A SHORT NATURAL HISTORY OF CURAÇAO

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> No man can wash himself in the same river twice, for he will have changed and the river will have changed - *Heraclitus.*

Introduction

The islands of Aruba, Curaçao and Bonaire together with the Venezuelan islands of Los Monjes, Islas Aves, Los Roques, La Orchila and La Blanquilla form an archipelago north of the Venezuelan coast. Of these islands Curaçao is the largest with a surface area of 444 km^2. In this article an overview is given of the changes that have occurred in the natural environment of Curaçao, including the origin of its main geological features such as: Curaçao lava formation, limestone caps, lithification of coral sand and rubble, Knipformation and other phenomena. Changes in climate and sea level, extended dry periods, origins of the flora and fauna, the arrival of man and introduced species, overexploitation, naturalized species and invasive and "alert" species are also discussed.

Geology

Curaçao lava formation: Most of the island of Curaçao is of volcanic origin, this formation is called the Curaçao lava formation. It consists mostly of pillow lavas, with some basalt intrusions. Pillow lavas form when lava is extruded under the sea, in somewhat deeper waters. The water pressure causes the lava to expand slowly like a bubble. Its surface layer is rapidly cooled by the cold water of the sea and a hard crust is formed. Nevertheless the lava keeps expanding and eventually punctures the crust, a new bubble is formed on top or sideways of the previous one and the weight of these bubbles accumulating on top

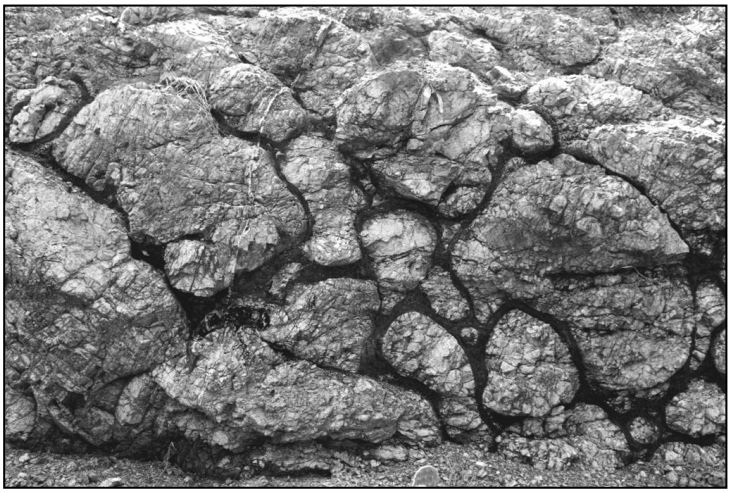

Figure 1 Sections of pillow lavas are commonly seen in Curaçao road cuts; this photograph was taken near Herst.

of each other then causes them to flatten into “pillow”- like structures. Sometimes a new mass of magma pushes through accumulated layers of pillows, thus this magma is cooled more slowly, not being in direct contact with the cold seawater, and basalt intrusions are formed (often both laterally as well as vertically). Later these submarine lavas and basalts were uplifted by tectonic forces and emerged above sea level. It is known that the Curaçao lava formation has a thickness of several kilometers (Klaver, 1987). The gently rolling hills found in most of Curaçao are the eroded surface of this Curaçao lava formation.

Limestone caps: When the island started to emerge from the sea, it eventually reached the zone where light could reach the bottom of the sea and corals and other marine life could start growing in the shallow waters on top of the underlying Curaçao lava formation. These coral formations formed calcareous marine sediments which were converted into limestone rock when they were uplifted above sea level. The oldest limestone caps or ledges are probably of Eocene age and some parts of the islands probably started emerging from the sea by then. Most of the older limestone caps were formed in the Miocene and were subsequently uplifted above sea level. The Panama seaway gradually closed and the oceanic circulation pattern in the Atlantic Ocean and Caribbean Sea changed. This event marked the beginning of the Pleistocene.

In 2009 the International Union of Geological Sciences (IUGS) confirmed a modification in the time period for the Pleistocene, changing the start date from 1.8 to 2.588 million years BP. The Pleistocene was characterized by ice ages, and while in the old days we used to learn at school that during the Pleistocene there were four major ice ages, it is now known there where in fact many alternating colder and warmer periods, each associated with a fall (during glacial periods) or rise (during the interglacials) in sea water levels. There is also some discussion about when to use the term “ice age”. For example, can we truly call any of the shorter periods with somewhat smaller fluctuations in temperatures and sea levels an “ice age”? Nowadays eleven “major” Pleistocene glaciation events and several smaller ones are generally recognized. In the early Pleistocene the island consisted of two separate islands, a Western and an Eastern one, which were later joined together. The lower limestone plateau in Curaçao was formed during the Pleistocene and on the North coast a submerged plateau also exists. At several locations notches in the limestone rocks indicate former sea levels. These were formed when the waters of the sea had stabilized for a period of time at the levels where these notches are found today. Such old sea levels can be correlated with corresponding interglacials, the times between the ice ages when sea levels were higher, and thus these levels can be dated. In practice however this is not so easy, especially as regards the older plateaus. The plateaus continued to be uplifted by tectonic forces and this uplift was not exactly the

same, neither for different islands nor even for different parts of the same island. In some places the limestone caps were tilted due to these tectonic forces. Thus when we see a sea level notch etched quite high on an old limestone plateau we cannot necessarily conclude that sea level once reached all the way up to where that notch is presently situated. Our present sea level started to stabilize about 5500 years ago after a rapid rise from much lower levels (about 120 m lower, in other ice ages an approximately 140 m lower level was reached). The sea has been more or less at the present level for the last 3200 years, at present however sea levels are rising again.

Lithification of coral sand and coral rubble: When a coral reef or a beach of coral sand is exposed to the atmosphere and freshwater from rain it slowly turns into limestone. This process is called lithification (Le Tissier & Scoffin, 2001). Corals are normally quite light and brittle; they consist mostly of calcium carbonate and 1 to 2% of strontium carbonate. The calcium carbonate is present in the crystal form aragonite. The aragonite is unstable. Under the influence of slowly percolating rainwater calcium carbonate is slowly dissolved, penetrates into the porous coral and precipitates and fills in the pores within the coral or coral sand. Meanwhile the crystal structure changes to calcite. Some magnesium calcite is also present which helps to cement the various reef components together. Thus the coral becomes denser, heavier and harder and is fused with the surrounding sand into stone. Geologically speaking this can be a fast process, depending on the amount of rainfall and whether the material is exposed to ground water. Complete lithification can take place in as little as 5000 years. If the coral material is not exposed to groundwater, lithification can take from 10.000 to 200.000 years depending on rainfall. But often much younger deposits are already partially lithified. The small loose, often cylindrical stones which are found on beaches and which in Curaçao we call *kraaksteen* consist of such partially lithified coral. Thus an ancient beach of coral sand is converted into a limestone plate, and ancient coral reefs become limestone ridges. When we cut through younger limestone rocks we can see that there is a very hard grayish outer crust, but the inner material is usually softer and whiter, because the lithification process has not yet been completed on the inside and there is very little or no discoloration. Much older rocks such as those on the Tafelberg are harder throughout. There has been more mineralogical change, there is no aragonite left, and the mineral dolomite (calcium magnesium carbonate) has also formed (dolomite was named after the Triassic dolomite mountains in Northern Italy). Often the interior may be discolored pinkish, reddish or brownish, due to iron-rich solutions which washed through overlying soils. Silicates and some phosphates are also frequently present.

