Invasive Alien Species in Aruba, Curaçao and Bonaire

Introduction pathways, population establishment and environmental impacts

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1. General introduction

1.1 Aruba, Curaçao and Bonaire are arid islands in the southern Caribbean Sea, population density, population pressure

Aruba 190 km², Curaçao 444 km² (Klein Curaçao, 1.2 km² included), Bonaire 288 km² (including Klein Bonaire 7 km²).

Table 1 POPULATION DENSITY OF ARUBA, CURAÇAO AND BONAIRE

Island	Inhabitants 2023	Inhabitants / km² Excluding illegals	Tourists / year in 2023	Estimated number of Illegals, in October 2022 according to UNHCR
Aruba	106,227 midyear	560	1,224,935 stayover 817,670 on cruise ships	17,000
Curaçao	192,077 midyear	433	582,409 stayover 710,623 on cruise ships	14,000
Bonaire	24,090 on Jan 1, 2023	84	169,706 stayover 647,747 on cruise ships	Not available

Nowadays there is increasing urbanization and tourist development on all three islands. The number of tourists is increasing. Many houses are also built or owned by ex-patriates, who use them only part of the year. Tax advantages have been created to stimulate such developments. In Bonaire the population is increasing rapidly. In Aruba these tourist developments have been strongest but Curaçao and Bonaire are catching up fast. Whole areas have changed completely. The hotels and houses all have gardens, with introduced ornamental plants and this generates an influx of invasive species. Irrigated gardens enable invasive species to survive long periods of drought and thereby provide refuges from which invasive species can spread out into the remaining wild areas.

Especially in the calcareous coastal zone in Curaçao there has been quite some housing development in recent years (Jan Thiel, Bapor Kibra, Blauwbaai, Boca St Michiel, Rif area, Cas Abou, Coral Cliff, Lagun, Westpunt-Playa Kalki). In the past no one would build in these areas; there would often be too much salt spray, and no good soil for a nice garden. This can be clearly seen when comparing housing on the old Werbata maps, with the situation now. These maps were made during the period 1911-1915 (van der Krogt, 2006). The triangulation of Curaçao started in 1904; that of the other islands shortly afterwards. By comparing maps of various periods, these developments can be accurately documented. In Bonaire we see similar developments in the calcareous areas. In Aruba there is a lot of development but the calcareous areas are less extensive.

1.2 Nutrients in the groundwater

In Curaçao most of the houses have cesspools (called "beerputten" in Dutch) and a large part of the groundwater in the inhabited areas is derived from sewage water. When it rains only a small fraction of the rainwater reaches and contributes to the groundwater. The water in the cesspools however infiltrates directly into the ground and thus contributes substantially to the quantity and quality of the groundwater. It is estimated that in inhabited areas roughly half of the groundwater is derived from cesspools (pers. comm. C.W. Winkel). Consequently, this ground water is heavily polluted with bacteria, (van Buurt, 2022) and also contains a lot of nitrogen products (high total nitrogen). In some wells nitrate concentrations as high as 100 ppm have been found. The water is often pumped up from wells and is suitable for irrigation, but should never be used for drinking, or for drinking water for animals, or for bathing. Even when it looks clear and does not smell it is full of bacteria. Trees which have deep roots that reach into the groundwater profit from these nutrients. It helps maintain green areas which otherwise would not be present, but by doing so also creates suitable conditions for many invasive species to survive.

1.3 Nutrients in the sea

In recent years it has become increasingly clear that high concentrations of nutrients, especially nitrogen cycle products such as ammonia, nitrites and nitrates can be a serious problem for coral reefs. While the nitrate norm for drinking water for human beings is 20 ppm, corals in a sea-water aquarium will die at 2 ppm and corals on a coral reef are seriously stressed at much lower levels. Corals are adapted to a nutrient poor environment; some corals that grow in lagoons can tolerate somewhat higher levels of nutrients. The threshold for dissolved inorganic nitrogen on coral reefs is only 1.0 µm (Lapointe et al, 1997). Above this level corals are already seriously stressed. In the sea there is usually enough oxygen present to fully oxidize ammonia and nitrites to nitrates. Nevertheless, ammonia and nitrites, to which corals are even more sensitive can be present near outflows or in lagoons and inner bays. Sewage waters are a major problem. A study by Bak & Nieuwland (1995) indicates that coral cover at three transects in Curaçao and one at Karpata in Bonaire has declined considerably during a period of twenty years. The Karpata area is a fully protected area; there is no fishing, or anchoring in this area. This decline can thus be related to global causes, to a nutrient problem or more likely a synergistic effect between the two.

In many areas, nutrients on the coral reef are derived from excess fertilizer used in agriculture, which is washed out to the sea. This is for example a large problem on islands such as Martinique and St. Lucia, among many others, where bananas are produced. In Aruba, Curaçao and Bonaire there is no large-scale agriculture; some small-scale horticulture exists. In addition, in these operations one of the problems is usually that the operators use insufficient fertilizer, there is thus hardly any loss by wash-out of fertilizers. Nutrients in Aruba, Curaçao and Bonaire coastal waters, lagoons, inner bays and groundwaters are thus almost exclusively derived from household wastewater. Use of agricultural pesticides is also very limited. Most pesticides are used in households.

Nowadays everyone wants to have a house with view over the sea, or wants to be as near to the sea as possible. The plots nearest to the sea have the highest value. These plots are also the ones that will be most exposed in case a hurricane passes by. Insurance companies will not issue insurance for certain areas; without insurance you cannot get a mortgage either. None of this deters the owners who apparently have enough money to pursue their dream of living by the sea. These houses are usually not connected to a centralized sewage system. In Curaçao almost none of them are connected to such a system. In Bonaire we see the same trend. Coastal development in Bonaire has also taken place in calcareous limestone areas, where there was very little or none in the past. In Bonaire a centralized sewage system now exists, but many houses higher up on the calcareous plateaus are not connected to this system. Because of the hard limestone rock, it would also be very costly to construct such a centralized sewage system. Aruba now also has such a system and in Curaçao the sewage waters of the town and of certain other areas are connected to centralized sewage systems. The new developments in the limestone areas have caused quite some seepage of sewage waters directly to the sea via cracks in the porous limestone. Phosphates will tend to get bound by the limestone but the nitrates will reach the sea. Apparently after heavy rains phosphates will be released from the calcareous materials and there will be a sudden phosphate flush to the sea (pers. comm. Dr. Mark Vermeij). Because of the hydrostatic overpressure the nutrient enriched ground water usually surfaces along the blue edge and comes up through the bottom, in the coral zone. This has now been proven and measured with microprobes in the bottom. However, most nutrients, especially those derived from the Curaçao lava formation, tend to end up in the inner bays and flow out to the sea in surface waters. The nutrients stress the corals which become much more sensitive to many coral diseases. Some of these coral diseases are almost certainly caused by alien disease agents. Indo-Pacific strains of coral diseases, which are more virulent than similar Caribbean ones could be involved. In the case of the 1983-1984 mass mortality of the Caribbean black sea urchin *Diadema antillarum* it is suspected that the disease agent came from the Pacific and that the closely related *Diadema mexicana* is resistant to it (See 1.9). Wastewater collected at the intake of the sewage treatment plant Klein Hofje in Curaçao typically contains about 83 ppm of N products (data from the former DOW laboratory at Klein Hofje). This value is probably indicative for other local wastewater as well. In Curaçao there is also seepage of sewage water via inner bays (Spanish water, Schottegat, Piscaderabay) and directly into the sea via groundwater (Gast, 1998). Curaçao had a large population since the oil industry established itself, in any case there must have been considerable seepage of N cycle products, especially via the Schottegat and this could very well have been a factor in the decline of corals near the harbor entrance. This however did not affect areas further downstream, where the decline of coral cover set in much later. The inner bays also act as buffer zones, mangrove areas absorb nutrients. The main difference with the situation nowadays would be that there were few developed areas along the coast, in limestone areas. Still, it is quite possible that natural nutrients leached from the Curaçao lava formation, which reach the sea via groundwater seepage can be an important contributing factor. In many areas, this may not have been critical in the past, but may now in some cases raise concentrations above a certain critical threshold level. The outflow of nutrients from the Curaçao lava formation is now being measured in a new ongoing project by PhD students from Technical University Delft and Wageningen University. The pillow lavas and basalts from the Curaçao lava formation contain radon; this radon is measured in wells and is followed toward the sea. Nutrients are also measured. The radon can be traced in the sea and this will indicate where it enters and how much enters the sea via this flow path.

Some nutrients are present in the ocean and belong to a "general Caribbean background level", which has increased during the last decennia.

Sewage treatment alone is not the solution. Nutrients remain and have to be reduced or eliminated from the effluent. There has to be a form of tertiary treatment. The nutrient problem can be solved to a large extent by first treating the effluent and subsequently using the water for irrigation of landscaping, ornamental plants, golf fields (grass absorbs a lot of nitrogen), fodder for animals (such as Sudan grass, buffalo grass or Sorghum) or horticulture. Fodder with an excellent C/N ratio has been obtained using these waters.

A central sewage system can be used and/or a smaller local treatment system. Depending on the volumes of water available, the distance to a central treatment facility and the area where the wastewater can be used, a choice can be made. Local water prices are very high. Consequently, people use little water and sewage water tends to be highly concentrated in comparison with household sewage waters elsewhere. In the calcareous areas the inhabitants generally have more money and use more water. It would in many cases be possible to connect a cluster of houses to a small treatment facility and divert the water from the calcareous areas to the Curaçao lava formation, where it can be used as described above. This could even be done with large tank trucks, which pick up water from a holding tank, say once or twice a week.

1.4 Transportation of alien species

In the past there was a lot of commerce mostly with South America. Nowadays this has changed, on all three islands. For example, ornamental plants are imported from the United States (US), mostly via Miami, many fruits come from the Dominican Republic and some plants are even flown in from far away, for example orchids from Thailand. Date palms were imported from Egypt. Airlines, cargo vessels, cruise ships and yachts connect Aruba, Curaçao and Bonaire to many different destinations. Consequently, there are many pathways for the introduction of invasive alien species, many more than in the past. Transportation is also much more rapid than in the past. Species that in the past could not have survived a long sailing voyage now arrive quite rapidly in containers, sometimes in cooled containers such as reefers, or in ventilated containers, or are flown in.

1.5 The bioregion of the ABC-islands

1.5.1 Zoogeographical sub-region of the South American realm

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 island archipelago north of the Venezuelan coast. Biogeographically, Aruba, Curaçao and Bonaire do not belong to the West-Indian region. Their flora and fauna are mainly of South American origin, with some West-Indian elements, especially in the flora (Stoffers, 1956). There are many endemic elements, in both flora and fauna, which justify the view that Aruba, Curaçao and Bonaire can be considered to form a small but distinct zoogeographical sub-region of the South American realm.

1.5.2 Geology and soils

The Caribbean plate originated in the Pacific, it originally moved in a northerly direction, where it hit the Bahamas bank, but later rotated eastward. There has been a long ongoing discussion whether it was formed completely in the Pacific or whether parts of it were formed locally in the Caribbean. James Pindle is a tectonics geologist who holds the first view and Keith James is a petroleum geologist who holds the second view. A paper by Giunta, et al, 2002, proposes a "near Mid-America" original location of the Jurassic-Cretaceous Caribbean oceanic realm (proto-Caribbean phase). New oceanic crust was generated that can initially be referred to multiple spreading centers into a thickened oceanic plateau locally associated with picrites, in Costa Rica, Hispaniola, Venezuela, and Dutch and Venezuelan Islands. There are also "accreted terranes". This paper thus supports the views of Keith James.

The Caribbean-South American plate boundary is diffuse and forms the so-called Southern Caribbean Deformed Belt (SCDB). In north western Venezuela there is underthrusting of the Caribbean plate beneath northwestern South America (Guedez, 2007). This underthrusting has been uplifting the islands from Aruba to Los Roques and to a lesser extent La Blanquilla (Leeward Antilles Ridge). This started in the Middle Miocene; the Caribbean plate rotated a bit and started moving eastwards from an initially more northerly direction. The uplift is still ongoing but it is relatively small. A study for Curaçao indicated an uplift of about 5 cm per millennium (Schellmann et al., 2004). Of course, in a mere 100.000 years this is 5 meters of uplift. A later study however indicates this estimate is probably too high (Rubio-Sandoval, et al., 2021). At such low rates it is very difficult to estimate the rate of uplift. In any case the estimates are markedly smaller than the rate of sea level rise. At present (2023), mean sea level rise globally is 3.9 mm/yr and steadily increasing (NASA, 2022). In the Caribbean it is about 3.5 mm /yr. In addition to the general overall rise, there will be a shift of water toward the tropics when the mass of land-ice at the poles is reduced. As an ice sheet loses mass, its gravitational attraction on the nearby ocean is reduced, causing ocean water to migrate away from the ice sheet. This shift has now become detectable with the latest advanced satellites, and computers which are capable of analyzing the huge flow of data. It is called the 'sea level fingerprint' (Coulson et al, 2022). With the recent (2018) launch of Earth observation satellites carrying LiDAR sensors that are known to have much higher vertical accuracy than earlier radar data sources, a new generation of global elevation models is evolving.

There are marked similarities, but also marked differences in the geology of the islands. On all three islands we find calcareous limestone caps dating from Miocene and Plio-Pleistocene times. In Curaçao there are also small remnants of earlier Eocene reefs. The calcareous areas have been described by Buisonjé (1974).

