current terrestrial fauna and flora of the Aves islands are no doubt much less diverse than they once were prior to the late 19th century mining exploitation.

As largely uninhabited areas, these archipelagos have played no major roles in written colonial history apart from one notable incident dating from 1678. After conquering Tobago from the Dutch in December 1677, a French fleet under command of vice-admiral Count Jean D'Estrées struck the reefs of the Aves islands in May 1678 while underway to attack Curaçao. With the loss of 17 vessels of the French Caribbean fleet, Curaçao was spared a major confrontation (Hartog 1961). While since 1938 the Aves islands formed part of the Venezuelan Federal Dependencies (Dependencias Federales), in 2011 they were administratively integrated into the "Miranda Insular Territory" (Territorio Insular Miranda) for which the main seat is Gran Roque. This is the main populated island of Los Roques National Park. Since 1963, the Los Roques Scientific Foundation (FCLR), has run a Marine Biology Station on Dos Mosquises Island. Until 2010, science at the station resulted in 105 scientific publications, 16 technical reports, 58 thesis and 28 other reports and publications (Molina 2010). However, in 2014 the government revoked the concession to the FCLR (Decree 0270 published in the Official Gazette N. 40.443, June 30, 2014) and passed it over to the organization named FUNDAMAR, which has yet to get started.

Lobster fishing has long been an important fishery in Los Roques. This industry is centred around the village of Gran Roque Island with about 1500 inhabitants (Instituto Nacional de Estadística, 2014) and produces approximately 40% of the lobster for consumption in Venezuela. About 20,000 kg of lobster are extracted annually during the season by roughly 228 fishermen (Insopesca, pers. comm.). In recent years, tourism has replaced fishing as the main economic activity. More than 75,000 tourists visit annually (Inparques 2017), staying in one of the 60 available lodges. Garcia-Melon et al. (2012) studies stakeholder views according to an Analytic Network Process based on questionnaires. They conclude that over the last decades, since the park's inception in 1972, the interaction between the various stakeholders of the park (tourists, inhabitants, authorities, environmentalists, tour operators, etc.) appear to have effectively converged to a common and largely shared vision regarding sustainable development for Los Roques.

NATURE MANAGEMENT

Los Roques is managed since 1972 by the National Park Institute (INPARQUES- Official Gazette N° 4.106; Decree N° 276) and the Territorio Insular Francisco de Miranda (Official Gazette N° 39.797) is responsible for administrative aspects since 2011. Spearfishing in Los Roques has been prohibited since 1972 while fishing with nets has been prohibited since 1992 (Elise et al. 2015). Posada (1992) provided a basic overview of the fishery resources of Los Roques, which were principally coral reef-based and

primarily consisted of fish, conch and lobster (respectively, 55.8%, 27.3% and 16.9% by weight and 29.8%, 21.3% and 48.9% by market value). He warned of potential over-exploitation and stressed the need for diversification of the fishery towards underutilized species. Towards this goal, Brownell et al. (1977) described laboratory rearing and aquaculture potential of the West Indian spider crab, *Mithrax spinosissimus*, listed by Posada (1992) as a significant but underutilized artisanal fishery resource. Another common and formerly abundant shellfish resource is the West Indian topshell, *Cittarium pica*. The most recent population assessment for this species in Los Roques was provided by Castell Perez (1987). The species is of significant aquaculture potential (Bell 1992, 1996) and following the conch, is the second-most important gastropod resource of the Caribbean. High catchability and yield-per-recruit calculations based on growth and fecundity parameters predict that the species should be quite vulnerable to recruitment overfishing (Debrot 1987). While the species remains an important fishery resource in several areas of the Caribbean (e.g. Nelson and Oxenford 2013) it is generally overfished, as it also is in Los Roques (Bastidas et al. 2015). Debrot & Posada (2004) describe the catch and release, recreational Bonefish (*Albula vulpes*) fishery based on licensed fishing guides in Los Roques and 400 visiting anglers annually. Weinberg & Posada (2008) describe the diet of this species of commercial sportfishing value. Finally, Ortaz et al. (1996) provided information on two clupeids of commercial importance. Bjorkland (2011) documents intensive pelagic long-line fisheries that take place all around Aves and Los Roques. These are based on long-liners coming from the mainland ports and not on fishermen operating from the islands proper.