Fossil fringing reefs: The Lower plateau along the North coast can best be envisioned as a fossil fringing reef such as exist in many parts in the world (for example, in Bora

Bora). The highest sea level was reached 125.000 years ago during the last glacial interstadial, the Eemian which lasted from about 130.000 – 110.000 years ago, (the generally short stable warm periods during the interglacials are called interstadials). Afterwards the sea level was lowered relative to the land. The reef became exposed and lithified; it became a rocky ledge while the lagoon behind it filled up with sediments. The outermost limestone rock facing the sea contains corals such as *Acropora palmata* which typically grow in exposed areas; these had been growing on the outer reef. In some parts of the plateau which are not covered by the reddish iron rich clayey sediments, we find fossils of corals which are typical of lagoons. The notch that indicates the former sea level in the limestone wall of the Middle terrace is quite narrow. This indicates that it formed behind a protective reef; if it had been fully exposed to the force of the open sea the notch would have been much wider (see: de Buisonjé, 1964 and Focke, 1978). The Middle, Higher and Highest terraces were similarly formed during periods of change in sea level and also as a result of tectonic rising of the land; however their genesis is substantially more complicated and falls outside the scope of this short overview.

Karren: When the surface of limestone rocks is etched away by the dissolving power of slightly acidic rainwater, there are often sharp protrusions on the top of the surface which is exposed to the rainwater. Along sea shores we can see the same effect where the limestone is exposed to the spray of the sea. Such structures are called karren or karren fields. When they are caused by the spray of the sea they are also called spray fields. Fossil karren fields can sometimes be seen on Curaçao's inland limestone plateaus. In some areas high karren are found which may have formed during past epochs with high rainfall.

Knip formation and St. Christoffel: In some areas of the Christoffel nature park in the Western part of the island the geology is somewhat more complicated. Here we find the so called Knip formation, which consists of finely grained marine sediments (mostly fine calcareous sands with some embedded fine clays and some silicates), which were deposited in deepwater and subsequently uplifted to form the backbone of the highest hill of the island, the 386 m high St. Christoffelberg and its surrounding area called "Zevenbergen" (seven hills). Curiously enough the top of this hill is capped by a siliceous chert which consists almost entirely of the skeletons of so called radiolarians. Radiolarians are plankton animals with a silica skeleton. When they die their skeletons slowly sink to the bottom of the sea, just as do the skeletons of other animals or plants with calcareous (Calcium carbonate or Calcium phosphate) skeletons. However calcareous skeletons will gradually dissolve in the sea water, especially in deeper waters and therefore these skeletons cannot reach the bottom of very deep seas. Thus in very deep waters only the siliceous skeletons of the

radiolarians, which do not dissolve so easily, will remain. Thus the highest point of Curaçao consists of deepwater marine sediments which have been pushed up by tectonic forces (similarly the top of Mount Everest in the Himalayas also consists of marine sediments).

Sedimentary soils: In many areas we find the eroded remains of the Curaçao lava formation. These can form quite fertile alluvial soils. In the Middle Curaçao area however, we find poor clayey soils, often mixed with calcareous residue from the surrounding limestone areas. Thus the island consists mostly of areas with soils of volcanic origin and of calcareous origin. In many areas we find sediments where these are mixed together. The calcareous areas can store water better than the volcanic areas and consequently have somewhat different vegetation. Almost all groundwater and soils are alkaline, the calcareous soils even more so than the volcanic soils. This also has its effect on the vegetation. Only the Knip formation contains some less alkaline, slightly acidic rocks and soils. Acid loving plants do not grow well on Curaçao. In the Knip formation a rare ground orchid, *Polystachya foliosa* (formerly: *Polystachya cerea)* is found, which only grows on the rocks of this formation.

Inner bays: During the glacial periods when sea level was very low, Curaçao had a very dry or desert climate. When it rained occasionally there would be a lot of erosion and broad flat river valleys were formed. Such valleys are called wadis after the valleys found in the Middle East. When sea levels came up again the wadis were inundated. In some cases a reef wall formed at the entrance of the bay, often forming a porous wall. As sea water levels kept rising the corals and the reef wall grew with it and the inner bay kept filling up with sediments. Consequently the coral rubble reef wall and the sediments in the inner bays behind it can be very thick, something that is usually not realized. Seismic tests at the reef wall in front of Rif St. Marie have indicated that it is built up of at least 120 meters of coral rubble.

Sea water rise, hurricanes: It is estimated that during the last 100 years (1900-2000) the sea has risen about 20 cm. Between 1990 and 2006 sea levels rose at an increased rate of 3.3 mm per year. It is certain that sea water rise is accelerating as a result of global warming. Projections of further sea water level rise vary considerably; some higher projections predict an increase of about 90 cm in 2100 compared to 2000. A small group of scientists however, hold the opinion that any projected increase of less than a meter is not realistic and that in a worst case scenario the sea level could rise by as much as 1.4 meters or even more during the 21st century. The sea water rise and global warming will also influence the direction and strength of sea currents; this in turn will have its effect on the migration routes of pelagic (open ocean) fish. Such effects will also be felt in Curaçao and indeed there is some speculation that such

changes may already be occurring. The migration routes of several species of pelagic fish, such as tunas seem to have shifted northward and such fish now tend to pass north of Curaçao. From the 22nd to the 23rd of September 1877 a strong hurricane hit Curaçao. Nowadays with average sea level about 20 cm higher, a similar hurricane would be tremendously destructive. There is some concern that hurricanes can become much stronger and may be also more frequent due to higher seawater temperatures. However there is still considerable ongoing debate regarding this subject. It is also possible that the hurricane belt could shift more northward, as it may have done during past interglacials. If so Curaçao, which nowadays lies at the southern edge of the hurricane belt, would fall outside of it.

Climate

Rainfall & temperature: The climate throughout the archipelago is quite arid. In Curaçao the mean rainfall is 553 mm/year (30 year average 1971-2000, as measured at the airport). The hilly areas receive slightly more rain than the rest of the island. Rainfall can be quite variable from year to year. Some years are very dry, with only 200-300 mm of rain. In other years rainfall is quite abundant, the maximum-recorded yearly average is about 1100 mm, the driest year on record is 1914 with an average of 207,9 mm. Normally the dry season runs from March to June. A dry year has a longer dry season, say from February until the end of September, with only a little rain falling in the rainy season from October to December. The rainy season usually starts at the end of September. October and November have most rain and the season tapers off until the beginning of January of the next year. The mean temperature is 28° C.

Extended dry periods : Several times each century extremely dry periods of two or three dry years in a row and more rarely, four succeeding dry years occur (See Table 1). For Curaçao rainfall data are available since 1830, with short interruptions from 1875-1883 and from 1892-1894. Dry periods also extended to the other islands of Aruba and Bonaire, where rainfall patterns are very similar. In historical times, there were several dry periods which resulted in food shortages. At the end of very long dry periods, even the opuntia cactus start to shrivel, emaciated iguanas cling to trees or fall on the ground and the bush becomes "transparent". Many trees succumb to the boring larvae of longhorn beetles. Goats and sheep starve. In the past the thorns of the opuntias were burned of with flamethrowers, thus enabling the goats to eat them. Goats can survive in this way for a short time; but if the rains take too long to arrive they will die anyway. Often such burning would cause brushfires. From 1902 to 1905 there was a very long dry period and food had to be imported from Venezuela. There was also a serious famine in 1743, during which many of the last Caquetío Indians left for Venezuela. Today goats and sheep which roam around in the bush are likely to be stolen. Consequently, there are only few animals out in the bush and grazing pressure

is much less than it used to be. Thus the extended dry periods do not affect the vegetation to the same extent as in the past, and at present opuntias are not being burned anymore, imported foods being available. Also nowadays many "garden refugia" are available, which enable many animals to survive which otherwise would have perished.