ARUBA Aruba has a plutonic history; a large batholith mass of tonalite (also called diorite, which strictly speaking is a type of tonalite) was pushed up to and exposed on the surface. This formation is called the Aruba lava formation. Aruba has also been exposed to more interactions between the plates; metamorphic schists are for example found. There are some areas with pillow lavas, which also form a part of the Aruba lava formation, but not many. Westermann (1932) describes the geology of Aruba.

CURAÇAO In Curaçao the Curaçao lava formation, which consists of basalts and pillow lavas, dominates (Klaver, 1987). There are also alluvial soils derived from eroded parts of the lava formation, such as the Middle Curaçao formation. This middle Curaçao formation also contains silica rich sediments and clays. In the western parts of the island there are deep-water sediments, which were uplifted; the so called Knip formation (Beets, 1972). The Knip formation consists of silica-rich cherty limestones, cherty mudstones, cherts and radiolarites. Originally Curaçao consisted of two separate islands; a western and an eastern island, which later on became connected to each other. The geology of the island was first described by Molengraaff (1929).

BONAIRE Bonaire has a fairly different volcanic geological origin. It also has a volcanic formation, the Bonaire Washikemba formation (BWF); it is divided into a northern and a southern part. Near Rincon we find the fairly small Rincon formation. This formation consists of Late- Cretaceous limestones. It is similar to the somewhat younger (Danian) Knip formation in Curaçao. Bonaire has been exposed to the outflow of a large river. The island was once situated much more to the west, near La Guajira in eastern Colombia. The Eocene Subi Blanco formation is of fluviatile origin. In the Subi Blanco formation, there are so called 'foreign pebbles' (Pijpers 1931), which probably derive from eastern Colombia (Urbani et al, 2013). The geology of Bonaire is described in Pijpers (1933).

A look at the geological maps shows that all three islands have a very complex geology. In recent years many more publications have been covering this subject. Hippolyte and Mann (2011) give a good summary of the more recent work for the three islands. Scheffers (2002) is the first publication on the effects paleo-tsunamis or fairly recent pre-historic tsunamis have had in Aruba, Curaçao and Bonaire. There are also several later publications which deal with the effect of such tsunamis in Bonaire; where the effects have been stronger and more pronounced. Engel et al (2012) is the most important one.

The islands have areas with soils of volcanic origin and also calcareous areas. The calcareous areas can store water better than the volcanic areas and have different vegetation. Aruba has dioritic soils, which are less permeable, it also has lower rainfall and thus the island is even more arid than the others. On the other hand, because of the impermeability of the soil it has bodies of standing water (tankis) where water lasts much longer.

1.5.3 Climate

The climate of Aruba, Curaçao and Bonaire is quite arid. The mean rainfall is respectively; 409, 553, and 463 mm/year (30-year average 1971-2000, as measured at the airports). Unfortunately, the 30 yr. average for the period 1971-2000 as measured at the airports is the last which has been published for the three islands. The data for the 1981-2010 30 yr. period average, as measured at the airports were not available at the time of writing. The yearly averages can show a fairly large deviation from the 30-yr average, even at the same location. The hilly areas receive slightly more rain than other parts of the islands.

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 (in Curaçao).

The islands are characterized by warm tropical temperatures with the highest mean temperatures occurring in September. The seawater around the islands averages around 27°C and is coldest (Avg. 25.9°C) around February-March and warmest (Avg. 28.2°C) around September-October. The skies are in general mostly clear to partly cloudy. Normally the dry season runs from March to June. A dry year has a longer dry season, say from February till the end of September, with only 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 till the beginning of January of the next year. The mean temperature is about 28o C for all three islands.

Data for this section are from the Meteorological Department Curaçao, https://www.meteo.cw/climate.php?Lang=Eng&St=TNCC&Sws=R11

1.5.4 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. At the end of such 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 off with flamethrowers, thus enabling the goats to eat them. They can stand this food and survive for a short time. If the rains take too long to arrive, they will die anyway. Often the burning would cause brushfires. For Curaçao rainfall data are available since 1830, with short interruptions from 1875-1883 and from 1892-1894 (van Buurt, 2010). These same dry periods also extended to the other islands, rainfall patterns being very similar. The records on Aruba and Bonaire started much later. Aruba has rainfall data starting in 1929, but for Oranjestad only and Bonaire for Rincon and Kralendijk starting in 1905 (de Palm, 1985). In 2001 Aruba had 5 measuring stations; Curaçao had 13 and Bonaire 3 (Martis et al, 2001).

In historical times, there were several periods with food shortages (Renkema, 1981). From 1902 to 1905 there was a very long dry period; food had to be imported from Venezuela. Nowadays 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 nowadays opuntias are not being burned anymore, imported foods being available. Also, nowadays many irrigated 'garden refugia' are available, which enable many plants and animals to survive that otherwise would have perished.

Figure 1 Map of the three Leeward Islands, Aruba, Curaçao and Bonaire, located north of the South American mainland, near Venezuela (adapted from map made by Fred M. Chumaceiro).

1.5.5. Endemic species

Aruba, Curaçao and Bonaire have many endemic species. These can be found mostly in the reptiles, cactus and agave species and land snails.

The endemic reptiles are the following:

LIZARDS

· *Cnemidophorus arubensis*	Aruba
· *Cnemidophorus murinus*	Curaçao, Klein Curaçao
· *Cnemidophorus ruthveni*	Bonaire, Klein Bonaire
· *Anolis lineatus*	Aruba, Curaçao
· *Anolis bonairensis*	Bonaire, Klein Bonaire
· *Phyllodactylus martini*	Curaçao, Bonaire, Klein Bonaire
· *Phyllodactylus julieni*	Aruba
· *Gonatodes antillensis*	Curaçao, Klein Curaçao, Bonaire, Klein Bonaire, Las Aves, La Orchila

SNAKES

· *Liophis triscalis*	Curaçao
· *Crotalus unicolor*	Aruba
· *Leptodeira bakeri*	Aruba, some localities in Paraguaná

There are some species which are not strictly confined within the political borders of Aruba, Curaçao, Bonaire, but are also found in small areas in Venezuela, such as the snake *Leptodeira bakeri* or the lizard *Gonatodes antillensis*, the agave *Agave vivipara* and the cactus *Opuntia currassavica*. These species can nevertheless be considered endemics since they have a very restricted range.

There are also some endemic elements in the flora. We find some endemic agaves (Wagenaar Hummelinck, 1936 and 1938). *Agave vivipara* is found only in Aruba, Curaçao, Bonaire and areas around La Guaira in Venezuela. In the Cactaceae we also find endemic species, *Melocactus macracanthos* is endemic to Aruba, Curaçao and Bonaire. *Melocactus stramineus* is endemic to Aruba (van Proosdij, 2012). *Opuntia curassavica* is found in Aruba, Curaçao, Bonaire and Isla La Tortuga.

The Sabal palms found on Curaçao have now been proven to be different from those on Bonaire. They were described as *Sabal antillensis* (Patrick Griffith, et al., 2017). This original description was based exclusively on morphological characters. A DNA analysis has now confirmed this species identification. The Sabal on Bonaire has now been described as *Sabal lougheediana* (Clugston et al, 2024).

Since many palms show a very high variability depending on their growing conditions, there is some discussion, whether such new species can be described based using morphological characters only. In their natural habitat the *Sabal antillensis* grow slowly on the very poor, somewhat acidic soils of the Knip formation. Often, they grow on steep inclines. The strong winds may also be a factor involved. Some of these still look exactly the same as when I saw them some 30 years earlier and did not grow noticeably. These *Sabal* can be considered to be 'bonsai' palms. Dr. Antonie van den Bos planted seeds from these 'bonsai' palms in his garden in Julianadorp at Dam no. 2. Large palms, totally different from the ones on the St. Christoffel, Seru Gracia and Seru di Bientu were thus obtained on rich deep alkaline soil and with plenty of irrigation. There is an initial period of about 2 or 3 years, when they do not seem to grow at all, but under these circumstances they then start growing quite fast. Evidently their first priority is to make deep and extensive roots.

The 'Field Guide to the Palms of the Americas'- (Henderson, et al., 1995) states the following: "*...this overdescription of palm species was based on a herbarium species concept. In this approach, if a specimen looks different from others in the herbarium, it is automatically described as a new species ......One of the first investigators to try to resolve this problem was the Dutch botanist Jan Wessels Boer, working in Suriname and Venezuela in the 1960's. He collected palms exclusively in the field, and appreciated the great natural variation within species....*". This field guide recognizes 550 species in 67 genera in the Americas, which is markedly less than previous works, which had more than 700 species.

1.6 Invasive and alien species

Alien species are those that are not indigenous. Alien species are defined as any live specimen of a species, subspecies or lower taxon of animals, plants, fungi or micro- organisms introduced outside its natural range.

Invasive species generally are those that have caused problems elsewhere.

Invasive species are species whose introduction or spread has been found to threaten or adversely impact upon biodiversity and related ecosystem services. Invasive species may also pose risks for public health, infrastructure or the economy. Invasive species can be alien as well as indigenous.

It has proven to be very difficult to come up with a workable description of traits which make species invasive. Generally speaking, species from a completely different climate zone or an ecologically very different area are unlikely to be invasive on Aruba, Curaçao and Bonaire. For example, a penguin could never be invasive on these islands. Plants from acid soils, such as those of the forests of the Rio Negro area in Brazil for example, are very unlikely to be able to establish themselves on alkaline soils. Wood borers in wood imported from Canada or Siberia, will probably not survive in the tropics.

There have however been surprises.

Who would have thought that the Sapo (*Rhinella marina*) could have successfully established a population on an arid island like Aruba? This toad is normally found in wet tropical climates. It was originally imported to many Caribbean islands from French Guiana, to combat insect pests in sugar cane (Lever, 2001). It has also been imported in Australia (Shine, 2018). The Corn snake (*Pantherophis guttata*), nearly managed to establish a population on Curaçao (Perry et al., 2003). This is a subtropical species. Subtropical species usually need colder periods for their reproduction. The Corn snakes on Curaçao could have originated in South Florida and could thus have been pre-adapted to higher temperatures (van Buurt, 2006). Boi Antoin photographed one that had been killed by a car on a road in Bonaire in 2003.

1.6.1 Effects of invasive alien species

Invasive alien species (IAS) often have negative effects, on biodiversity and ecosystems in introduced ranges. Sometimes their effects seem to be neutral, sometimes there does not seem to be much effect at all, and sometimes even a positive effect. These introduced species can also be dormant, for a long period, causing problems only much later.

Ecological effects of IAS are, however, defined from a human point of view. We consider invasive species as negative if they affect things that we value, such as biodiversity and/or ecosystems. Some examples are their detrimental effect on the survival of endemic species, negative effects on food crops or ornamentals we cherish, on our health and negative effects on a landscape we value. Nature itself would presumably be hardly concerned whether an island is populated by alien cockroaches or whether endemic species can survive.

Species which are indigenous to our area and part of the 'normal' situation can be invasive alien species elsewhere and pose a problem according to the perception of people there. An example is the indju tree (*Prosopis juliflora*) (Figure 2a), which is called kwihi, kuigi, cuihi, kuihi in Aruba and kuhí, kuí, kwida in Bonaire (van Buurt, 2014). In English the Mexican name Mesquite (from Nahuatl, 'mesquitl') is used. This tree has overgrown large parts of Ascension Island in the South Atlantic and has also been introduced in Hawaii. It is nowadays established in large parts of the arid areas of Africa and Asia and is also found in Australia. It is a relatively fast- growing hardwood which also provides good firewood. In some areas it provides food for the *Anopheles* mosquito, a malaria vector. It thus enhances the transmission of the malaria parasite (Muller et al., 2017). Another example of a species indigenous to our area, which is causing serious problems elsewhere, is the shrub *Lantana camara* (IPBES 2023) (Figure 2b)

Figure 2A *Prosopis juliflora*, the mesquite tree. Photo: G. van Buurt.

The term 'invasive' conjures images of soldiers and tanks rapidly advancing over a beach, of fast action. Some 'invasive' species work very slowly however. An example is the Crown of Thorns (*Balanites aegyptiaca*). It was introduced in Curaçao in the mid 1880's by Cornelis Gorsira (Shon "Nene") and has spread out very slowly but relentlessly from the areas where it was first planted, c.q. plantations which Gorsira owned. He was a religious man who felt that plants mentioned in the bible should grow in Curaçao. He visited the Middle East in 1882 and brought seeds with him. He also introduced the Appeldam or ilb (*Ziziphus spina-cristi*) and the Doum or ginger palm (*Hyphaena thebaica*), but these are not regarded as invasive alien species (van Buurt, 2010). *Balanites aegyptiaca* has changed whole landscapes. Since it advances so slowly it is often not even mentioned as an invasive species. In my opinion this species could very well be the worst Invasive species we have. This species should not be introduced in Aruba and/or Bonaire. Other examples of invasive plants can be found in van Buurt (2010).
Not all alien species which are introduced have negative effects. Again, it is necessary to emphasize that what is considered negative is a human determination, which depends on the value we place on the species or ecosystems which are affected.

Figure 2B *Lantana camara.* Photo: G. van Buurt.

An introduction that can wipe out, or severely reduce the population(s) of (a) native endemic species is considered negative. And so are those that reduce the populations of cherished indigenous species and those that affect food crops and/or cherished ornamentals or which can affect our health or the health of our pets. The introduction of the Sapo (*Rhinella marina*) in Aruba is considered negative since many dogs and sometimes cats who bite this animal die. On the positive side this animal eats many cockroaches, but this does not change our perception of its presence being negative. It hurts when the beloved family dog dies.

