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Cerion uva on a *Stenocereus griseus* candelabra cactus © G. van Buurt

Sommaire

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Ligne éditoriale

La priorité est donnée aux articles traitant de malacologie continentale, autrement dit de la faune terrestre et dulcicole. Exceptionnellement, des articles sur la faune saumâtre ou marine peuvent être acceptés.

Sur le plan géographique, il n'est donné aucune limitation, les faunes des contrées les plus lointaines ayant ici autant leur place que les faunes de nos jardins.

Enfin, les articles peuvent concerner aussi bien des observations biologiques ou naturalistes, des inventaires faunistiques, que des travaux effectués sur les collections anciennes ou sur les personnes qui les ont constituées.

Les articles d'ethno-malacologie, d'archéo-malacologie ou de paléontologie sont également admis.

Du fait du caractère électronique de la revue, les descriptions de taxons nouveaux pour la science, ainsi que les nouvelles combinaisons ne sont pas acceptées.

Soumission d'articles

Les manuscrits sont rédigés au format Word dans la langue souhaitée par l'auteur. Ils sont accompagnés d'un résumé et de mots clés lorsque la longueur de l'article le justifie ; des résumés dans d'autres langues sont aussi admis.

Ils sont envoyés par voie postale ou par mail au rédacteur en chef et seront soumis à deux relecteurs du comité de lecture, éventuellement à des référents extérieurs.

Recommandations

Il n'y a pas de recommandations particulières dans la rédaction des articles : nous nous chargeons de la mise en forme en accord avec vos souhaits.

Néanmoins, il peut être avantageux de partir d'un article de la revue comme modèle, notamment pour la mise en forme des citations bibliographiques et la présentation des figures.

Nous vous demandons d'utiliser la nomenclature latine et de ne pas utiliser les noms vernaculaires sauf exception ou dans une perspective historique par exemple.

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Field observations on some Curaçao landsnails, and new records for its fauna.

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Abstract : Currently 31 species of terrestrial snails are known from Curaçao, 28 of these are indigenous. The taxonomy of Curaçao land snails has been studied quite well. An inventory of species and subspecies exists. About their ecology however much less is known. The influence of salt spray from the sea on the distribution of some species is discussed. By observing snails in the field some conclusions about their ecology have been reached; these and some further assumptions are hereby presented. Three of the larger species of indigenous snails are discussed. These are *Cerion uva*, *Drymaeus elongatus* and *Tudora megacheilos*. The introduced snails *Bulimulus guadalupensis*, *Zachrysia provisoria* and *Achatina fulica* (= *Lissachatina fulica*) are briefly mentioned; the latter two are new records for Curaçao.

Key words : *Cerion uva*, *Drymaeus elongatus*, *Tudora*, *Bulimulus guadalupensis*, *Achatina fulica*, *Zachrysia*, salt spray, wax compounds.

Introduction

Currently 31 species of terrestrial snails (including the freshwater snails), are known from Curaçao. BURRINGTON BAKER (1924a, 1924b) and WAGENAAR HUMMELINCK (1940) have described several subspecies for some species. A checklist for the islands Aruba, Curaçao and Bonaire has been published by HOVESTADT (1987). Molecular studies have now been completed for the subspecies of *Cerion* (HARASEWYCH, in press: 2014). Many of the land snails living in Curaçao are small (BURRINGTON BAKER, 1924a) and live in leaf litter and/or beneath stones; additionally many of these micro-molluscs look similar and are difficult to differentiate. *Drymaeus elongatus* is the largest of the indigenous landsnails, it has a maximum length of approximately 30 mm and a diameter of 11-13 mm. *Guppya molengraaffi* is one of the smallest with a diameter of about 2.4 mm. Some like *Neosubulina* are long and narrow, with a maximum length of about 17 mm.

The field observations of land snails in this article have been limited to the larger and more easily observed species. As ecological data on Neotropical land snails are scarce, such observations are of interest. Most of these land snails are indigenous; only three species are known to have been introduced. *Bulimilus guadalupensis* was introduced in 1972 (BREURE, 1975). *Zachrysia provisoria*, the Cuban Garden snail is a recent introduction to Curaçao. On the 16th of January 2013 the giant African snail, *Achatina fulica* (= *Lissachatina fulica*) was first found on Curaçao (pers. comm. Manuel Boot, Vitis gardening company). It is now established in some residential areas and is likely here to stay. Both *Zachrysia* and *Achatina* are new records for the Curaçao fauna.

Climate and Ecological conditions in Aruba, Curaçao and Bonaire

Curaçao is an oceanic island. It was never connected to the mainland and is separated from the mainland by deep water. The Island may have first briefly emerged in the late Eocene. The ABC islands were emergent during the Oligocene, they subsided below sea level in the Middle Miocene and subsequently slowly reemerged (FOUKE ET AL, 1993). Most of the fauna and flora of Aruba, Curaçao and Bonaire is of South American origin (WAGENAAR HUMMELINCK, 1940) and from a zoogeographical point of view these islands are considered to form part of the South -American realm, they are not considered to be part of the West-Indian region. Aruba, Curaçao, Bonaire and the Venezuelan Islands of Las Aves, Los Roques, La Orchila, and La Blanquilla and Los Hermanos do not fall within the boundaries of the West-Indian region as described by BOND (1936).