Global warming, increase in carbon dioxide levels, acidification of the sea:
Since the beginning of the industrial revolution the concentration of carbon dioxide (CO_2) in the atmosphere has been increasing as a result of the burning of fossil fuels and deforestation, giving rise to the phenomenon of global warming Methane (CH_4), which is produced in the guts of ruminants and in rice paddies, is another important greenhouse gas contributing to the problem. The increase of these gases creates a greenhouse effect by trapping warmth, which would otherwise escape into space (i.e. global warming). Such warming affects the climate. During glacial periods Curaçao had a desert climate which became much wetter during the warm interglacials. Thus one would expect rainfall to increase because of contemporary global warming, which indeed seems to be the case. Based on a moving average analysis of 30 years of rainfall data a statistically significant increase of about 10% is found.
There is some discussion as to whether this increase is at least partly due to a natural tropical multi-decadal weather cycle or whether it is mostly related to global warming (personal communication Dr. A. A. E. Martis, Meteorological service NA&A).

Current global warming is not based on the so called Milankovitch cycles, astronomical cycles which determine to a large extent the occurrence of ice ages. Current thinking is that, based on the Milankovitch cycles, the world was slated for a cooling trend leading to a new ice age. Human induced global warming has been superimposed on this cooling trend, converting it into a warming trend instead. This warming trend is thus somewhat different from those in the past and this may invalidate predictions based on past changes in climate. The increase in CO_2 levels also has an impact on the sea. The sea absorbs and buffers a lot of CO_2, which is mostly precipitated in the form of carbonates. Because the sea has not been able to absorb all the extra CO_2 available at present, its concentration in sea water has increased. It is now thought that this extra CO_2 disrupts the balance between the zooxanthellae, the symbiotic unicellular algae which live within the tissues of corals (and some other marine animals) and the corals themselves. When this happens corals expel their symbiotic algae. This could be one of the major causes of coral bleaching, more so than the increase in temperature per se. An increase in nutrients in the water would have a similar effect on coral, which are adapted to a nutrient poor environment. Such "stressed" corals are much more sensitive to various coral diseases. The higher levels of dissolved CO_2 also lead to a lowering of the alkalinity of

sea water, and this acidification could cause serious problems for many marine animals which have carbonate skeletons.

Origins of the indigenous flora and fauna

Origin of the faunistic zones: In the early Triassic there was only one continent, the continent of Pangaea. Somewhere in the Middle Triassic 180-200 million years ago this continent split into two parts, a Northern part called Laurasia and a Southern part called Gondwana. Laurasia basically encompasses the area that is now North America, Greenland, Europe and Asia with the exception of India and Arabia. Laurasia split into three parts: Western North America, Eastern North America/Europe, and Asia. Later these landmasses got rearranged, with Europe splitting from North America and ultimately we ended up with the situation we have now: one North-American continent and the land-mass of Eurasia. Gondwana split up into South America, Africa, Arabia, Madagascar, India, Antarctica, Australia and New Zealand. About 90 million years ago South America started to split from Africa and started moving west. About 65 million years ago the separation of South America from Africa was completed. For millions of years this continent was almost completely isolated, and developed a unique South American fauna (Simpson, 1980). Among the most characteristic of this fauna were all sorts of marsupials, litopterns, (a family of large herbivorous animals with a long neck and a tapir snout), a large variety of rodents, and armadillos. Today we associate marsupials with the continent of Australia. At some stage there was contact between South America and Australia via Antarctica. This enabled some marsupials to reach Australia where the typical Australian marsupials probably developed out of this South American stock.

The Neotropical zone: About 15 million years ago South America started approaching North America and was separated from this continent by a series of islands. Some fauna could cross over via the islands. With time the series of islands became a full land-bridge which was probably finally established at the end of the Pliocene when Panama was formed (about 8 million years ago). A persistent gap probably existed in Western Colombia, where we now find the Atrato river valley and the Golfo de Urabá. There is some discussion about the time period when this last remaining gap was finally closed. This is usually thought to have taken place 3-5 million years ago. In the resulting faunal exchange the South American fauna was clearly the loser. The marsupials almost became extinct and the litopterns died out completely. Many North American animals such as raccoons, members of the cat family, mastodons (a type of elephant) and several families of birds, became firmly established. An example of a North-American family of birds that reached South-America is the ICTERIDAE (blackbirds, orioles and trupials). A few South American animals such as sloths, armadillo's and hummingbirds made it northward. Due to this faunal exchange (the so

called “Great American Biotic Interchange”) a new faunal region was formed, the Neotropical region (the "new" tropical region or the tropics of the New World). This region extends from Southern Mexico down and includes all of South America. The term was coined by Alfred Russell Wallace, a contemporary of Charles Darwin and an important evolutionary naturalist in his own right. The term Neotropical also includes regions such as the Andes highlands and the southern parts of South America which are clearly not tropical. This Neotropical region can be subdivided into several distinct faunal zones. In our area there is a distinct West-Indian zone encompassing the islands from Cuba to Grenada and also San Andrés and Providencia which have a West-Indian fauna. Grenada can be considered an intermediate area with a strong South American faunal influence. Within the Neotropical region the island archipelago north of the Venezuelan coast, consisting of Aruba, Curaçao and Bonaire together with the Venezuelan islands of Los Monjes, Islas Aves, Los Roques, La Orchila and La Blanquilla forms a separate distinct sub zone, which does not belong to the West-Indian zone but which instead has affinities with parts of South America.

The colonization of islands; After the eruption of the volcano Krakatau in 1883, the first studies were made of how new islands are colonized. Colonization usually starts with wind-blown seeds coming in. Several insects have live-stages which easily disperse through the air. Insect eating spiders can come in on thin webs and float through the air, sometimes even crossing oceans. Other seeds are brought in by birds and bats. Many plants have floating seeds that can resist saltwater for long periods of time (e.g. coconuts and cotton). Seedlings of mangroves can drift to faraway shores. Some animals disperse easily; others cross salt water only with great difficulty. Examples of good dispersers are geckos (locally called: *pega-pega*) which have eggs with thick calcareous shells which they hide in logs etc. Gecko's are amongst the few reptiles that have managed to colonize far-away islands via waif dispersal. The females of various species of gecko lay their eggs in the same spot. If such a collection of eggs were to reach an island hidden in a seaborne log then the new population sprouting from such eggs would already have quite some genetic diversity. Other reptiles that can reach islands are crocodiles, which are very strong swimmers (reaching Palau, Madagascar, and the Cayman Islands).

Examples of animals that do not disperse easily to ocean islands are amphibians and animals such as those freshwater fish that do not tolerate salt water (primary freshwater fish). A strange reversal from what one would expect is that freshwater turtles have great difficulty crossing salt water; they can only make it by raft dispersal. Tortoises can float and have a much thicker skin and thus have made it to far-away islands such as Aldabra in the Indian Ocean and the Galapagos Islands. In the West Indies they reached the Bahamas, where they are now extinct. In Cenozoic times there

were also similar, giant tortoises (of the genus *Geochelone*) on the island of Curaçao (Hooijer, 1967), which were later also found on Aruba and Bonaire. These became extinct when the climate turned drier in the Pleistocene.

When only a few animals (or plants) arrive at a new island, these constitute a sample from the larger founder population. Since the sample is usually very small, it is usually not fully representative of the larger founder population. There will thus be a shift in genetic composition for the new population (founder effect). When only a few individuals of a species reach an island, pure chance can play a bigger role in determining survival and the genetic make-up of the new population can shift considerably compared to the parent population on the mainland (genetic drift). The animals and plants change as a result of natural selection. Since the situation on the island is usually different from the situation on the mainland or other region where the founder population came from, natural selection tends to select differently and act in different ways. There usually is a change in optimum size, related to a change in prey, predators, competitors and food habits. In most cases size is reduced, but sometimes animals become larger. Thus the island gradually develops its own characteristic island fauna and given sufficient time, new endemic species and/or sub species often evolve.