The introduction of Boa constrictor on Aruba has impacted the populations of the lizard *Anolis lineatus* (endemic to Aruba and Curaçao), which is no longer found in wild areas, such as the Parke Arikok anymore but only in inhabited areas where people eliminate the snakes (Zilber, 2017). In 2017 I corresponded with Rotem Kadan-Zilber and she could not find any *Anolis lineatus* in areas where I had photographed them and where they were plentiful before. *Boa constrictor* has also been introduced in Cozumel, Mexico, in 1971 (Martínez-Morales and Cuarón, 1999), in Puerto Rico and on St. Croix where it has been found since 2012 (Gilliland, 2023).

The populations of various indigenous birds have also clearly been affected by Boa constrictor. No studies which quantify such declines exist, but for at least two species, such a decline is obvious. These are the Crested bobwhite (*Colinus cristatus*) and the Aruba sub-species of the Brown throated parakeet (*Aratinga pertinax arubensis*). The parakeets land on candelabra cactus, where the boa is waiting for them. Other bird species are probably also affected, we simply do not know (the known unknowns).

The Crested bobwhite is called cucuí in Aruba and cocoí or sloké in Curaçao. Recently, someone has introduced this species on Bonaire where it did not occur previously. I am a correspondent for the local newspaper Boneriano in Bonaire. In 2022, the editor Mr. Boi (Franklin) Antoin. Boi published an article on the presence of the sloké on Bonaire, in the local newspaper Boneriano of the 19th of September 2022. This bird is sometimes seen near "Tanki di Shon Leu ", North East of Rincon.

In Curaçao several times through the years large boas have been caught in the wild. Once a man who had been raking leaves in his garden, brought several juveniles which he had caught to my office. He had put them in a

plastic pail; they were still too small to get out by themselves. The mother was nowhere to be found. In the so-called Kabouterbos a large one was caught with two large iguanas in its stomach (van Buurt, 2001). In 2012 a large one was caught near Choloma and in the same year another one more to the west. In July 2023, there was a lot of concern about a large 4 m boa which had escaped. The owner was warning people to take care of their dogs and was asking to help him find it. I am pretty sure that this was not a boa but a Burmese python. A boa may be able to reach a maximum size of 4.5 meters (Glaw and Franzen, 2016), but they are seldom larger than 2.5 meters. Although it is now very difficult to bring in snakes, since it is prohibited, some people still have one. This man was earning money in town by letting people photograph themselves with a Burmese python. This was probably the snake that escaped, but he may have kept other snakes as well, so we do not know this for sure. This is very dangerous since the snake was getting bigger and bigger and could easily strangle someone. Especially on a warm day. Normally for such photo sessions, the snakes are cooled off in a fridge before the pictures are taken, to keep them sluggish. The latest sighting of a boa in the wild in Curaçao, was on September 25, 2024. It was photographed at a place called "kloof" and was fairly large. The lady who photographed it, was afraid of it (not without reason, since they can bite viciously) and did not kill it. Without a specially trained dog it is next to impossible to find back such a snake.

In any case we have been very fortunate, very lucky, that *Boa constrictor* has not established itself on Curaçao and Bonaire. Snakes do escape, but I also suspect snakes are still being released in the wild, probably by persons who cannot bring themselves to kill a pet, which they have raised for so long, but which they cannot handle anymore. On the other hand, such animals are unlikely to be gravid females. Less likely some snakes may still be smuggled in. A boa or other snake can also come in accidentally, most likely with the transportation of large plants for landscaping. Our luck may not hold forever.

Any new snake, with the possible exception of the blind worm snakes, is likely to pose a large risk for many indigenous species. There are of course many threats to reptiles, but in my opinion the foremost most acute threat would be a newly introduced snake.

Some species that established themselves are considered to have neutral or even slightly positive effects. The orange tube coral, also called orange cup coral (*Tubastraea coccinea*) from the Indo-Pacific oceans has established itself in the Caribbean. It spread rapidly through the Caribbean and became very common in the early 1950's. It was found in Curaçao around 1950 (Cairns, 2000). My biology teacher Benno de Jong used to tell us in the 1960's, how he had witnessed the rapid establishment of this coral in Curaçao in the early 1950's. A recent publication (Hoeksema, et al, 2023) gives an overview of alien corals travelling on semi-submersible platforms.

Tubastraea coccinea inhabits shaded vertical surfaces and caverns down to huge depths. It is very common in the shady overhang of local limestone cliffs. Orange-tube corals often dominate tropical habitats not occupied by other coral species. It is generally considered a colorful addition to our underwater fauna that did not affect other species, occupying a niche that was not previously occupied. Almost certainly this is not completely true. Its presence must have affected some species of sponges and other benthic invertebrates, which however for us hold a lower value. Apparently, it also affects some plankton feeders, with which it competes.

The Cuban treefrog (*Osteopilus septentrionalis*) is a problem on many Caribbean islands where cisterns are used for drinking water. Its skin has poisonous glands and these frogs enter the cisterns, especially in the dry season. It is almost impossible to keep them out since there have to be openings for the rainwater to enter unobstructed when it rains. There can be large numbers of such frogs in a cistern and this renders the water unfit for drinking. In Bonaire a Cuban treefrog was found in 2002 and had established itself by 2004 (van Buurt, 2005). It was introduced in Curaçao in 2007 (van Buurt, 2007). In Aruba it has been found in the garden of a hotel, but has not established itself. In Aruba, Curaçao and Bonaire we use tap water; the Cuban treefrog is not a great problem, but it is definitely a nuisance. It enters houses. One morning I went into the kitchen, grabbed my coffee mug and a treefrog jumped out, splash on my face. It enters water bowls used by dogs and cats and eats the geckos in the house. These frogs can be very variable in color. The color can be a yellowish white (when they hide in dark places), or can be reddish brown, light brown, a somewhat darker brown, light green or olive green. They can have a very pronounced blotched pattern, or can be can be quite uniformly colored. However, even in very uniformly colored animals a blotched pattern is always visible on the upper legs.

There have also been pleasant surprises. Ganoderma butt rot of palms, a palm fungus (*Ganoderma zonatum*), which has wreaked havoc on palms in Florida and Georgia, turned out to be practically harmless in Curaçao. It does not infect even adjacently growing palms easily. Probably the climate is too arid and the humidity too low. Conceivably this could change if the climate became more humid.

Some invasive species have sometimes established a foothold, but did not (yet?) manage to break out, or disappeared after some time. During a meeting in Aruba in 2008 I discovered small populations of *Anolis porcatus* and *Anolis sagrei* in the hotel garden of the Radisson Aruba Resort and photographed them. I already knew them since I had seen them earlier in Cuba. The landscaping for the hotel was imported from Cuba. The name of the hotel was later changed. Andy Odum went looking for them in 2009. He could not find *Anolis sagrei* anymore, but *Anolis porcatus* was still there (Odum & van Buurt, 2010). During a Dec 2018/Jan 2019 survey (Behm, Busala, Helmus, 2022), *Anolis sagrei* was not found either, but Anolis porcatus was still there. This occurrence of Anolis sagrei has been documented in Fläshendräger & Wijffels (2009). On the 21st of October 2006 there was a Facebook post by Sipke Stapert who found both a male and a female *Anolis sagrei* on Bonaire and photographed them. According to Sipke, *Anolis sagrei* is still there at Green Label Garden in NW Tera Kora. The tokay gecko (*Gekko gecko*), has established itself in the Sta. Catharina neighborhood in Curaçao (Behm et al, 2019). It did not spread out from there yet.

The following amphibians and reptiles were introduced and established themselves, see (van Buurt, 2005, 2007 and 2010), (Behm et al,2019), (van Buurt, Smulders,2022), (Behm, Busala, Helmus, 2022), (Wagensveld, T.P. van, Burg, M.P. van den, 2024).

· *Rhinella marina* (formerly *Bufo marinus*) on Aruba,
· *Pleurodema brachyops* on Curaçao and Bonaire, introduced from Aruba,
· *Osteopilus septentrionalis*, the Cuban treefrog, on Aruba (did not spread out), Curaçao and Bonaire. *Boa constrictor* on Aruba,
· *Indotyphlops braminus*, the flowerpot blindsnake on Aruba, Curaçao and Bonaire.
· *Hemidactylus mabouia*, the cosmopolitan house gecko on Aruba, Curaçao and Bonaire,

· *Hemidactylus frenatus*, the common house gecko on Aruba, Curaçao and Bonaire,
· *Lepidodactylus lugubris*, the mourning gecko on Curaçao and Bonaire.
· *Cnemidophorus arenivagus* (syn. *C. lemniscatus*), on Aruba.

· *Anolis cristatellus* was found in the garden of the Hyatt Regency Hotel on Aruba and *Anolis gingivinus* in the gardens of several adjacent residential buildings in Oranjestad. The survey was done Dec 2018/Jan 2019 (Behm, Busala, Helmus, 2022). Since the population of *Anolis cristatellus* was fairly large, it is probably still there. It is not known whether the *Anolis gingivinus* are still there.

Some species of alien birds also established populations in Curaçao, sometimes for quite a long time, but later disappeared (see under 1.8).

So, there have been several alien invasive surprises and it seems probable that there will be other surprises in the future.

"There are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns, the ones we don't know we don't know. ...it is the latter category that tends to be the difficult ones", Donald Rumsfield (2002).

1.6.2 Introductions that can or could threaten endemic species either through competion or by predation.

In Curaçao three new species of land snail have been introduced. These are *Bulimulus guadaloupensis* (Breure, 1975), *Zachrisia provisoria*, the Cuban garden snail and *Achatina fulica*, also called *Lissachatina fulica*, the giant African snail which was established in Curaçao in 2013 (van Buurt, 2016). *Achatina fulica* has also been reported from Bonaire, by Boi Antoin in his newspaper Boneriano of 14 november 2022. It is now established on Bonaire. In Aruba it has been found but did not establish itself. This snail does not seem to be a threat to the indigenous species, since they are found mostly in gardens and do not seem to be able to penetrate into the dry bush, where the local indigenous species live. However, if the climate were to become more humid, this could conceivably change. In gardens and horticulture *Zachrisia provisoria* and *Achatina fulica* are important pests. It is almost certain that all three introduced snails came in with soil from plants.

In the Pacific islands various species of flatworms (Platyhelminthes), are important predators of land snails. These are the so-called hammerhead flatworms, of which several species exist in the genera *Bipalium* and *Diversibipalium* and also the New-Guinea flatworm (*Platydemus manokwari*). Such flatworms spread out with the soil of potted plants (Thunnissen et al., 2020). Thunnissen et al (2020), contains many pictures and descriptions of land planarians, which can be useful for identification purposes. It cautions however that identification is not always possible by visual means. These worms can be fairly large and can reach a length of about 30 cm. The New-Guinea flatworm has already reached several places 'nearby', such as Miami, Florida, San Juan, Puerto Rico and French Guyana (Justine et al., 2015). Hammerhead flatworms have also reached our 'neighborhood' and have been reported from, French Guiana, Martinique, Guadeloupe, Saint Martin, Saint Barthelemy and Montserrat (Justine et al., 2018). It has now also been reported from Bonaire in the newspaper Antilliaans Dagblad (AD, 18 januari, 2024).

This article is based on a press release by the Dutch Caribbean Nature Alliance (DCNA), on the previous day (January, 14, 2024).
https://www.naturetoday.com/nl/en/nature-reports/message/?msg=31813

A hammerhead flatworm (Figure.3) has recently been found in Houston, Texas (Aguirre, 2023).

Figure 3 Terrestrial Hammerhead Flatworm, *Bipalium choristosperma*.
Photograph taken from Aguirre (2023).

Do not touch these worms, they contain tetrodoxin. This is the same toxin found in puffer fish. For humans, the threat posed by hammerhead worms is not so great, but for smaller creatures, like pets, this toxin can be fatal (Estulin & Barlow, 2023).

These worms form clones. Only one individual is needed to establish a foothold. If ever introduced on Aruba, Curaçao and Bonaire such predators could conceivably constitute a great danger to the local land snails. But then again, we do not really know. This is a "known unknown". It could very well be that Aruba, Curaçao and Bonaire are too arid for such worms to survive. In any case it would be best to try to keep them out!

1.7 Biological invasions with time

Usually after a few years, the effect of an invasive species seems to have diminished somewhat. There are some reasons for this. In the case of the Red Palm Weevil (RPW), (*Rhynchophorus ferrogineus*), the palms that were most susceptible were completely or almost completely eliminated fairly rapidly. The Fiji palm (*Pritchardia pacifica*), which used to be fairly common in Curaçao is not seen anymore. It is of course possible that there are still some somewhere in a garden, but I have not seen one in a long time. The Canary date palm (*Phoenix canariensis*) has also been severely reduced in numbers, but a few can still be found. The much less susceptible Arabian date palm (*Phoenix dactylifera*) can still be found. Birds have presumably learned to recognize the weevils as edible prey. I saw a bird eating one. The RPW is still around, it has not disappeared. It attacks *Bismarckia nobilis* palms, *Pandanus* and sometimes Arabian date palms. But its appearance is definitely less frequent.

With the invasive lionfish, something similar has been observed; they are much less common now. Local groupers have apparently developed resistance to their venom, they started to eat juveniles, gradually developed resistance and then progressed to larger fish (Maljkovic & van Leeuwen, 2008; Mumby et al, 2011).