The management plan includes a user zoning plan and distinguishes seven management zones. This zoning plan is currently being updated (Taller de Trabajo para la Elaboración del Documento Técnico de la Propuesta de Revisión y Actualización del Plan del Parque Nacional Archipiélago Los Roques; Min. Poder Popular para Ecosocialismo y Aguas). The task of nature management falls under the National Parks Institute (INPARQUES), while fishery management is the responsibility of Ministry of Fisheries and Aquaculture, through the Socialist Institute of Fishing and Aquaculture (INSOPESCA) in cooperation with INPARQUES and the National Guard. Up to 2002, INPARQUES had seven park guards and one superintendent based on a small annual budget of about US\$ 30,000. This was only a small portion of the funds collected by the authorities for the stated purpose of park management (US\$ 418,505 from entrance fees alone) (ParksWatch 2002). The current situation is not well known because of the lack of official information.

Lack of staff and funding has meant that illegal fishing and overfishing has always been a serious problem (ParksWatch 2002, Weil 2003). When the lobster season is closed from February through September, queen conch poaching intensifies (Matos 2000). Fishing in restricted zones is a frequent occurrence as is under-reporting of catches (up to 80% under reporting) and the poaching of sea turtles. Venezuela is signatory to various international treaties to protect sea turtles and, while indigenous people are partially exempted, has enacted national legislation to prevent sea turtle consumption (Barrios-Garrido et al. 2017). In principle, sea turtles should be afforded full protection in the Aves islands. To address these matters, the Venezuelan Ministry of Popular Power for Eco-socialism and Waters oversees an extensive sea turtle conservation and management effort (IAC 2016). In 2002, De Los Llanos (2002) found 30% of the nests laid by the four species of sea turtles to have been poached. In general, management implementation in Los Roques appears weak and vulnerable.

There is no formal nature management regime for the Aves islands other than that it should be expected that the coastguard might partially enforce the conch moratorium and sea turtle conservation measures. As an area without legal protection it can be vulnerable to overfishing without there being any record of it. Furthermore, the Aves islands are regularly visited by touring yachts, especially from the nearby Dutch ABC islands and one worrisome development is the apparently growing interest in kite surfing because this activity can disturb the abundant nesting seabirds. This is particularly the case for the smaller terns which in these islands especially choose to nest in sun-exposed areas of bare coralline sand and rock (e.g. Ginés & Yopez 1960, Debrot et al. 2009). In such areas, disturbance of nests, when the adult birds fly up repeatedly or for prolonged periods, the eggs and chicks can be expected to be vulnerable to heat and desiccation stress.

A significant threat for both archipelagos are pollutants transported with the currents, such as oil spills. In Los Roques the majority of floating garbage gets into the park through the Sebastopol "mouth". The most recent case of a major oil impact was in 2017, with the PetroTrin oil spill originating from Trinidad & Tobago and which impacted Los Roques and others Venezuelan oceanic islands, including probably Las Aves archipelago. Bonaire, Curaçao and Aruba were also affected.

Anthropogenic litter is a big problem in the southeastern Caribbean in which plastics are by far the most common type of litter (e.g., Debrot et al. 1999, 2013). From casual observation, in absence of actual data, it appears as though the beaches of Las Aves have relatively low litter densities and that they might be less vulnerable to the accumulation of litter than other larger, populated islands. Small uninhabited islands not only generate less of their own litter but may also less effectively entrain and entrap beach litter than large islands.

CONCLUSIONS

The Los Roques and Las Aves oceanic archipelagos of Venezuela lie in a biogeographically unique area of the Caribbean (Miloslavich et al. 2010) and possess extensive coral reefs, lagoonal seagrass beds mangroves and shallow macroalgae meadows rich with sea life. The reported similarity of their fauna reflect the ecological connectivity these two areas have and highlight the relevance of establishing legal protection of Las Aves Archipelago which Los Roques already possesses as a managed National Park. Additionally, the evidence available of migration of sea turtles of Bonaire and Curaçao to the Aves and Los Roques, exemplifies the connection between these islands, as part of a biogeographic unity of the Lesser Antilles Ridge islands.

Los Roques and the Aves islands are without question, an excellent partner for a Transboundary World Heritage site nomination, which has long been a Dutch Caribbean ecotourism policy intention (Debrot et al. 2018). As soon as feasible, this very promising option for a transboundary cooperation should be pursued further. As a first important step, the waters surrounding Bonaire also have already been designated as a shark sanctuary (Beek et al. 2014) so collaboration with Venezuela on this highly migratory group of endangered fishes also offers interesting scientific and conservation opportunities.

Given the ecological and conservation significance of the Los Roques and Las Aves archipelagos, it is necessary to implement a proper monitoring program for their marine and coastal ecosystems. A new baseline biological inventory for Las Aves is particularly critical considering the fragmentary information available for this archipelago. A proper ecological assessment is an essential first step towards the conservation of the ecosystems of this important coral reef and seabird nesting archipelago.

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