Flora and fauna of Curaçao: Curaçao has been moving slowly from the west to the east on the Caribbean plate. Long ago it was probably lying much closer to an early group of West Indian islands. The flora and fauna are mainly of South American origin but a few “ancient” remnants of an original West Indian flora and fauna remain. There are also a few "modern" West Indian immigrants. Examples of old remnant West Indian fauna are the land snails *Cerion uva* (*cocolishi di kalakuna*) and several species of snails of the genus *Tudora* (*cocolishi di kabritu*) which are endemic to the

Figure 2 and 3 *Cerion* and *Tudora* are two West-Indian genera of land snails. These snails are considered remnants of an old West-Indian fauna. *Cerion uva* is endemic to Aruba, Curaçao and Bonaire and Klein Bonaire, but is not found on Klein Curaçao. Several species of *Tudora* exist on these islands.

islands of Aruba, Curaçao and Bonaire. The genus *Cerion* has a West Indian distribution and *Tudora* is related to West Indian genera (Wagenaar Hummelinck, 1940).

The Sabal palm which grows at Seru Gracia and Seru di Bientu in the Christoffelpark in Curaçao and which also occurs in Bonaire is probably an example of a West Indian remnant in the flora. This Sabal is clearly indigenous and is probably an endemic sub species. In the latest revised (3rd) edition of Arnoldo's *Zakflora* (van Proosdij, 2001) this Sabal has now been tentatively classified as *Sabal* cf. *causiarum*. *Sabal causiarum* is a West Indian species that occurs in Hispaniola and Puerto Rico. Certain fresh and brackish water amphipods and some species of isopod, which are found in caves, are also of remnant West Indian origin.

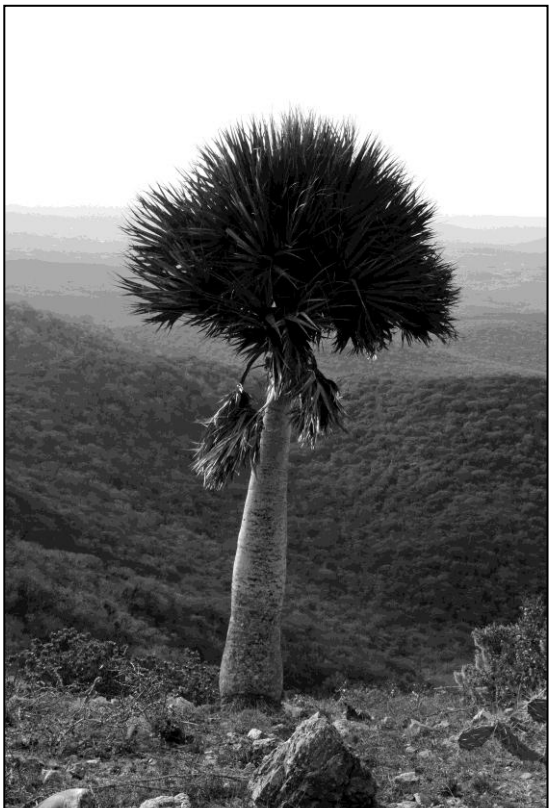

Figure 4 Indigenous Sabal palm, Christoffel Park

The reptiles evolved from South-American stock. The Curaçao island snake or Three-scaled groundsnake *Liophis triscalis* is endemic to Curaçao. Some other reptiles are endemic to Curaçao and one or more of the other islands in the archipelago. The Curaçao whiptail lizard (*Cnemidophorus murinus murinus*) is endemic to Curaçao and Klein Curaçao, the striped anole *Anolis lineatus* is endemic to Aruba and Curaçao and the leaf-toed gecko *Phyllodactylus martini* to Curaçao, Bonaire and Klein Bonaire. The gecko *Gonatodes antillensis* is endemic to Curaçao and Klein Curaçao, Bonaire and Klein Bonaire.

The avifauna is largely of South American origin, but most "modern" West Indian elements can also be found in the avifauna, which is not surprising since birds can fly and can cover large distances. Many of these are probably recent or fairly recent arrivals; they constitute a new West Indian fauna. Examples of breeding birds (non-migrating) of West Indian origin are the Caribbean Elaenia, (*Elaenia martinica*), the Black-whiskered Vireo *(Vireo altiloquus)* and the Scaly-naped pigeon (*Colomba squamosa*). A recent arrival of West Indian origin, which may have reached the islands on its own, via Venezuela, is the Caribbean or Lesser Antillean Grackle (*Quiscalus lugubris)*. Some of the local birds include migrating birds of North American origin which visit the island during their southward migration as well as a

smaller group of South American birds visiting while migrating to the north (Voous, 1983).

The arrival of man

The Amerindians: 2500 years BC there were already Indians living on Curaçao, whom we nowadays refer to as the Archaic Indians. Later, probably around 500 AD, the Caquetío tribe, a group of Indians belonging to the Maipure-Arawak tribes in Venezuela arrived. It is not known what happened to the Archaic Indians and whether or not Curaçao was inhabited between 2500 BC and 500 AD, up to now no remains of Indian settlements that can be assigned to this interval have been found. From the earliest arrival of man there must already have been an impact on nature. The island has many inner bays and a long shoreline, which in those days had plenty of protein rich food available for small groups of wanderers. It was particularly rich in tasty shellfish, such as Queen conch (*Strombus gigas*), Crown Conch (*Melongena melongena*), West-Indian top shell (*Cittarium pica*) and many others. Lobsters, crabs, fish and turtles were also plentiful.

Old Indian shell middens contain many large Crown Conch shells. The Crown conch is probably extinct in contemporary Curaçao and in Bonaire, only very few much smaller individuals can still be found. It is difficult to explain this evident contrast. It seems likely that overexploitation of this shell already started with the arrival of the Archaic Indians. Since the largest animals were taken first there could have been a strong genetic selection against large size, but other factors may also have been involved.

During several archaeological excavations remains of animals from the South-American mainland were found (Haviser, 1994; Hooijer, 1963). Some of these were probably kept as pets. Animals like the “cottontail jack-rabbit" (*Sylvilagus floridanus nigronuchalis*) and the white-tailed deer (*Odocoileus gymnotis currassavicus*) must have been introduced by the Indians, since these animals could not possibly have crossed the relatively large distance from the mainland on their own. These animals must already have had some impact on the original environment. Since their remains have only been found in Caquetío settlements and not in those of the Archaic Indians, it seems likely that these animals were introduced by the Caquetío.

It is known that several native species of ground sloth existed on some islands such as Cuba, Hispaniola and Puerto Rico and that some of these were contemporary with early Amerindians and were very likely extirpated by man.

On Curaçao, at the Tafelberg, remains of a small fossil ground sloth (*Paulocnus petrifactus*) have been found from an earlier era (Hooijer, 1967). At San Juan plantation in Curaçao an imperfect axis vertebra was found at a late pre-Colombian

Caquetío Indian site named Sint Jan II, in March 1960. It also seems to represent *Paulocnus* (Hooijer, 1963). If this identification is correct then ground sloths probably survived on the island until the arrival of man and were probably still around during the late pre-Colombian times of the Caquetío. It also indicates that they were probably extirpated by man (see: overkill hypothesis, WI ground sloths, Martin, 2005).

At a Caquetío settlement at Sta. Barbara, near the shore of the Spanish Water near Sta. Barbara Land house, remains were found of the West-Indian monk seal (*Monachus tropicalis*) which is now extinct. In a directive from early colonial times by Peter Stuyvesant the Director of the Dutch West-Indian company (WIC), a vessel is sent to Klein Curaçao with an order to try to catch some seals (de Smidt, Schiltkamp & van der Lee, 1978).