When the Agave weevil (*Scyphophorus acupunctatus*) arrived in 2012, it initially did some damage. In view of the damage this weevil has done elsewhere, for example on the British Virgin Islands (BVI), personal communication by Gad Perry, we feared greatly for the local agaves. However, it

seems to have disappeared. Were local predators already present? Could this weevil have been present in the past? Several species of agave were introduced in 19th century for their fiber (Renkema, 1981); van Soest, 1975).

In the literature 'boom & bust' cycles are described (Strayer et al, 2017), whereby populations of invasive species can undergo marked fluctuations and, in some cases, even disappear completely. The process is not completely understood. In the examples mentioned above the easy prey for the invader diminished and the invader itself became prey for local predators. It is also likely that the prey learns how to avoid or evade the predator. Similar processes undoubtedly play a role in 'boom & bust' cycles and also others such as diseases which are governed by population density, and very likely other unknown factors as well.

Many plants protect themselves against grazers and borers, both with chemical compounds and physical barriers, to avoid being eaten. There is usually a long co-evolution of plant-herbivore interactions (Becerra et al, 2001 and 2009). Many articles document such interactions on a longer timescale. Plants, trees in the families Anacardiaceae and Burseraceae for example, protect themselves against grazers and borers, by producing chemical compounds, such as various terpenes and/or sesquiterpenes. Could such plants possibly sharpen their defenses fairly rapidly, say within a few years or a decade? Almost nothing is known about this last subject. Could such plants for example rapidly increase concentrations of certain terpenes, or may be shift production to those compounds which are most effective to slow down a new predator, such as a wood borer?

1.8 Pathways for introduction

There are at least five pathways for introduction of invasive species to Aruba, Curaçao and Bonaire. **The most important one by far is the transportation of live plants**, ornamentals for landscaping and gardens. Trees are sometimes transported in open-top containers. This is how the date palms containing the Red Palm Weevil came in from Egypt (6 to 7 large palms in an open top container) in 2008. From Curaçao palms were exported to Aruba, and the weevils thus also reached Aruba. They have now been reported from Saint Martin (in the local Curaçao newspaper Amigoe, Jan 4, 2024). How did they get to Saint Martin? The only other islands in the Caribbean where this weevil was present were Aruba and Curaçao. They are not present in Florida. Or were they introduced from France?

Many species have a high or possibly even very high rate of survival when transported in such open top containers. These are used to transport larger plants. When it rains during the journey, they get some water and in any case the plants are transported with humid soil, often wrapped in burlap. Sometimes the open-top container is covered with a tarpaulin. The container does not overheat easily, it is cooled by the sea breeze.

In the case of closed containers with potted plants, so called ventilated containers are used (Figure 4). These have several ventilation fans, which are usually found on the top and bottom side rails of the container. These are known as 'active container vents', and use fans to circulate air effectively. Active vents are also designed in such a way so as to prevent rain and sea spray from entering the container during shipping. They are also often known as 'coffee containers' because they are used to transport coffee beans, as well as cocoa beans, and other high-moisture goods. Standard containers also have some vents, but these are very small.

Figure 4 20 ft ventilated containers. Photograph XChange.com.

Survival of invasive species in these ventilated containers is probably as high as in the open top container. The soil of the plants is kept moist. Snakes are often introduced via the potted soil of larger plants. A live poisonous Eastern coral snake *Micrurus fulvius* came in this way from Florida. At the time it was brought to my office in a plastic pail. I identified it and killed it. The Cuban tree frogs which established themselves in Curaçao also came in by this route (van Buurt, 2006 b). The Cuban tree frogs in Bonaire almost certainly came in with imported plants from Florida as well. They were first found near a store selling such plants. When a first container arrived in Curaçao from Cuba with *Washingtonia* palms in 2000, several anoles got out and sped away rapidly. A Cuban tree frog which was slower was caught. The anoles were not seen again. Luckily, they did not get established. They seemed full of energy and did not seem to be noticeably weakened by their long voyage. These palms were shipped in an open-top container, which was transshipped via Venezuela and took aproximately 5 weeks to arrive (van Buurt, 2001 and 2005, see photo 75 in 2005). Snails and slugs can also come in (Cowie, 2008). In many cases the soil contains viable eggs. Containers shipped from Miami normally arrive in about 7 days (from the moment the doors are closed to delivery at the customer's location). It then depends upon the customs when the doors are opened.

In Aruba, Cuban anoles and an unidentified Cuban *Eleutherodactylus* frog (which did not establish itself) came in with landscaping trees and mulch for a hotel.

Most live plants are nowadays imported from Miami, Florida. Any invasive species which are already present in Florida could potentially come in. These are already on or near 'our doorstep' and also on the doorstep of many other Caribbean countries, so to say. A recent publication makes precisely this point. (van den Burg et al, 2023).

The second important pathway is via the importation of fruits and vegetables. Many plant diseases came in via this pathway. These containers are always cooled containers or reefers. Compared to the transportation of live plants, the risks are much more manageable. Examples of diseases of pests that very likely came in this way are: Sweet potato weevil (Cylas formicarius), Citrus hindu mite (*Schizotetranychus hindustanicus*) and Papaya Ringspot Virus (PRSV-P).

I found Citrus hindu mite (*Schizotetranychus hindustanicus*) around 2000. My first photograph of it is dated July 15, 2004, but this is the date when I scanned a slide which I already had, with a new slide scanner. At the time I did not know what it was and could not identify it. They already had it in Aruba, but did not know what it was either. It is also present on Bonaire, but I do not know when it arrived there. It was first found in Brazil, in Boa Vista, in 2008 (Navia & Marsaro, 2010). In their report it is said that it had also been found in Venezuela in Zulia, near Maracaibo, but that this was unpublished at the time. Cas Vredebregt in Aruba found this report. Then we finally knew what it was. There is a road from Boa Vista to Sta. Elena de Uiarén in Venezuela. It is very well possible that this mite came from India to Aruba. Aruba had frequent flights to Maracaibo, Venezuela. It could have spread to Boa Vista from Venezuela. It could also have come in from India to Curaçao and spread to Aruba from here. In this case there could have been a traveler from India who had fruits with him.

The third would be the pet trade. *Boa constrictor* in Aruba very likely came in with the pet trade. From the coloring of wild boas, the region from which they came can often be deduced. In the Aruba population we find several with the white blotches of albino boas, which is an indication that they came in with the pet trade. In any case they do not have the typical coloration of Venezuelan boas.

In Curaçao many birds which escaped became established in the wild. Examples are: The Chestnut-fronted ara (*Ara severus*, Figure 5), various Amazon parrots such as, the Yellow-crowned parrot (*Amazona ochrocephala*), the Orange -winged parrot (*Amazona amazonica*), the Red-lored parrot (*Amazona autumnalis*), The Yellow-shouldered parrot (*Amazona barbadensis*), (van Buurt, 2010; de Boer et al, 2011). These Amazon parrots often form mixed-species flocks.

The Yellow-shouldered parrots (*Amazona barbadensis*) on Curaçao, are very likely escaped pets, or derived from escaped pets (de Boer et al, 2011). This is the Bonaire parrot. This parrot is also present in drier areas of Venezuela, it has a large range and is found in the states of Falcón, large parts of Lara and parts of Anzoátegui and Sucre. This species is in decline (Hilty, 2003). Its current IUCN conservation status is listed as vulnerable. It is for example present in Paraguaná, on La Blanquilla and on Macanao, the drier Western part of the Isla de Margarita. It has been extirpated on Aruba

(Voous, 1983) and probably in Curaçao as well (van Buurt, 2010), but later some became established there again. In Bonaire it is properly protected, but this is not the case elsewhere in its range. The name *Amazona barbadensis* is a misnomer, since it was never found on Barbados. Linnaeus received the type specimen via Barbados.

Many years ago, an uncle of mine, Julius S. Joubert told me he had seen a pair of parrots coming in over the sea from Bonaire, regularly, early in the morning, almost daily. At the time he was working on a sand-dredger which was harvesting sea-sand at the entrance of the St. Joris Bay. He would stay there overnight. A few times he saw them flying back, a few hours later, around 10.00 in the morning. But at that time, he would be at work and had no time to watch parrots. The distance from the entrance of the St. Joris Bay to Punta Wecua in Bonaire is about 45 km, a distance that Amazon parrots can cover quite easily. So, it could also be that a few arrived in Curaçao by themselves and decided to stay.

In Curaçao there are also flocks of feral parakeets such as the Blue-crowned parakeet (*Aratinga acuticaudata*) and the Scarlet-fronted parakeet (*Aratinga wagleri*).

The Rose-ringed parakeet (*Psittacula krameri*) and the Green-rumped parrotlet (*Forpes passerinus*), had also established feral populations, but both seem to have disappeared. I have never seen a Green-rumped parrotlet in the wild, but my mother Rosa Anna Joubert told me that in the 1930's in her childhood years, they were fairly common at Klein Piscadera plantation (where we both grew up). This bird has a Papiamentu name 'Bibitu'. This also indicates that at some time it must have been fairly common.

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 extended drought (personal Communication, Joost Pronk).

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. They later travelled to Bonaire on a ship that was transporting rice. The ship came from Bonaire with rice, some was spilled on the deck and when the ship returned the sparrows hitched along. 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.

The shiny cowbird (*Molothrus bonairensis*) was first found in the wild in Curaçao, 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 Curaçao the population is probably derived from escaped caged birds (Debrot & Prins, 1992).

During the last part of the 20th century monkeys and parrots were often smuggled in from Venezuela. They came in with the Venezuelan fruit vessels. During the years controls were intensified and this matter was gradually brought under control. Then maritime traffic with Venezuela ceased altogether. It has recently been reestablished. It is hoped that this problem will not resurface in the future. Although these monkeys themselves are not invasive species they can carry diseases which are a public health problem. The parrots can carry psittacosis (2.3.1. under 4 and 5).

The African green monkey (*Chlorocebus sabaeus*) has however established itself in St Kitts and on St. Martin. So, maybe we should not completely discount the possibility of a monkey which is adapted to dry regions

Figure 5 Chestnut-fronted ara (*Ara severus*) overflying my house in Toni Kounchi
Photo: G. van Buurt.

establishing itself on Curaçao. But even so, this seems quite unlikely and even less likely on Aruba and/or Bonaire.

The fourth pathway would be individual persons smuggling in animals or plants without phytosanitairy certificates. In the past this was not illegal and people would simply bring in animals and plants when returning from vacation. This is how *Rhinella marina* (which in those days was called *Bufo marinus*) was introduced in Aruba, from Colombia (van Buurt, 2001, 2006). The land snail *Bulimulus guadaloupensis* was also introduced in Curaçao from Saba in this way, in 1972. It came in with plants collected on Mt. Scenery (Breure, 1975).

The last pathway is a combination pathway of transport by human activities, to or within the region, which is then further dispersed by winds. Many insects have stages that can be transported by the wind and can travel from island to island. This is of course a natural process, but once many pests reach the Caribbean region, they will spread out over the region with the winds and are then practically unstoppable. Some species thus travel by a combination of pathways. It is also known that birds and presumably other animals as well, can become trapped in the cores of hurricanes and can so be transported over large distances and carried far from their normal range (van den Broeke, 2022).

Figure 6 *Vanessa cardui.* Photo: Carel P. de Haseth.

A transatlantic crossing by Painted lady butterflies (*Vanessa cardui*) spanning at least 4200 km, from West Africa to South America (French Guiana) has now been reported (Suchan, T., et al, 2024). This butterfly has now also been found and photographed in 2016, in Curaçao, in an area called Patrick, by Carel P de Haseth.

The pink mealy bug (*Macronellicoccus hirsutus*) first entered the Caribbean in 1994 (FAO, 1995) and reached Curaçao in 1997. It was suspected that it came in by ship and its further spread was thought to have been assisted by the wind. The adult males are small flies and the first instar nymphs can also be transported by the wind. At the time the late Bisessar Chackalall, from FAO, told me that it very likely came in with a Taiwanese tuna longliner which transited the Suez Canal and from there went to Grenada without stopping at any other port. In Egypt they bought bananas to consume during the voyage. The pest was first found in Grenada near the mooring place of this vessel. From the pattern by which the pest then spread out further to other islands, it seems it was spread by the wind. But since none of this could be proven conclusively it was not published at the time (nor afterwards). Of course, as an organization that is part of the United Nations system, FAO would have to be very careful not to be accused of making false accusations.

Although sometimes it is obvious, it is not always easy to establish how and when something came in. In 2011 while photographing snails on the north coast plateau, at Patrick in Curaçao, I found *Icerya purchasi*. This is the cottony cushion scale originating from Australia; it was present everywhere on various local plants. How did it get there, how long has it been there? I suspect it must have been there for quite a long time already. Maybe it came in somewhere the region by ship or with an airplane and then spread out with the winds. But without historical data from its presence elsewhere it is impossible to know the pathways for introduction and spread of this species.

1.9 Marine invasive alien species

In the years preceding the 1970's ballast tanks of ships used to be heavily polluted with oil. Small beaches on the northern coasts of Aruba, Curaçao and Bonaire were quite regularly polluted by small patches of oil, due to discharge of ballast water (van Buurt, unpublished observations, 1960 -1966).

Headquartered in London, the IMO (International Maritime Organisation), was created by a convention adopted at the UN Maritime Conference in 1948. The convention came into force on March 17, 1958. The IMO started to address the problem of dumping oil-polluted ballast water at sea and a marked improvement resulted. But oil and tar on the northern beaches remained a problem for a long time (Debrot, et al, 1995); though not to the same extent as in the early 1960's. It was only much later that it was realized that many organisms could now survive in this cleaner ballast water and that this was now causing problems. New regulations were enacted, which in addition to the earlier measures regarding dumping oil-polluted ballast water at sea also prevent the spread of alien species with ballast water. The International Convention for the Control and Management of Ships' Ballast Water and Sediments, (IMO, BWM Convention, 2004), entered into force globally on 8 September 2017.

A summary of invasive alien marine species in Aruba, Curaçao and Bonaire is given in Debrot et al (2011).

The two most destructive alien invasive species in the waters around Aruba, Curaçao and Bonaire have been the following. A causative agent of the 1983/84 mass mortality of the black sea urchin (*Diadema antillarum*) and the lionfish (*Pterois volitans*).

1. The causative agent of the 1983/84 disease of *Diadema antillarum*, the black sea urchin, or long-spined sea urchin which caused mass mortality of this species of sea urchin throughout the whole Caribbean. This sea urchin was up to 1983 the most important herbivore on Caribbean reefs. Its densities throughout its range in the tropical western Atlantic were reduced by 97 %. This is documented in Lessios (1988) and Lessios, Garrido, Kessing (2001). At the time the causative agent was not identified. For years there was much speculation whether it could be a bacterium, a virus or may be a PPLO (pleuro- pneumonia like organism). In 2022 there was a new outbreak and for this outbreak the causative agent has been identified (see below). During the years there has been a very slow recovery of *Diadema antillarum* populations, in different locations in the Caribbean, which has been documented in various publications, the last of which covers a 40-year period. See: (Lessios, 1995), (Hunte & Younglao, 1998), (Cho & Woodley, 2000), (Vermeij et al, 2010), (Del Rio Torres & Galvan, 2015). Then in 2022, there was a new outbreak of mortality with very similar symptoms (Hylkema, et al 2023) and (Levitan et al, 2023). This outbreak

had its epicentrum in the US Virgin Islands and from there started to spread further into the Lesser and Greater Antilles. Within four months the die-off was distributed over 1,300 km from north to south and 2,500 km east to west (Hylkema, et al 2023). Whereas the 1983-1984 die-off advanced mostly with the currents, the 2022 event has appeared far more quickly in geographically distant areas. First die-off observations in each jurisdiction were often close to harbor areas, which, together with their rapid appearance, suggests that anthropogenic factors may have contributed to the spread of the causative agent. Levitan, et al. (2023) state that in other respects though, the spread is slower and more patchy than during the 1983/1984 outbreak. This could be because the sea urchins' populations nowadays have a much lower population density and also because some resistance is nowadays likely present. This time the causative agent was identified (Hewson et al, 2023). It turned out to be a scuticociliate of the genus *Philaster* (*Philaster* sp.). Although no absolute proof exists, it seems very likely that the 1983/1984 die-offs were also caused by this same organism. There are unfortunately no preserved samples from the 1983/1984 period available, which would enable to prove this. It is thought that the organism probably came in from the Pacific, with ballast water from a tanker. The outbreak started at the San Blas islands, west of Colon in Panama (Lessios, 1988). The very closely related *Diadema mexicana* in the Eastern Pacific is very likely resistant to this disease.

2. The lionfish (*Pterois volitans*). There is a closely related lionfish (*Pterois miles*), which however did not reach the Southern Caribbean (Betencur et al, 2011). Lionfish are voracious predators. The Lionfish (*Pterois volitans*) was first observed in Bonaire and Curaçao in October 2009, (Schofield, 2010) and (Côté et al, 2013), give an overview of its spread through the Caribbean from Florida. The populations are derived from escaped aquarium animals. After an initial population explosion, their numbers have now diminished. See under 1.6 and 3.3.3.

3. A new threat has now reached the Caribbean. The Indo-Pacific soft coral *Unomia stolonifera*, has now established itself in Cuban (Sáez et al, 2023) and in Venezuelan waters (Ruiz - Allais et al, 2021). At the time of writing (april 2024) it had not yet been found in the waters around Aruba, Curaçao or Bonaire. But it seems likely that this will happen sooner or later.

1.10 - Aim of the publication

The above overview illustrates that alien species are increasingly being introduced via various pathways and that invasive alien species may pose significant environmental risks for Caribbean islands. For many alien species, however, it is insufficiently documented when, from where and how they were introduced, whether they can establish viable populations, further spread and cause undesirable environmental effects on islands. For several cryptic species, it is even unknown whether they are native or alien. Therefore, the overarching aims of this publication are:

1) to analyze the introduction pathways, population establishment, spread and environmental impacts of recent invasive alien species on Aruba, Curaçao, and Bonaire.

2) to discuss appropriate management measures to prevent, control or mitigate negative effects of these biological invasions.

The publication will focus on biological invasions of alien species in terrestrial ecosystems and will particularly examine recent invaders (i.e., IAS introduced in the period 1960-2023) and considers various taxonomic groups (e.g., amphibians, reptiles, insects, and land snails). The following research questions will be answered:

1) Which IAS have recently been introduced in Curacao and what is known about their introduction pathways, establishment, secondary spread and environmental impacts? (Chapter 2). Which of these are also known to be present on Aruba and Bonaire.

2) Recommendations for invasive species management are given in Chapter 3.

2. Listing and analysis of introduced invasive alien species in Curaçao

2.1 Some plant diseases and pests introduced in Curaçao since the 1960's

Several of these I also encountered while visiting Aruba and Bonaire.

Aruba	Bonaire	Curaçao
•	•	• Papaya Bunchy Top (MLO), early 1960's
		• Spittlebug (*Aeneolamia reducta*), probably 1986
•	•	• Whitefly (*Bemisia tabaci*), 1989
		• Black Citrus aphid, Brown Citrus aphid (*Toxoptera citricida*), 1989
		• Sweet potato weevil (*Cylas formicarius*), 1990
		• Palm Thrips (*Thrips palmi*), 1994
		• Cuban Laurel Thrips (Gynaikothrips ficorum), 1996
		• Citrus miner (*Phyllocnistis citrella*), 1996
•	•	• Pink Mealy bug, Hibiscus mealy bug (*Macconellicoccus hirsutus*), 1997
•	•	• Citrus hindu mite (*Schizotetranychus hindustanicus*) probably 2000
	•	• Zachrysia snails (*Zachrysia provisoria*), probably 2002
		• Papaya Mealy bug (*Paracoccus marginatus*), 2002
		• Papaya Ringspot Virus (PRSV-P), 2002
		• Sorghum ergot (*Claviceps africana*), probably 2003
		• Ganoderma butt rot of palms (*Ganoderma zonatum*), 2003, 2010
•		• Red Palm Weevil (*Rhynchophorus ferrogineus*), 2008
		• Several fungal palm diseases, probably *Gliocladium* and *Fusarium* spp. also came in, almost certainly with these date palms imported from Egypt.
		• White partridge pea bug (*Crypticerya genistae*), 2009
		• Agave weevil (*Scyphophorus acupunctatus*), 2012
	•	• African Giant snail (*Achatina fulica*), 2013
		• Kissing bug, vinchuca bug (*Triatoma infectans*) vector of Chagas disease, 2013
		• Red ring nematode (*Bursaphelenchus cocophilus*) is probably present!
		• *Phyllosticta* fungus, especially on *Opuntia*, 2013
		• Hawaiian carpenter ant (*Camponotus variegatus*), 2014
		• Trap-Jaw ant (*Odontomachus bauri*), 2014
		• *Pulvinaria* sp. (a scale insect, cactus pest), 2014
		• *Planuncus tingitanus* s.l. (North African cockroach), 2018
		• *Camponotus atriceps*, 2018
		• *Tapajosa* sp. (sharpshooter treehopper, leafhopper), 2018
		• A new mosquito *Aedes vittatus*?, 2021
•		• Milkweed bug, seedbug, *Spilostethus pandurus*, 2023
		• Nigra scale, pomegranate scale, *Parasaissetia nigra*, 2024 (Found and photographed by Carel P. de Haseth on an agave in July 2024. It is a species that attacks many different plants.)

2.2 Methods

When new pests were reported these Invasive alien species were investigated and photographs were taken. Often 1mm graph paper was used as a background, or a coin was used to provide scale. Amphibians and reptiles were sometimes photographed on 1 inch graph paper. Photographs were also received from informants. The photographs were identified by me or forwarded to an expert for identification. In a few cases samples were taken. These samples were conserved in 96% ethanol with a little concentrated acetic acid added (vinegar essence from the supermarket) and subsequently stored in the fridge for later identification.

2.3 Observations and comments regarding this list

· The list is certainly incomplete

· The list clearly indicates there is a problem, almost every other year something new arrives.

· The list does not include invasive species known to have arrived before the 1960's

· The list does not include species which are not plant diseases or pests, such as for example some of the millipedes and the *Varroa* mite of bees. These are however discussed in, van Buurt and Debrot (2012 a and b). Many invasive species which were reported after 2012 have been added, for the most up to date view.

Figure 7 The rusty millipede (*Trigoniolus corallinus*). Photo: G. van Buurt.

The rusty millipede (*Trigoniolus corallinus*), originally comes from somewhat drier areas in South-East Asia, in Myanmar and Thailand. It almost certainly came in with potted plants from Miami. I photographed them in my garden in 2011, where I first saw them about a year earlier, but by that time they must surely have been on the island for some time already.

Another millipede that appeared around 2011 is *Eurhinocricus* sp. Millipeds have chemical defenses. Some people got a nasty allergic reaction to this animal. Do not touch it! They were less common than the rusty millipede to begin with and now I have not seen them for a long time, unlike the rusty millipede which is still around.

· There are various identification problems. Insects and mites can be difficult to identify.

The spittlebug, *Aeneolamia reducta* was originally identified as *Aeneolamia varia*, which is a common pest in Venezuela. It was assumed that it came in from Venezuela. An expert who is usually specialized only in certain families of insects is needed. Marco de Haas of Museum naturalis identified it as *Aeneolamia reducta* from a photograph. During field work in Curaçao he did not find *Aeneolamia varia* either.

It can also be difficult to identify species from photographs, often conserved specimens are needed. The sharpshooter treehopper *Tapajosa*, was originally identified as *Tapajosa spinata*. It turns out to be a

Figure 8 *Eurhinocricus sp. milliped.* Photo: Carel P. de Haseth.

local species, which had first been found in 1956, and which for some reason has been dormant for many years. It is not a new invasive species. The difference can only be noted in the genitals, which are of course not visible in photographs. This species has now been named *Tapajosa arawaka* (de Haas & Gaiani, 2024).

With fungi there are similar identification problems. These were provisionally identified by me based on the symptoms of the diseases they cause, using books that describe palm diseases (Chase and Broschat 1991 and Elliot., (Eds), 2004). But this diagnosis may of course be wrong. A well-equipped laboratory and experts in this field are needed to identify them properly.

· The years given are the years when the presence of the species was first noted, but they may have been introduced much earlier.

In 2002 Dr. Moses Kairo, who at the time was working at CABI in Trinidad visited Curaçao. He asked whether we had Papaya mealy bug, which at the time was a problem in the Caribbean area. We said no, we do not have it. The very first papaya tree he inspected turned out to have them, but they were not causing problems because many parasites were also present, evidently controlling their numbers. This of course raises many questions. Could this papaya mealy bug be native and was it originally feeding on some other plant, before the papaya got introduced, their natural predators already being present. Or were papayas introduced from an area where these parasites were present?

Ganoderma zonatum came in more than once. One was found in a garden in 2003 and eliminated. In 2010 they came in again.

- This listing is for Curaçao only. Many of these pests have also reached Aruba and Bonaire, but a more or less 'complete' listing for Aruba, Curaçao and Bonaire is not available, since a thorough inventory has not been made. When species are however known to be present on Aruba and/or Bonaire this has been noted. It is also possible that invasive alien species which are not (yet) found on Curaçao are present on these islands or on one of them.

- Species which came in but were intercepted and did not manage to establish themselves are not mentioned.

Figure 9A & 9B *Calcisuccinea campestris* on one millimeter graph paper and on a guava fruit. Photo: G. van Buurt.

For example, in February 2020, guava fruit imported from Florida and infected with the snail *Calcisuccinea campestris* were found in a local supermarket. This species is known to be a pest species of fruit and horticultural crops.

In one case a photograph was received of a candelabra cactus with what seemed to be a heavy infection of *Harrissia* mealy bug. This photograph was taken west of the airport on the Hato plain. But the cactus could not be found again, and no *Harrisia* cactus mealybug pest has ever been seen or reported since. *Harrisia* cactus mealybugs are native to northern Argentina and Chile, westernmost Brazil, Paraguay and southern Perú. They have been introduced on several Caribbean islands (Carrera- Martinez et al., 2015., Hodges and Hodges, 2009., Zimmermann et al., 2010).

The small parasitic wasp (*Anagyris kamali*) and the ladybug (*Cryptolaemus montrouzieri*), which were introduced to combat the pink mealy bug, are not included in the list either, since they are not plant pests (see under 3.3.1.4).