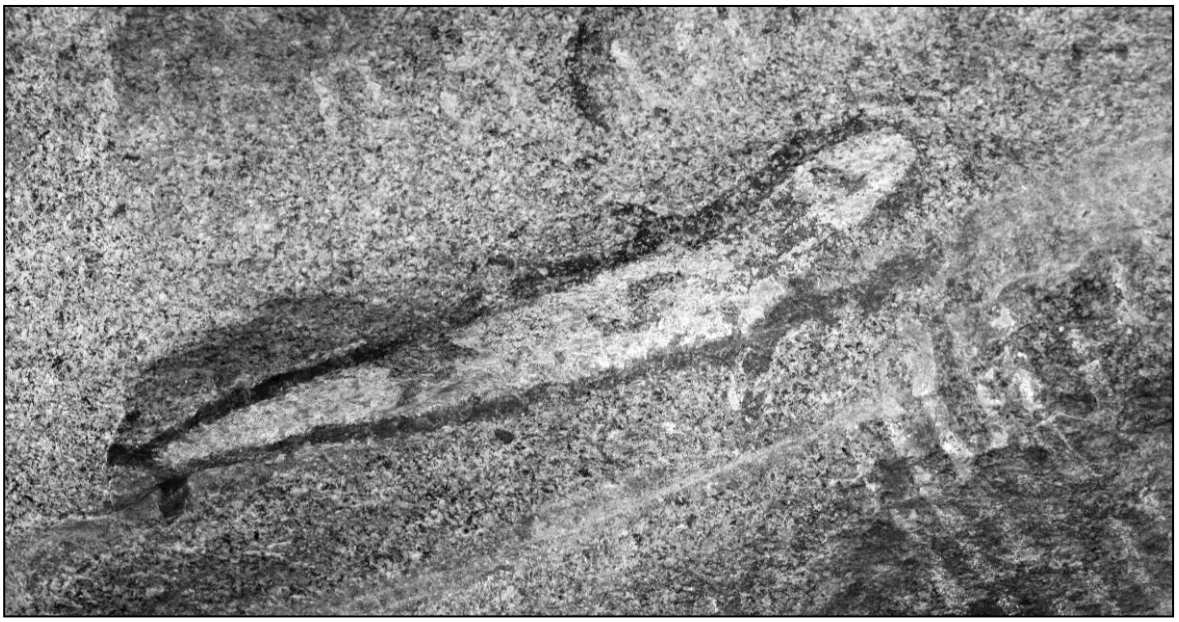

Figure 5 In Aruba, at the Cunucu Arikok in the Arikok National Park, a curious petroglyph made by the Caquetío Indians is found. Such petroglyphs can represent real or mythical animals. This petroglyph was possibly inspired by, or could represent the extinct West-Indian monk seal (*Monachus tropicalis*).

In Aruba a petroglyph is found at Cunucu Arikok on a rock called Seru di Bonchi (Wagenaar Hummelinck, 1961), which may represent a monk seal. Thus in the early days when Amerindians lived on these islands, Monk seals were still around and probably formed part of their diet at least occasionally. In 2005 a Manatee (*Trichechus manatus*) was found in Ascencion bay, on the north coast of Curaçao. There had been some earlier sightings, and again it seems probable that such animals could have been more abundant on the island in pre-colonial times and maybe were occasionally also part of the menu.

The Amerindians also introduced some plants. Many nowadays consider the calabash tree (*Crescentia cujete*) to be an indigenous tree, which is not the case. It is known that the calabash tree, which is a tree found in Central and South America, was normally dispersed by early elephants, such as mastodons and gomphotheres and also by New World horses, which existed in the Americas. These would eat the large fruits and disperse the tree. Such elephants were also present in Venezuela in the nearby state of Falcón (Gruhn & Bryan, 1984). When the elephants and horses became extinct, the tree was dispersed by man. When horses and donkeys were introduced by the Europeans in colonial times, the calabash tree could again be dispersed by animals (Janzen & Martin, 1982). This tree can have reached Curaçao only with humans and since the Indians used many calabash utensils it is almost certain that it was introduced by them. The calabash can survive in the wild and is nowadays dispersed to a limited extent by donkeys and goats.

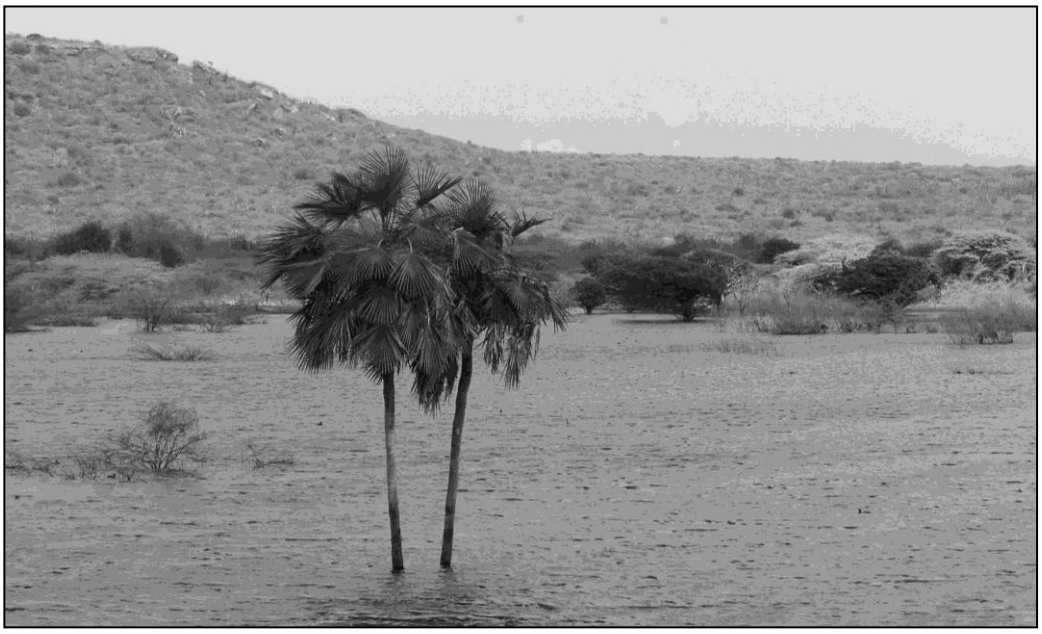

Figure 6 The "palmiet" *Copernicia tectorum*, was very likely introduced by the Caquetío Indians. These are or were mostly found growing near former Caquetío settlements

Other trees which are likely to have been introduced by the Amerindians are the *hoba* (*Spondias mombin*) and the *palma llanera* (*Copernicia tectorum*), stands of which are (or were) often found near old Indian settlements. The fruits of this palm are edible and its durable leaves can be used as roofing material. The Indians used New World cotton; *Gossypium hirsutum* may have been introduced by them from Northern South America, but also may have been an indigenous plant, although this seems less likely. In Curaçao it is found growing in the wild. The wild cassava (*Manihot carthaginensis*) was almost certainly also introduced by the Caquetío Indians from the dry regions of

South America. In Papiamentu it is called *marihuri, manihuri*. In Aruba it is called *yuca amara, yuca guajira* or *yuca di mondi*. Its roots are poisonous, and have to be treated like all bitter cassava to be eaten. It has a lower food value than normal cassava, but its roots are much more durable and it can stand considerable drought. In former times this plant was used as a reserve food for very bad times, *tempu berans* (Litt: 'rancid times', from Dutch *beransd*). Obviously it was not a preferred food, but something that was eaten only when practically nothing else was available. Nowadays this plant is very rare in the wild.