2.3.1 Invasives that can affect human health

There are a few invasive species which can affect human health;

1) A new *Aedes* mosquito probably came in, in Curaçao, but still has to be properly identified. It could be *Aedes vittatus*. These mosquitos are also active and bite during the daytime; they are a vector for yellow fever, zika and West Nile virus. The Asian tiger mosquito (*Aedes albobopictus*) is already present in Miami, in Colombia (Echeverry-Cárdenas, et al, 2021), Venezuela and the Dominican Republic (Navarro, et al, 2009). If it is present in the Dominican Republic, it must surely also be present in Haiti. It is thus already present in all major "gateways" to Aruba, Curaçao and Bonaire. This mosquito species is a known vector of chikungunya virus, dengue virus, zika and dirofilariasis. The yellow fever mosquito (*Aedes aegypti*) can transmit, yellow fever, dengue, chikungunya, zika. This mosquito has already been present on Aruba, Curaçao and Bonaire for a long time, but it is not active during the day time. Any mosquito present in Miami is 'on our doorstep' and could come in easily especially with transportation of live plants.

2) *Triatoma infestans* is a common vector for Chagas disease. This species has been found in roof materials for 'palapa'beach huts in Curaçao, by Gisette Seferina in 2013. She found it in a large percentage of 'palapa' roofs.

Figure 10 *Triatoma maculata.* Photo: G. van Buurt.

The species *Triatoma maculata* (Figure 10) is a vector for Chagas disease in Venezuela. (García-Alzate, et al., 2014). It is present in Curaçao; it is also present in Bonaire and very likely on Aruba as well. It is not a recent invasive species and has probably been present for quite some time. It could even be native. In houses in Curaçao it does not seem to be very common. In my house where I have been living since 1987, I have found them only a few times on my porch, where I killed them immediately. In Venezuela *Triatoma maculata* is living in association with the gecko *Thecadactylus rapicauda* (Reyes-Lugo., et al., 2011). This gecko has a large range in tropical South America, Middle America and the West Indies. It is also found on Aruba, Curaçao and Bonaire. Since the introduction of the Tropical house gecko *Hemidactylus mabouia*, this gecko has displaced *Thecadactylus rapicauda* (Figure 11) in houses. *Hemidactylus mabouia* could of course also become a vector for Chagas disease.

Chagas disease is named after the Brazilian physician Carlos Chagas, who discovered and described the disease in 1909. It is caused by the parasite *Trypanosoma cruzi*, which is transmitted to animals and people by insect vectors and is found only in the Americas (mainly, in rural areas of Latin America where poverty is widespread). Chagas disease (*T. cruzi* infection) is also referred to as American trypanosomiasis. Chagas disease has an acute and a chronic phase. If untreated, infection is lifelong.

Figure 11 *Thecadactylus rapicauda.* Photo: G. van Buurt.

There has been one case of Chagas disease reported in Curaçao. A boy who was 8-year-old at the time, had the disease but he probably contracted it in the Dominican Republic, while spending a vacation with his uncle. It is a disease medical doctors have to report and the local bloedbank has now taken preventive measures.

If and when a case presents itself in Curaçao, the Red Cross Blood Bank Foundation, locally called "bloedbank" is now able to detect it and will run a test screening program (pers. communication Dr. Ashley J. Duits, director of the bloedbank). However, blood of animals which can carry the parasite such as dogs or mice (Panti-May., et al., 2024) cannot be tested locally.

A major concern regarding kissing bugs such as *Triatoma infestans* is ana- phylactic reactions to their bites, which frequently result in emergency department visits. Salivary antigens from kissing bug species cause allergic reactions in sensitized individuals. The spectrum of allergic reactions to kissing bug bites encompasses local reactions (eg, angioedema at the bite site or elsewhere) to more systemic reactions, including mild to severe anaphylaxis.

3) The African giant snail *Achatina fulica* can contain a parasitic worm. *Angiostrongylus cantonensisis* is a parasitic worm of rats. It is also called the rat lungworm. The adult form of the parasite is found only in rodents. Infected rats pass larvae of the parasite in their feces. Snails and slugs get infected by ingesting the larvae. These larvae mature in snails and slugs but do not become adult worms. The life cycle is completed when rats eat infected snails or slugs and the larvae further mature to become adult worms. People can get infected, under unusual circumstances. However, even if infected, most people recover fully without treatment. Sometimes however the disease can be fatal. People can get infected by eating raw or undercooked snails or slugs that are infected with this parasite. In some cultures, snails are commonly eaten. People also can get infected by accident, by eating raw produce (such as lettuce) that contains a small snail or slug or part of one, or snail slime.

The problem is usually encountered in areas where snails and rats are found living in close vicinity. The black rat (*Rattus rattus*) is locally fairly common around houses. Irrigated gardens also attract the snails. This rat problem has a lot to do, with the availability of food; often left over dog-food and cat-food, which the rats eat at night. The name black rat is a misnomer on Aruba, Curaçao and Bonaire because here it is never black. They can be grey, light grey-brown, beige or dark or light brown (Husson, 1960). In Europe they are usually black. The black rat is an old invasive species that came in right after 1499. The snails also like the dog-food and this creates a snail-rat interface.

It is possible to eat the snails provided they are handled with gloves and well-cooked at high temperatures in a pressure cooker or baked in an oven. See 3.3.3.

4) Diseases carried by monkeys. Monkeys can carry diseases such as the yellow fever virus (Coelho Couto de Azevedo Fernandes, N., et al., 2017), the malaria parasite (de Abreu F.V.S., et al., 2019), and the Zika virus (Terzian, et al., 2018). These can then be transmitted to humans by mosquitos. For Aruba, Curaçao and Bonaire yellow fever holds the largest risk.

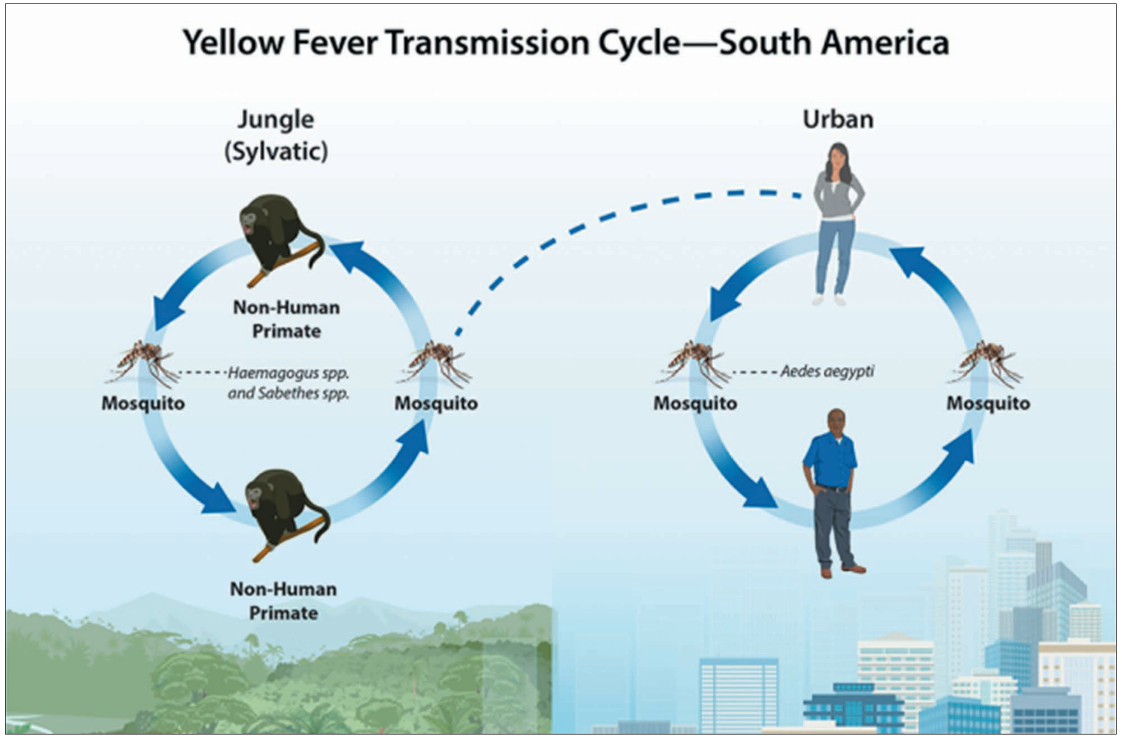

Figure 12 Yellow fever transmission cycle. Source: Centers for Disease Control and Prevention, National Center for Emerging and Zoonotic Infectious Diseases (NCEZID), Division of Vector-Borne Diseases (DVBD). The monkey depicted in the drawing is a Howler monkey, called Araguato in Venezuela. Several species of howler monkeys exist.

A confiscated monkey was once brought to the zoo. It died under mysterious circumstances. The veterinarian (O.B. de Haseth) suspected rabies. A hole was dug with a backhoe excavator and the animal was covered with quicklime, Calcium oxide (CaO) and buried approximately 2 meter deep.

5) Diseases carried by parrots. Parrots can have psittacosis. In humans, the symptoms are fever, headache, chills, muscle pains, cough, and sometimes breathing difficulty or pneumonia. If left untreated, the disease can be severe, and even result in death, especially in older people. Some people may only experience mild flu-like illness, or have no illness at all (Dembek et al, 2023). In the past there have been cases in Curaçao caused by smuggled parrots.

6) Africanized Honey Bees (AHB)

On the day of all Saints, November 1, 2006, a lady was attacked by bees while visiting a grave at the Soto cemetery in Curaçao and died the next day. On both the 'day of all Saints' (November 1) and the 'day of all Souls' (November 2) people tend to visit the graves of family members. These bees were very aggressive. The medical doctor who tried to save her, Marcel Sommer, is also a beekeeper and he reported that these bees were extremely aggressive. There were, however, some factors contributing to her death. The lady was over 90 years old and had a weight of more than 90 kg. She could not get out of the way rapidly when attacked. According to Sommer graveyards often provide good nesting spaces for bees, since there are open crypts available to them, awaiting their new occupants, Sommer (1992). It turned out that there were 6 colonies present in the Soto cemetery. In later years a loader driver was also killed by bees at Westpunt, after he hit a tree with a nest in it. He jumped out of the loader and fell on a spike on its blade, and may have died from internal bleeding, or at least the internal bleeding probably contributed to his death. But then there will probably always be such or similar contributing factors when such accidents happen. Most accidents have contributing factors. The bees that killed the lady, were investigated and it turned out that they were partly Africanized (Gisette Seferina, pers. comm.).

Various people were attacked during the years and had to be hospitalized. In February, 2021, various hikers in the bush near Jan Thiel were attacked. One had to be evacuated by helicopter. There was also an attack at the

Westpunt cemetery in 2022, by bees nesting in crypts. Many dogs which were leashed to a chain in the garden and could not escape have been killed during the years. The most recent incident occurred on the 26th of October 2023, when a loader took down a tree with a bee-nest in an area called Bonam. Several people living in surrounding houses had to be taken to the hospital by ambulance and three dogs which were all on a leash and could not escape were killed.

Bees can be aggressive, especially during the end of a long dry season, in the xerophytic bush, locally called mondi, when there is little food available. In the inhabited areas there are many gardens and there is usually some food available to them even during a severe dry season. When honey bees are infected with the ectoparasitic Varroa mite (*Varroa destructor*), they are generally always much more aggressive, but especially so under the circumstances mentioned above. Bitter (1950) mentions very aggressive honey bees on Aruba. This was before African bees (*Apis mellifera scutellata*) were introduced in the Americas. Very likely the Varroa mite was already present in Aruba at the time (van Buurt & Debrot, 2012b). The Varroa mite was probably introduced in Curaçao around 1992, by a beekeeper who wanted to introduce 'new blood'. Earlier it was reported that they came in around 1996 (van Buurt & Debrot, 2012b), but it now turns out that they came in a few years earlier. It took a 'lag phase' of a few years for the mite to spread out and make its presence felt on the island.

Recently there was an article, in a local Curaçao newspaper, with an alarming tone, stating that some beekeepers were planning to smuggle in African honey bee queens to establish new colonies on the island. The African honey bee is known to produce more honey. It is difficult to judge whether this article is based on fact, or whether it is just purely sensational journalism to help fill a morning tabloid. In any case it does indicate that at least some people must have considered this idea.

One of the reasons why the Africanized honey bee produces more honey is because it is less susceptible to diseases spread by *Varroa* mites (Tibata et al., 2021). It also exhibits grooming behavior (Rivera-Marchand et al, 2012), whereby bees groom each other and kill the mites.

It is clear that in a fairly urbanized environment, such as exists in Curaçao, such African honey bees will inevitably kill more people and pets. In Surinam fully Africanized honey bees are extremely aggressive. They are known to attack people on roads even though their hives are situated and hidden in the jungle several hundred meters from the road. If even partially Africanized bees already constitute a problem, it does not take much to understand that fully Africanized bees will be much worse and that this would sort off be another “category” altogether.

Its possible effects on nature are more difficult to judge. The introduction of the European honey bee, must already have affected indigenous local bees such as *Mellipona* spp. These can still be found but are nowadays exceedingly rare. Other bees may have disappeared completely; we simply do not know. Competition for available resources must have had an effect. Several other types of bees, such as, the metallic orchid bees (*Euglossini* sp.) and carpenter bees (*Xylocopa* sp.), are still quite common. This in itself already indicates that these species do not directly compete with honey bees. Honeybees for example are never seen on *Senna alata*, which is however visited by *Xylocopa* (pers. comm. M Sommer). It thus seems unlikely that fully Africanized bees would make much difference. But again, there can always be surprises.

Normally the European honey bee is not aggressive, but wild bees in the dry bush can sometimes become aggressive, especially at the end of a long dry season when there is no food available. With the introduction of the *Varroa* mite, they became considerably more likely to be aggressive, though we will probably never know to what extent. There may have been other effects as well. Local nature probably already learned how to cope with aggressive bees. The AHB might not make too much further difference. In Bonaire where the Varroa mite has not been introduced wild bee nests can normally be approached quite closely. In Curaçao this is usually not the case.

Marcel Sommer thinks that some African bees dispersed from Venezuela, to Banda Abao, the western part of Curaçao on their own and that these could have provided the African genes present in the Curaçao bee populations. Crew members of some Venezuelan fruit schooners travelling to Curaçao reported to him that they had seen large swarms of bees travelling low over the water in the direction of Banda Abao. Sometimes there are favorable winds from the mainland which would have helped them along. If they could reach Curaçao in this way, then it must be, or have been, much easier for both Varroa infected bees or African bees to reach Aruba. Bonaire is situated much further from the Venezuelan coast. Presumably bees could travel to Bonaire from Curaçao, but if they travel just above the sea, they would have to travel against the prevailing wind. This seems unlikely.

7) Phlebotomine sandflies (Diptera: Psychodidae)

Phlebotomine sandflies are small blood-feeding insects. Some sand fly species have been found to transmit human pathogens, such as the phlebovirus causing Toscana fever and the bacteria *Bartonella baciliformis* causing Carion’s disease, and zoonotic pathogens like *Leishmania* spp. Other sand fly species have been shown to transmit a wide range of animal pathogens that are relevant to veterinary and wildlife health only. A single specimen of the sand fly species *Micropygomyia* (*Sauromyia*) *trinidadensis* (Newstead, 1922) has now been found on Curaçao. This record is the first finding of phlebotomine sand flies in the Dutch Caribbean. The potential risk for the public and (wildlife) veterinary health caused by sand flies on Curaçao is unknown, and as yet, difficult to assess (Beek, J.G. van der, et al, 2024).

2.4 Various caveats notwithstanding the listing is very useful and gives important information.

· It gives an idea which species can/could be a problem for the drier areas of the Caribbean.

· It gives an idea, some understanding of the timeline and the routes by which certain diseases and pests spread to and through the Caribbean.

· It is clear that the importation of plants, from a new area, such as in this case the date palms from Egypt, has opened a can of worms and has brought in not only the Red Palm Weevil, but very likely many other problems, such as various fungal diseases of palms, as well. These seem to have arrived at about the same time. There is however no proof, they could also have come with palms from elsewhere, most likely from Florida. Anyway, these are now in the Caribbean and constitute a danger to other countries as well.

2.5 Research priority

· First of all, such lists should be made for the other two islands as well. This will give a much clearer picture of threats from and to similar islands nearby.

· Other listings c.q. databases which also include species that were successfully intercepted and others which are not pests should also be made and maintained for the 3 islands.

· Fungi should be identified. Genetic analysis of such fungi could provide an answer as to where they came from.

2.6 Comparison with Amphibians and Reptiles

· Amphibians and reptiles are usually easier to identify, but some groups such as the *Eleutherodactylus* frogs and the blind snakes can be a problem.

· Like the Plant diseases and pests, amphibians and reptiles come in with live plants, but the amphibians and reptiles usually do not come in with fruits and vegetables. Snakes which are typically found in bananas are an exception. *Leptodeira* species and a *Leptophis* came in with bananas. An *Imantodes* snake was once found near a local fruteria. These are also known to be transported with bananas.

3. Recommendations for invasive species management

It is clear that many invasive species are coming in and that there is a problem (as described above). If we accept that there is a problem, then we are supposed to try to do something about it.

If we use a logical framework matrix then we can reach the following conclusions:

· it is important to detect threats early, before they come in, those that are already on our doorstep so to speak and can be considered “alert species” and to be prepared for them. Knowing how they tend to come in, what to look for, etc.

· next we have to take measures to prevent such species from coming in. Such as give customs information and help, what to look for, check certain shipments more thoroughly. Interceptions of non-indigenous species at a biosecurity border are very important (Kachigunda, et al, 2023).

· if this fails, we have to develop measures to control the pest such as, biological control, elimination through sterile insect programs, adequate use of the most appropriate pesticides and very likely some of the above in combination with each other, in a program of Integrated Pest Management (IPM).

3.1 Organizational structure which is needed

The next step is to formulate what kind of organization should do this, what the legal powers of such an organization should be, who should oversee it and what the characteristics of such an organization should be. Such as the level of knowledge and other institutional requirements needed and how it should be manned.

How it should be paid for and who should pay for this.

Generally, the importers of plants are not affected financially when invasives come in. They might take a hit when plants die on their premises, but usually infected plants are simply sold off to the public. When the importation of date palms for landscaping stopped due to the Red Palm Weevil, the importers switched to black olive trees and *Tabebuia aurea* trees. It created a replacement market.

It is for this reason that the "gebruiker betaald" (user has to pay) philosophy cannot be used. It is the general public that pays, especially the many small horticulturists who produce vegetables for the local market. They lose crops and have to pay much more for insecticides and other pesticides and do not profit in any way from the import of plants.

Record keeping and informing stakeholders and the general public

This organization should keep detailed records, of intercepted pests and animals and actions taken, which can be used to provide feed-back and inform the government and stakeholders. Such records should preferably be open to the public and assessable via a web-site. It should provide the general public with information quite regularly.

Maintain regional and other contacts

It should also maintain good contacts with, among others; their counterparts on Aruba and Bonaire and regional organizations such as CABI in Trinidad and the FAO regional office in Barbados, which have always been very helpful in the past. Museum Naturalis in Leiden, the Netherlands can assist in many identification matters.

3.2 Ban all import of live plants

The importation of live plants is by far the most important pathway for new arrivals of invasive species and also difficult to control, since many (or their eggs), are well hidden in the soil. It has been proposed to ban the importation of live plants altogether (seeds, seedlings on agar and cuttings in soilless potting mix would be permitted). Such a prohibition would surely prevent many serious problems with invasives. The invasives that tend to come in with live potted plants are presumably the ones that could potentially do most damage.

Although plants must be accompanied by a phytosanitary certificate, this is hardly a guarantee at all. It is also clear that in several instances such phytosanitary certificates were given even though those signing them must have known very well they were infected. Once something leaves your country, it is not a problem and we certainly would not want our good friend the exporter to suffer losses, would we? The US is one of the worst offenders. In some cases, in Venezuela, phytosanitary certificates turned out to be (very good) forgeries.

All plants would then have to be produced locally, which has some advantages because they will be better adapted to the environment. They would cost more, but more would survive.

This proposal is however politically totally inacceptable and would also run afoul of WTO rules. In the past the Dominican Republic has enacted restrictions on the import of certain groups of plants to avoid certain diseases coming in, and this led to immediate angry protests and threats of retaliation, by the US State Department. In fact, the US does not hesitate to take similar measures, when this so suits their interests.

It will be necessary for the international community to relax WTO rules in these matters and to give a higher priority to the problem of Invasive Alien Species vs. sometimes quite narrow commercial interests.

3.3 Control of pests.

3.3.1 Biological control of Pink mealy bug (*Macronellicoccus hirsutus*)

In Curaçao the Pink Mealy Bug plague was largely brought under control by introducing a small parasitic wasp (*Anagyris kamali*) and also a small ladybug (*Cryptolaemus montrouzieri*), which originally comes from Egypt but has now been introduced to many countries. The project was documented in internal documents which however have been lost. Kenneth A. Heidweiller bought some *Cryptolaemus* in the Netherlands from the firm Koppert BV Nederland (insect disease free) and released them in a Sorghum field at LVV Klein Kwartier. This single introduction was successful. This ladybug is in any case still around, but according to Heidweiller they are now smaller than the original ones which he released.

3.3.2 Control of New World screw-worm fly, (*Cochliomyia hominivorax*), using sterilization methods

The New World screw–worm fly (*Cochliomyia hominivorax*), is an obligatory parasite of living warm-blooded animals, including man. The female oviposits on any lacerated or bloody area or wound. The New World screw–worm fly had established itself on Curacao twice; it was extirpated both times, which required costly campaigns. It is supposed to have been introduced in Curaçao at least since the 1860's (Baumhoven 2002). The first campaign to eradicate it took place in 1954, when this fly was successfully extirpated using sterilized males. These males were sterilized by irradiation with Cobalt 60, and then released in the wild from airplanes, the so-called SIT method (Sterile Insect Technique). About 150,000 sterile screwworm flies per week were released over Curacao, a small island of 444 square kilometers (176 square miles); within 3 months and 4 generations of the targeted insect, the screwworm was eradicated from the island. From the Curacao experiment, it was learned how to put together a full-scale eradication program. Components of the experiment included mass rearing of screwworm flies, proper sterilization equipment and procedures, and an efficient aircraft method of dissemination (Knipling 1959). In the 1970's the screwworm fly was reintroduced and by the end of 1975 it was firmly reestablished. It was found on dogs and goats which were the principal hosts, but also on other mammals. During the Dec 1975 - August 1976 period, there were 14 cases, including one possible death, of screwworm infestation in humans. In those years thousands of head of live cattle were yearly imported to Curaçao from infested areas in South America (Snow et al., 1978). This time the screwworm fly was extirpated using a combination of attractants, poisoned bait and the SIT method (Baumhoven 2002). By October 1977 the screw-worm fly was again extirpated.

3.3.3. Reducing and controlling giant African snail populations by eating them.

Catching and eating lionfish has been a successful tactic in helping to control their populations. (Barbour, Allen, Fraze, Sherman, 2011 & Côté, et al., 2014). The venomous spines are either cut of or burned with a small burner.

The African giant snail is considered a delicacy in many African countries and many African recipes on how to prepare them can be found on You-

Tube. They were first introduced into the Caribbean probably by people from Senegal for this very reason. In the Caribbean they were first encountered in Parc National de la Guadeloupe, on the island of Basse Terre in 1984 (APHIS PowerPoint presentation by Robinson and Fields). From here it was spread through the Caribbean.

Because of problems with the rat lungworm, as described earlier, there is great reluctance to utilize these snails as food. This rat lungworm can indeed be present and is dangerous, but it is usually not very common. We eat many things that can be problematical, it is necessary to take the right precautions. A few examples may suffice. *Listeria* infection is a foodborne bacterial illness that can be very serious for pregnant women, people older than 65 and people with weakened immune systems. It's most commonly caused by eating improperly processed deli meats and unpasteurized milk products. Salmonella infection (salmonellosis) is a common bacterial disease that affects the intestinal tract. Salmonella bacteria typically live in animal and human intestines and are shed through stool (feces). Humans become infected most frequently through contaminated water or food. Salmonella infection is usually caused by eating raw or undercooked meat, poultry, and eggs or egg products or by drinking unpasteurized milk.

It is possible to eat the snails provided they are handled with gloves and well-cooked at high temperatures in a pressure cooker or baked in an oven (as is often done with escargots).

3.3.4 Some examples of problematical control with pesticides

In many cases there is no alternative to using pesticides. The red palm weevil can only be treated with neonicotinoids, these are absorbed by the palm very rapidly and can kill the weevils when the first symptoms appear and might still save it. Other insecticides take too long to be absorbed. We know now that such neo-nicotinoids disorient bees and kill them indirectly. Some hotels were treating their palms with heavy doses of other insecticides regularly, preventively, but this led to dead birds everywhere which had been eating the fruits of these palms.
Hopefully in the future biological control measures will become available. In Spain and in the Middle-East a lot of effort is made to develop biological control of palm weevils using *Steinernema* nematodes (Llacer, Martínez de Altube, Jacas, 2008).

Another example of problematic use of pesticides is the case of white fly, (*Bemisia tabaci*) which came in in 1989. It turned out to be a serious horticultural pest. At the time Mr. Roy Alderlieste who was the manager of the SOLTUNA foundation (a foundation dedicated to developing local horticulture), was fumigating them with Phosdrin, once every two weeks. In the beginning this worked marvelously. But the white fly developed resistance very rapidly and very soon he had to fumigate every 2 days, so he stopped using Phosdrin. Then he tried several other insecticides with little success. Nowadays Actellic is used, usually in combination with a growth inhibitor with reasonable success, but it is almost the only thing that works effectively against white fly.

Thus, advice should be given to the public about the best way to combat certain pests. This would not necessarily be the task of the same organization that is tasked with managing invasive species. They should however keep in close contact with each other and keep contacts with regional and other organizations which can provide guidance.

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My work on invasive species spans a very long time-frame. Inevitably some of those who were helpful are not alive anymore. The late Dr. Henny E. Coomans provided me with my first information on longhorn beetles and on Curaçao land snails. Even more importantly he was a very positive thinker who provided lots of encouragement, which in retrospect was much needed. It is not easy to start work on subjects you know next to nothing about.

Kenneth A. Heidweiller, Ingeniero agronomo, introduced me to the subject of plant diseases. He proposed we team up to write a book together in Papiamentu for the local horticulturists. He had knowledge of the subject and I had the writing skills. In this book we mentioned when pests or plant diseases were encountered for the first time on Curaçao and this is how the problem of invasive species became increasingly visible and the first data were collected. My cousin Dr. Sidney M. Joubert corrected the Papiamentu text.