The arrival of Europeans: The first Europeans to arrive were the Spanish in 1499, who brought goats, sheep, cows, donkeys, horses, cats, dogs and swine with them. These of course began to wander around and had an enormous impact on the original vegetation and nature in general. Inevitably Old World rats and mice came along (belonging to the family of the MURIDAE), these displaced the native New World rats and mice (belonging to the family CRICETIDAE). *Oryzomys curasoae* may have survived until colonial times and may have been displaced by Old World rats and mice; the Vesper mouse (*Calomys hummelincki*) still exists, but is now very rare in Curaçao.

Many plants were also introduced, some early on by the Spaniards, others later on by the Dutch. Several of these have established themselves in the wild. Examples are *karpata* (*Ricinus communis*); the oil in the seeds was used for lamp oil; Giant Milkweed or *madar* (*Calotropis procera*) originally from the Sahel and aloe (*Aloe vera*). Many Old World grasses were also introduced (*Melinis repens* and others), which largely displaced native ones. Two species of Indigo (*Indigofera tinctoria* and *Indigofera suffruticosa*) were introduced by the Dutch and are now commonly found in the wild. *Euphorbia lactea*, locally called cactus Sűrnam (Surinam cactus), was probably introduced by the Dutch. It does not come from Surinam, but may have been introduced from there. It is an Old World plant which was often used as a fence for corrals. Stands of it survive in the wild but it does not seem to spread out by itself, some factor governing its dispersal is probably absent. Of course many food crops and fruits were also introduced by both the Indians and the Europeans, but most cannot survive in the wild. The Dutch introduced the mango tree from Mauritius in 1782 (Renkema, 1981). Some of the fruit trees like tamarind trees (*Tamarindus indica*) and the Arab date palm (*Phoenix dactylifera*) can survive when the areas where they have been planted revert to the wild, but are unable to spread out and disperse by themselves. Several species species of agave such as *Agave sisalana* (sisal), *Agave karatto* and *Agave cocui* were introduced and are found growing in the wild, like the indigenous species *Agave vivipara* and *Agave boldinghiana*.

Figure 7 Sisal (*Agave sisalana*) an introduced species of Agave growing in the wild at Malpaïs.

The arid climate and the extended dry periods help to keep out many species which are invasive in other areas. An interesting example is the African civet (*Civettictis civetta*) which was introduced from West-Africa in the 17th century by the Dutch West-Indian Company (WIC) in order to produce civet, a type of musk. Some animals escaped and feral populations existed up to the 18th century (Husson, 1960). Eventually however these feral populations did not survive. Nevertheless with the passage of time more species arrived, some of them invasive species which were able to permanently establish themselves in the wild. Several of these have had detrimental effects on the local flora and fauna. There are indications that the yellow-shouldered parrot *Amazona barbadensis* was indigenous on Curaçao until the early 19th century but was extirpated; in Aruba it became extinct during the period 1940-1950 (Voous, 1983). It still occurs on Bonaire.

More recently introduced invasive species

Balanites aegyptiaca: This is a desert tree, sometimes called desert date, which is found in the Sahel and parts of the Middle East. It was imported by Cornelis Gorsira who visited the Middle East in 1882 and brought seeds with him to Curaçao. He felt that plants growing in the Holy land should also grow on Curaçao, *Balanites aegyptiaca* being of special importance, since the branches of this tree were used to make the crown of thorns Christ was wearing. This indeed seems likely, although the name "Crown of Thorns" is also claimed for other plants. Cornelis Gorsira was the owner of plantage Zuurzak and from here this tree started spreading slowly over the

island, its fruits are eaten by goats, which disperse the tree. The vegetation and with it the ecosystem in whole areas in Eastern Curaçao have changed completely because of this plant. It has now reached Kleine Berg in the Middle of the island, and is found in some locations in Banda Abou, the western part of the island. In areas to the east of Kleine Berg it is already much more dominant than 40 years ago. Since it advances slowly it is not usually realized that this is definitely an invasive species. The wording "invasive" seems to imply something that spreads rapidly. It can not be eradicated by bulldozing, new plants sprout everywhere from the rhizomes. In Africa and the Middle East it is used for firewood, here it has no use. In another 100 years it might overwhelm all of Banda Abou, the Western part of Curaçao. Certainly this is a major, if not the major threat to the terrestrial Curaçao ecosystem. Gorsira also introduced the ilb or appeldam (*Ziziphus spina-cristi*), which is now a fairly common tree on the island and which sometimes grows in a semi-wild state. The legendary Doum palm (*Hyphaene thebaica*) was brought to Curaçao by Gorsira as well. King Salomon and the queen of Sheba are said to have met each other under a doum palm. A few stands of this palm are still found on the island.

Cryptostegia grandiflora or Palay rubber vine: this plant was imported from the area near Tulear in Madagascar during the First World War. Since it produces rubber it was thought that it could provide an alternative to rubber from the East Indies. However since the plant has to be shredded to extract the rubber, the product is of very poor quality. This plant is clearly invasive but some discussion is possible about whether it is really detrimental to the ecosystem.

The 1983 Long-Spined sea urchin die-off: In 1983 almost all Long-Spined sea urchins (*Diadema antillarum*) died within a very short period of time. In Curaçao this sea urchin is usually called the black sea urchin. Other species of sea urchin were not affected. It is thought that this disease was introduced from the Pacific Ocean via the ballast water of a ship, probably a tanker.

The disease started in San Blas in Panama and then spread to Curaçao, against the prevailing current but along the tanker routes. Then from Curaçao it spread all over the Caribbean clockwise with the currents (Lessios, Robertson & Cubit, 1984). The causative agent has never been identified and it is not known whether it is a bacterium, a virus, a mycoplasma or something else entirely. Starting in the late 1950's regulations were gradually introduced to clean up ballast water, which was an important source of oil pollution. In the 1960's for example most beaches on the north coast of Curaçao were quite regularly soiled by oil and tar. At the time it was not realized that the much cleaner ballast water would now enable many organisms to survive transportation from one ocean to another. By solving one problem another was

created. Nowadays newer IMO (International Maritime Organization) regulations have tackled this problem. The black sea urchin die-off had very serious consequences for the shallow water coral reef, since these urchins kept the reef free of algae. Their grazing helped the corals stay free of many algae and cleaned surfaces where coral larvae could settle. In many areas the shallow water coral reef disappeared completely and while many other factors were also involved it is certain that the demise of the black sea urchins was a major cause. Nowadays, more than 25 years later, the black sea urchin seems to be making a slow come-back, their numbers have been increasing in recent years. The species has probably developed some resistance to the disease. This could hopefully lead to some slow recovery of the shallow water coral reef.

The shiny cowbird: The shiny cowbird (*Molothrus bonairensis*) was first found in the wild in 1991. It is related to the trupials. This bird lays its eggs in the nests of other birds, just like a cuckoo. It especially likes the nests of trupials. In Martinique this bird is an important threat to the endemic Martinique trupial (*Icterus bonana*) and in Puerto Rico it has contributed significantly to the decline of the yellow-shouldered blackbird (*Agelaius xanthomus*). In Curaçao the Shiny cowbird has been present since the early 1990's and the population is probably derived from escaped caged birds (Debrot & Prins, 1992). It must certainly have had a detrimental effect on some of the local bird species; however there are no studies to date that document its impact.

Figure 8 The Red Palm Weevil (RPW) is a serious pest originating in South East Asia and Melanesia. It attacks a wide assortment of palms and is also known to attack agaves and sugar cane. In 2008 it arrived in Curaçao with date palms, imported for landscaping from Egypt.