Dr. A.S.H. (Bram) Breure has provided information, help and guidance for my work on snails. This turned out to be a quite difficult subject. A completely new field someone could study for a few lifetimes. I had bitten of more than I could handle and without his help and encouragement the work on snails which later turned out to be a very successful publication, with many downloads, would not have been realized. Dr. M. G. (Jerry)

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is an Aruban geologist, he showed me the schists at masiduri and explained to me what an "unconformity" is. We had several discussions about the geology of Aruba. With Mr. Ernesto (Tico) Rosenstand I went looking for *Tretioscincus bifasciatus* to photograph it, where he had seen it in the past. Unfortunately, we did not find it, but I took many interesting photographs of other subjects. Dr. Marinus Hoogmoed of Museum Naturalis in Leiden, kindly provided me with a picture of a dead specimen. I visited him there. Much later I found *Tretioscincus*, on Aruba, but did not manage to photograph it; since at that moment I did not have the right lens on my camera and not enough time to change the lens. Axel Fläshendräger gave me a lot of information on *Anolis*. He lived in Halle, Germany. Unfortunately, I never met him personally. I would send him *Anolis* pictures from my travels, which he would identify. We had a fairly extensive correspondence. I wrote him in English and he would answer in German, which worked out fine. I have lost contact with him. I was introduced to him by the late Leo Wijffels, a Dutch Anolis expert. I visited Leo in Enkhuizen where he lived. It was a memorable visit; we spoke a long afternoon. Shortly afterward Leo died, he was already seriously ill when we met.

In my life there have been many curious coincidences, some of them very strange; bordering on the paranormal. When you get older you start wondering increasingly whether these were just coincidences or whether they were pre-ordained. Whether these were signs we have to follow to accomplish certain tasks in life. Often also we do not fully realize our effect on the lives of others. I do not think, for example that Henny Coomans ever realized the full extent of the importance of his support for my work. When we are gone, we will surely know the answer to such questions.

This work gives an overview. It is pretty clear what should be done. Up to now considerable efforts to pass some legislation to prevent invasive species from coming in, to control them once they come in, and to establish a legal base for some other practical measures have hardly been successful. There are always some interests affected, sometimes even very minor ones, which can and will block any measures. Bureaucratic turf wars are just one example. There were only a few small successes. In a way this study simply documents an unstoppable decline, "*hemos arado el mar*". To a certain extent this is a general trend also seen elsewhere. Greed is deeply embedded in human nature.

Curriculum Vitae

Gerard van Buurt was born on the 22 th of September 1949 in Curaçao. His father came to Curaçao in februari 1946 from Gouda, where he met his mother who was working as a secretary for the Combinatie Pletterij Nederhorst. He grew up on Klein Piscadera plantation, where his mother's family lived. He has one sister. He finished Peter Stuyvesant high school, (HBS B) in 1966. Then he went to the TH Delft to study architecture which was not successful. In 1967 he started to study biology at the University of Groningen, where he obtained his master's degree (drs.) in 1974. His specializations were genetics and aquatic microbiology; he also worked on the development of fish eggs at the NIOZ institute in Texel, worked on primary production of benthic algae and obtained his teacher's certificate. He returned to Curaçao in 1974. In 1974 he had a temporary three-month job, at the 'Departement voor Welvaartszorg' to make an inventory of all reports on fisheries and aquaculture in their archives and make recommendations. Later on, this turned out to have been a crucial period in his career. From 1975 to early 1976, he worked at CARMABI for slightly more than a year, where he did underwater light and water flow measurements. In 1976 he became head of the laboratory of the local Amstel Beer brewery.

In 1977 he was offered a job, based on his earlier work at the 'Department voor Welvaartszorg' to work on the recommendations he made at the time. He accepted and worked at the Department of Agriculture and Fisheries of Curaçao (Dienst L.V.V.) from the first of July 1977 to the first of February 2006. He was head of the Fisheries section of the Department, but later he also ran the local zoo and worked on plant diseases and invasive species, a subject totally new to him at the time. The work at the LVV was very varied; he learned to write project documents, worked on new fisheries and nature laws, CITES matters and on FAD's (Fish Aggregating Devices), a project he initiated. While at LVV he also conducted deep water precision depth measurements, to be used to determine the best route for cold seawater pipelines, both in Curaçao and Bonaire. In 2006 he left LVV on an early pension (VUT regeling), but did many projects for consultancy firms, writing project documents and doing vegetation mapping and studies on invasive species for IMARES, Wageningen. At high school he learned French and German, but for his work at LVV he needed Spanish and learned to speak and write Spanish and later some Portuguese as well. He also wrote a book on Caquetío words in the Papiamentu language and on the origins of various names of plants and animals in this language. Several articles on local history were published as well.

At the end of his career, he became a member on the advisory board of a project called BRIGAID, led by Delft Technical University and funded by the EU. This project had a duration of four years. The project was about climate change, but not climate change in itself, but on ways of dealing with its practical impacts. The project basically had three components; management of forest fires, water conservation and flood control. One of the requirements was that the advisory board should have a biologist, who was not a specialist but a generalist. It turns out that there are few generalists. In his career his knowledge of languages turned out to be extremely useful, since it opens many doors, which would otherwise have been closed. This was also evident during the BRIGAID project, where Portuguese and Spanish companies participated.

Annex 1

List of my publications on alien invasive species in Aruba, Curaçao and Bonaire, or containing information on this subject.

My publications on Fish Aggregating Devices (FAD's) and various other subjects are not included in this list.

Behm, J.E., van Buurt, G., DiMarco, B. M., Ellers, J., Irian C.G, Langhans, K.E., McGrath, K. J. Tran, J.T. Helmus, M.R., 2019 - First records of the mourning gecko (*Lepidodactylus lugubris* Duméril and Bibron, 1836), common house gecko (*Hemidactylus frenatus* in Duméril, 1836), and Tokay gecko (*Gekko gecko* Linnaeus, 1758) on Curaçao, Dutch Antilles,and remarks on their Caribbean distributions. BioInvasions Records, 8, (1): 34–44.

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Lay-out: Steffen Maas, Rotterdam /Aruba

PLATES

PLATE 1 — ENDEMIC PLANTS

PLATE 2 — ENDEMIC REPTILES

PLATE 3 — SOME COMMON, MOSTLY ENDEMIC TERRESTRIAL SNAILS

PLATE 4 — INDIGENOUS BEES (CURAÇAO)

PLATE 5 — INTRODUCED REPTILES AND AMPHIBIANS

PLATE 6 — SOME INTRODUCED PESTS AND OTHER ALIEN SPECIES

The name of the island indicates where the photograph was taken; some of these species are also found on one or both of the other islands as well.

All photographs by the author unless otherwise noted.

1. *Agave vivipara*, Bonaire.

2. *Agave boldinghiana*,
Curaçao.

3a. *Melocactus macrocanthus*,
Hermanus, Curaçao.

3b. *Melocactus macrocanthus*,
Pannekoek, Curaçao.

4. *Opuntia curassavica*,
Bonaire.

5a. *Sabal antillensis.*

5b. *Sabal antillensis*,
Seru Gracia, Curaçao.

6 a. *Cnemidophorus arubensis*,
Aruba.

6 b. *Cnemidophorus arubensis*,
Aruba.

7 a. *Cnemidophorus murinus*,
Curaçao.

7 b. *Cnemidophorus murinus*, female.

7 c. *Cnemidophorus murinus*,
threatening posture. Klein-Curaçao.

8. *Anolis bonairensis*,
Bonaire.

9 a. *Anolis lineatus*,
Curaçao.

9 b. *Anolis lineatus*,
Aruba.

7 d. *Cnemidophorus ruthveni*,
Bonaire.

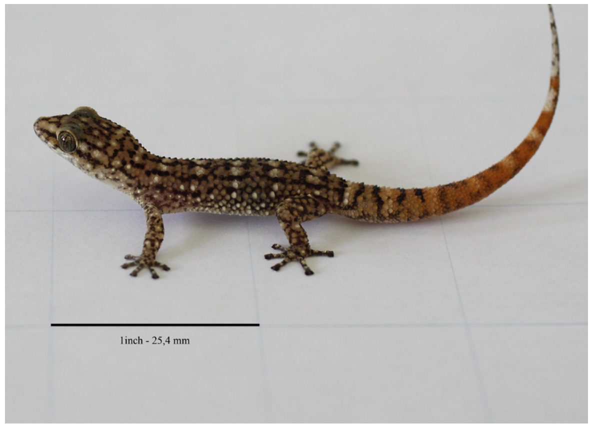
10. *Gonatodes antillensis*, female.
Bonaire.

11. *Crotalus unicolor*,
Aruba.

12. *Leptodeira bakeri*,
Aruba.

13. *Liophis triscalis*, juvenile.
Curaçao.

14a. *Phyllodactylus martini*, juvenile.
Curaçao. Photo: Corry van Heijningen.



14b. *Phyllodactylus martini*,
Curaçao.

(for *Phyllodactyllus julieni* no picture was available)

15a. *Cerion uva*,
Boca St Michiel, Curaçao.

15b. *Cerion uva juvenile* op
Melocactus macracanthos, Curaçao.

16a. *Drymaeus elongatus*, agglomeration.
Photo: Michele van Veldhoven.

16b. *Drymaeus elongatus*,
Sta Cruz, Curaçao.


17. *Tudora megacheilos pilsbryi*, Curaçao. Photo: Fred M. Chumaceiro.


18. *Tudora megacheilos*, Toni Kounchi, Curaçao.


19. *Tudora rupis* op *Stenocereus griseus*, Patrick, Curaçao.


20a. *Tudora aurantia*, Seru Largu, Bonaire.


20b. *Tudora aurantia*, Bonaire.


21. *Abeja metálica Hymenoptera Euglossini*, female. Photo: Carel P. de Haseth.


22. *Mellipona* sp.
Photo: Carel P. de Haseth.


23a. *Senna alata* met *Xylocopa* sp.


23b. *Xylocopa* op *Haematoxylum, brasiletto.*

24 a. *Anolis porcatus*, male,
Aruba.

24 b. *Anolis porcatus*, female,
Aruba.

25 a. *Anolis sagrei*, male,
Aruba.

25 b. *Anolis sagrei*, female,
Aruba.

26 a. *Hemidactylus mabouia*,
Curaçao.

26 b. *Hemidactylus mabouia*,
Curaçao. Photo: Paul C. Hoetjes.

27. *Cnemidophorus arenivagus*,
(syn *C. lemniscatus*), Aruba.

28. *Lepidodactylus lugubris*,
Curaçao. Photo: Michele van Veldhoven.

29. *Boa constrictor*,
Aruba.

30a. Cuban treefrog – *Osteopilus septentrionalis*, Bonaire.

30b. Cuban treefrog – *Osteopilus septentrionalis*, Curaçao.

31. *Rhinella marina* (formerly *Bufo Marinus*).

32. *Dori maco* (*Pleurodema brachyops*), introduced in Curaçao and Bonaire from Aruba.

33a. Red Palm Weevil – *Rhynchophorus ferrugineus*, larva.

33b. Red Palm Weevil – *Rhynchophorus ferrugineus.*

33c. Red Palm Weevil – *Rhynchophorus ferrugineus*, coccoon.

33d. Red Palm Weevil – *Rhynchophorus ferrugineus*, damage.

33e. Red Palm Weevil – *Rhynchophorus ferrugineus*, damage.

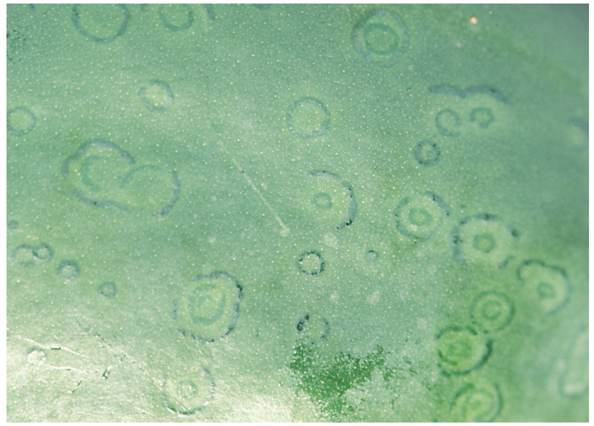
33f. Red Palm Weevil – *Rhynchophorus ferrugineus*, damage.

34. African giant snails – *Achatina fulica*, Jan Thiel, Curaçao. Photo: Rob S.E.W. Leuven.

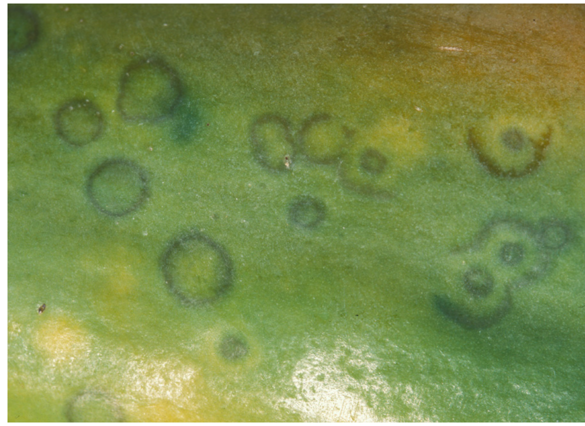
35. *Bulimulus guadalupensis*.

36a. 36b. Citrus hindu mite – *Schizotetranychus hindustanicus*.

37. Cuban garden snail – *Zachrysia provisoria*, Curaçao.



38a. Papaya Ring Spot Virus PRSV.



38b. Papaya Ring Spot Virus PRSV.

39. Milkweed bug or Seed bug – *Spilostethus pandurus*, Curaçao. Photo: Rob S.E.W. Leuven.

40. Spittlebug – *Aeneolamia reducta*.

41. *Phyllosticta* pad spot Opuntia, damage. Photo: Carel P. de Haseth.

PLATES