Red palm weevil (*Rhynchophorus ferrugineus*): Due to globalization and the internet, plants and other products that may contain undesirable species now arrive in Curaçao from practically anywhere in the world. Arabian date palms (*Phoenix dactylifera*) were imported from Egypt for landscaping purposes and in December 2008 a very serious pest that is harbored by this species, the red palm weevil (*Rhynchophorus ferrugineus*) was detected on the island and is now established. Some of these ornamental date palms were also exported to Aruba via Curaçao and since January 2009 the red palm weevil is also found in Aruba. This weevil originated in South East Asia and Melanesia, and from there it spread to Saudi Arabia, and is presently found all over the Middle East, the Mediterranean, the Canary Islands, and Madeira. The red

palm weevil attacks and kills many species of palms, especially date palms and coconut palms (Ferry & Gómez, 2002). It is very likely to become a threat to the indigenous Sabal palm. It is also known to attack agaves and sugar cane. There is now serious concern that the red palm weevil could spread to the South American continent from either Curaçao or Aruba.

Lionfish (*Pterois volitans/miles*): The lionfish, an exotic invader from the Indo-Pacific, has been spreading throughout the Caribbean from Florida since 1992 and has now reached Curaçao where it was first detected on the 27th of October 2009. There are two closely related species *Pterois volitans* and *Pterois miles* which are very difficult to distinguish from each other and both are now found in the Caribbean. Since often it is not known which species is present or whether both are present, it is usually referred to as *Pterois volitans/miles*. The lionfish is a predator that is protected by venomous spines; it is now rapidly increasing in numbers and is expected to have serious detrimental effects on the local coral fish populations.

Sparrows and saffron finches: The sparrow (*Passer domesticus*) arrived from Holland in 1953. For years they were only seen in the Mundo Nobo area where they were first introduced but after a long period of genetic adaptation they spread out over the whole island and also made it to Klein Curaçao. The saffron finch (*Sicalis flaveola*) was first seen in the wild in the late 1960's, and the population is almost certainly derived from escaped caged birds. Both the sparrow and the saffron finch tend to be more common in areas inhabited by humans, but they are sometimes also seen in the bush (locally called *mondi*). It is not known what effects their introduction has had on local birds, but the Rufous-colored sparrow *Zonotrichia capensis*, seems much less common in human inhabited areas than in the past.

Tubastrea coccinea: the orange tube coral, probably occupies an ecological niche which was previously empty and does not seem to have had any detrimental effects; it therefore can probably be considered a colorful addition to the underwater fauna. The froth-nest frog (*Pleurodema brachyops*) a native from Aruba was introduced in 1910 (Wagenaar Hummelinck, 1940) and can also be considered to be an enrichment of the local fauna. The neem tree (*Azadirachta indica*), which originates in India and Burma is also a recent introduction. Its fruits are dispersed by birds. It is able to spread into the wild and may turn out to have detrimental effects, although it seems too early to tell.

Feral populations of the parrots *Amazona ochrocephala* (yellow-crowned parrot) and *Amazona amazonica* (orange-winged parrot), the blue crowned parakeet (*Aratinga acuticaudata*) and also of the chestnut fronted ara (*Ara severa)* are now found on the

island, and their survival seems to depend on gardens. Feral populations of rose-ringed parakeets (*Psittacula krameri*) and the green-rumped parrotlet (*Forpes passerinus*) also existed up to relatively recent times, but were probably eliminated during periods of prolonged drought (See Table 1). The red-eared or black-rumped waxbill (*Estrilda troglodytes*) had established extensive colonies in the Groot St. Joris (Chinchó) area, but these were wiped out during the 1977-78 drought (personal Communication, Joost Pronk). The cosmopolitan house gecko (*Hemidactylus mabouia*), which was probably introduced in the late 1980's, has mostly displaced the endemic gecko *Phyllodactylus martini* in houses but is not found in the wild. The whistling frog (*Eleutherodactylus johnstonei*) was introduced in the late 1970's or early 1980's and the Cuban treefrog (*Osteopilus septentrionalis*) arrived in Sept/Oct 2006 (van Buurt, 2005; 2007). These species both depend on gardens and cannot survive in the bush.

Effects of drought and human habitation: In Curaçao extended periods of drought occur (see Table 1). These extended dry periods can eliminate many unwanted invasive species. Some species survive in or because of "garden refugia", where they either live or obtain supplemental food and water. Whistling frogs and Cuban tree frogs and several species of birds have been already mentioned in this connection. The cosmopolitan house gecko seems to depend on human habitation. Iguanas are now much more plentiful in inhabited areas with gardens than in the bush. For most snakes however "garden refugia" are not an option. Those species which cannot survive in the bush and retreat to gardens in the dry season find themselves in killing zones, where people see them and kill them. This is very likely how the corn snake was extirpated in Curaçao.

"Alert" species

With globalization and rapid transport by airplane and container ships from all over the world, the problem of invasive species and the spread of animal and plant diseases, is now recognized to be a major world problem, from which Curaçao and the rest of the Caribbean are not exempt. Invasive species which are already present on other islands in the Caribbean and which could soon reach Curaçao with very detrimental effects are called "alert" species. The cactus moth or nopal moth (*Cactoblastis cactorum*) is a small moth that lays eggs in the leaves of opuntia cactus. The orange larvae eat out the leaf, which usually becomes infected with fungi and the opuntia dies. If introduced here it would surely devastate the populations of the local opuntia cacti (*Opuntia wentiana*) which will probably lead to increased erosion. The South American Cactus mealybug *Hypogeococcus pungens* is a new threat which has now reached the Caribbean, it is found in Puerto Rico and Barbados and attacks and destroys candelabra cactus (Zimmerman et al, 2010). The agave weevil (*Scyphophorus acupunctatus*) is an insect which bores into agaves; these then become

infected and die. Fire ants (*Solenopsis invicta*) have been introduced on many Caribbean islands. These ants have a painful sting and a devastating impact on many native animals (Taber, 2000). The giant (East) African snail *Achatina fulica* is a serious pest, which is now present on many islands of the Lesser Antilles from Antigua to Trinidad and also in many parts of Venezuela, including Paraguaná. The cane toad (*Bufo marinus*) and the boa constrictor are now serious introduced pests on Aruba and could certainly survive on Curaçao.

The corn snake (*Elaphe guttata*) was introduced on Curaçao (Perry et al., 2003) but it has been successfully extirpated. If it were to be reintroduced, it could pose a threat to the local endemic three-scaled ground snake (*Liophis triscalis*). There are no doubt other alert species that pose a hidden threat to Curaçao.

Human activities that have had an impact on the natural history of Curaçao

Harvesting of trees and clearing of land for Sorghum cultivation: West-African trees which contained a red dye were called *pau-brasil* ('brasil wood') by the Portuguese after the word *brasa* which means 'arm' and also 'ember'. In Pernambuco the Portuguese encountered another larger tree, *Caesalpinia echinata*, containing dye, after which they named the region 'Brasil'. Presently, the species is nearly extinct in most of its original range as a result of its overexploitation in the past. Brazilwood is listed as an endangered species by the IUCN and it is cited in the official list of endangered flora of Brazil.

Figure 9 Dye wood or brasiletto, (*Heamatoxylum brasiletto*); this is a very old tree growing near Pannekoek.

In Curaçao and Bonaire and to a lesser extent Aruba, the tree *Haematoxylum brasiletto* is found, which also contains a similar red dye. Since this tree is much smaller than the Pernambuco *Pau do Brasil* or *Pau-de-Pernambuco* it is called "*brasiletto*" or "*palo brasil*". In Papiamentu it is called *brasia* or *palu brasil*. A third tree from Mexico called *Haematoxylum campechianum* is very similar to the brasiletto and is called *campeche*. The Dutch West-India Company (WIC) harvested brasiletto on the islands. The trunks and branches were sent to the *rasphuis* in Amsterdam, where the wood was pulverized with big files or

rasps, and the dye was extracted from the filings of the pith. Since the pith of this tree is extremely hard, this was very heavy work which was done by convicts. In the 16th and 17th century large quantities of dyewood were exported. In the 19th century exports from Curaçao were much reduced, probably as a result of overexploitation, but some harvesting of dyewood continued up to the late 19th century, when this dyewood was exported to the US. Dyewood from Aruba and Bonaire was transshipped via Curaçao (Renkema, 1981). There were some final exports from Bonaire directly to the US in the early 20th century.

Brasiletto was also used to make the walls of the traditional Curaçao "kunuku" huts which were in common use until the 1960s. The brasiletto was used for the inner reinforcement of the walls, because this wood does not rot and the branches are very irregular, so stones and adobe material used for the walls will stick to them very well. Brasiletto is a very slow growing tree. Since the 1960s harvesting of brasiletto has basically ended and while very thick trees which must be hundreds of years old are rare, more average sized trees which must be at least 50 or 60 years old have become very common. In Bonaire very old trees are more common, indicating that the level of their former exploitation in Bonaire was not as heavy as in Curaçao

Another tree that was harvested (albeit to a lesser extent than the brasiletto) in colonial Curaçao is the Wayaká or "Lignum vitae" (*Guaiacum officinale*). Since the wood contains saponins and has self-lubricating properties, it was used for bearings of ship propellers well into the 20th century. These saponins also have medicinal properties and because they inhibit the growth of spirochaetes, in former times they were used to treat syphilis and the tree was also called 'Sailors cure". The hard wood was also used to make tackle blocks and certain tools. In the wild, the Lignum vitae is a very slow growing tree, but in areas with some water it can grow much more rapidly. As in the case of the brasiletto, whereas very thick trees which must be hundreds of years old are rare, average sized trees are quite common.

In the past a lot of wood was used to produce charcoal, much of which was used in lime kilns to produce calcium oxide from limestone. This calcium oxide is called quicklime or lime and was used as mortar. A tree which is very suitable for the production of charcoal is the mesquite (*Prosopis juliflora*), which is called *indju* in the Papiamentu of Curaçao. Although the wood is heavy this is a surprisingly fast growing tree. In the late 19th century calcium kilns began to use imported coal and did not depend on local charcoal anymore. We can conclude that although the exploitation and harvest of wood must have been very heavy in the past, there has been a relatively long period of recovery and unlike the *pau-do-brasil* in Pernambuco none of these formerly heavily exploited trees is now endangered on Curaçao.

Robert Soublette and his son Tito were photographers, who took pictures in Curaçao from around 1869 until about 1923. In these pictures (Schiltkamp et al., 1999) we can see that many areas that are now covered with bush were then cleared to plant sorghum or had been cleared by grazing animals such as roaming goats, sheep and donkeys. Thus, contrary to what we might expect, the island is now much greener than it was in the late 19th and early 20th centuries.

Hunting: These same Soublette photographs show us that the late 19th and early 20th centuries were a time of extreme poverty. There were extended dry periods which caused famine on the island. Food had to be imported from Venezuela. As sources of protein, people hunted iguanas and cottontail jack-rabbits (*Sylvilagus floridanus nigronuchalis*), caught crabs and trapped species of doves like the *ala blanca* (*Columba corensis*), *ala duru* (*Leptotila verrauxi*) and *buladeifi* (*Zenaida auriculata*). When the Shell Oil Company established itself on Curaçao in 1916, the economic situation improved, but even so the countryside remained very poor until the middle of the 20th century.

In the 1960s life improved markedly for the poorer classes so that today there is very little hunting for food, although some (usually older) people still hunt iguanas. The younger generations do not possess the hunting skills of their parents or grandparents and few have the patience to pluck dozens of small doves to obtain just a few scraps of meat. The flexible type of rubber from bicycle tires which was formerly used to make catapults is not available anymore; the rubber of modern tires is much more rigid. Venezuelan TV has been watched in Curacao since 1958 and a local TV station started broadcasting in 1960. Obesity is a problem nowadays, since many sit in front of the television instead of hunting in the bush as their parents would have done in the past. Consequently the populations of doves and iguanas have rebounded and are much larger than in the past. The cottontail jackrabbit however did not recover, perhaps because so many are killed by motor vehicles. Crabs are now caught by immigrants from Guyana who use them in traditional dishes.

Firearm permits are now more difficult to obtain than in the past and while there are plenty of illegal firearms on the island, these are not used for hunting. In the 1955 edition of his book *de Vogels van de Nederlandse Antillen* Voous expresses surprise at the almost complete absence of adult crested caracaras (*Caracara cheriway*), called *warawara* in Papiamentu. This can be explained by the fact that at the time these caracaras were often shot since they sometimes attack small lambs. Today one does in fact encounter more adult *warawara*. The white-tailed hawk (*Buteo albicaudatus*) is also more common than in the past.

The Dutch traveler Teenstra who visited Curaçao during 1828/29 and 1833/34, mentions deer being common in many parts of the island. In the 1920's white-tailed deer were still found in the area where Julianadorp was later built. At that time the road to Bullenbaai did not yet exist and my mother told me they were also found at Klein Piscadera plantation where my grandfather J.J.A.H. Joubert (Shon Hyacinthe) shot the last one around 1929. Today they are still found in the Pos Spaño area, in the Christoffel National Park, and around Malpais, although a large area in nearby Weitje where they also lived has recently been bulldozed.

Human activities that impact the marine environment: Curaçao's marine environment has been heavily and increasingly impacted by human activities, including overfishing on the reef by local fisherman, the effects of commercial overfishing of pelagic fish in the Atlantic Ocean on the fish stocks around Curacao, the harvest of rare shells from the wild by collectors, and marine pollution (plastics in the ocean, nutrient pollution and bacterial and viral agents on the coral reef, oil pollution, fire retardants, PCB's, pesticides, marine pollutants dispersed through the air etc.). A more detailed discussion of the influence of these factors on nature in Curaçao has been kept outside of this overview, because even a cursory treatment of these topics would merit no less than another article of equal or greater length.

Extended period of drought	**Precipitation in mm/yr**	**Extended period of drought**	**Precipitation in mm/yr**
1841-1843	272 290 408	1947-1948	301,2 421,1
1868 -1869	226,2 296	1958 -1960	287,4 Hato 280,6 355,8 Hato 282,2 363,3 Hato 482,8
1898 -1900	479,6 357,7 437,4	1977-1978	355,5 Hato 270,5 389,2 Hato 271,1
1902 - 1905	313,4 382,3 473,9 413,6	1982 -1983	380,5 340,1
1919-1920	270,3 301,4	1986-1987	321,2 369,3
1929-1930	323,2 269,1	2001-2002	331,4 331,8

Table 1. Extended dry periods, 1830-2004, data for Curaçao (Meteorological Service Netherlands Antilles and Aruba).

Note: The data were interrupted from 1875-1883 and from 1892-1894. Data before 1954 are a weighted average of several locations on the island, after 1978 only the

data at Hato airport are given. In this table both values are given for 1958 to 1978. The Hato location is usually somewhat drier than the weighted average. Monthly data, which unfortunately are not available for the early years, give a better view of the true extent of the dry periods. The 2001-2002 dry period (so named based on the yearly values) for example, based on monthly data lasted until the end of September 2003, it thus lasted 2 years and 9 months. The 1982-83 dry period lasted until the end of September 1984. It also lasted 2 years and 9 months. A very dry period with one rain shower exceeding 70 mm, which will cause trees to bud and grass to sprout, will bring some relief and such a dry period will be less stressful than a year with the same amount of precipitation spread out more evenly. The 1958-1960 dry period started at the end of November 1957 and was interrupted by a rain shower of 104,3 mm (Hato airport) in January 1960, then the dry period went on until August 1960, with more rain following in October 1960. If we compare the Hato data with the weighted data for 1960 this strongly suggests that the 104,3 mm shower fell at Hato only. The rest of the island probably experienced a longer dry period lasting some 2 years and 8 months.

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