Aruba is the most arid of the Dutch islands while the western parts of Curaçao receive the most rainfall, the climate is semi-arid to arid. Average rainfall in Curaçao is about 575 mm/yr. Every century several extended periods of drought occur with practically no rain (Van Buurt, 2010). These can last up to 24 months. The indigenous species of *Cerion*, *Tudora* and *Drymaeus* are able to survive such extremely long dry periods, when the bush shrivels and even some cacti die. The lowest temperature measured in Curaçao during the last 30 years was 19 °C. Air temperatures vary between Av. (average) 26.5 °C in January and Av. 28.9 °C in September. The last week of January and the first week of February usually have the coldest air temperatures with an average of about 26.5 °C. Sea water temperatures vary between Av. 25.9 °C in February/March and Av. 28.2 °C in September/October (data: Meteorological Department of Curaçao, period 1971 -2000, on request). In comparison to other arid areas in the West-Indies yearly average temperatures are higher in the Dutch Leeward islands, since winter temperatures are much higher.

In Curaçao the trade winds are usually strong. The yearly mean wind velocity is 7.1 m/s (Beaufort 4). In June winds are strongest with a mean of 8 m/s. The prevailing direction of the winds is between 070°–110°; usually winds are due East (90°) (data: Meteorological Department of Curaçao, period 1971 -2000, on request). The sea on the northern coast is quite rough and many little drops of water are blown off the waves; such droplets evaporate and the air is heavily laden with small salt particles; such salt particles carry very far and are blown all the way across the island. On their North and East coasts the islands are almost continuously exposed to strong winds coming in from the sea. The sea in this area is notorious for its short wavelength choppy waves, which makes for a rough ride in small vessels.

Low rainfall, high mean temperatures and winds heavily laden with salt are undoubtedly major factors in the ecology of many of the landsnails.

The effects of salt spray

In an area called Tera Korá, the steel roof of a gas pumping station rusted through completely in a few years time. This gas station is situated at a shortest distance of 1600 meters from the sea at 85 meters above sea level and is much further from the sea if the prevailing direction of the winds is taken into account. It is the condition of this roof that made me realize that the influence of the salt spray is much stronger and reaches much further inland than I had previously imagined and this made me start to investigate this subject. Other gas pumping stations on the island have the same standard roof, so this condition was not related to the roof per se.

Now that I had been alerted to the strength of this salt spray I could also see its effects in the vegetation. On the Seru Gracia, which with a height of 297 meters is the second highest hill in Curaçao, the shrub *Gundlachia corymbosa* (yambush, Jamaica thrash), which is considered a halophilic plant, is growing on top of this hill. There are also *Cerion* living on the top of this hill. This is at a shortest distance of 3.8 km from the sea, while when measured in the direction of the prevailing easterly winds, the distance salt would have to travel is more than 6 km. The top of this hill consists of rocks and soil from the Knip formation. The Knip formation consists of generally light colored cherty limestones, dark cherty mudstones and pure cherts consisting mostly of radiolarites (Beets, 1972). The top of the Seru Gracia consists of the light colored cherty limestones, which would contain calcium. On the top of the Sint Christoffel mountain, which at 376 meters is the highest peak in Curaçao, *Gundlachia corymbosa* is also found (Fig. 1). Here it only grows on the exposed windward edge of the summit; no Cerion are found. The top of this hill consists of a more siliceous chert; which probably contains hardly any calcium. The slopes are steep; salt spray will wash off easily. Thus most of the island can be considered a salty environment with the possible exception of a small area on the top of, and leeward of the Sint Christoffel mountain; in this area there is also a somewhat higher rainfall than in other parts of the island.

Studies of the run-off of surface waters (pers.comm. C.W. Winkel, Dept. of Agriculture and Fisheries, Curaçao) in the volcanic areas of Curaçao, have shown that when the rains start after a long dry season, the first surface run-off has a conductivity value of around 500 microSiemens (µS/cm). When it keeps raining, part of the water percolates through the soil and the conductivity in small rivulets increases, usually to up to 1500 µS/cm. When the rains then continue the salinity in such rivulets goes down again. In places where water has accumulated white salt and calcium deposits can be seen when shallow pools, rivulets and ponds dry out again and often dried out films of calcareous algae are left behind. Thus there must also be significant amounts of calcium present. In the rainy season, heavy rains cleanse the earth of large loads of salts, which are washed into the sea and thus rejuvenate the soils. All of this is observed in the volcanic non-limestone

Fig. 1a - The halophilic plant *Gundlachia corymbosa* growing on the exposed windward side of the summit of the Sint Christoffel, the highest hill in Curaçao (376 m). Photo: Corry van Heijningen.

Fig. 1b - The halophilic plant *Gundlachia corymbosa* growing on the exposed (northern) windward side of the summit of Seru Gracia (297 m). Photo: Gerard van Buurt.

areas. In the limestone areas there is almost no surface run-off since limestone is much more porous.

If sufficient rain falls at the start of the rainy season, some of the water will percolate to the ground water level; this level rises and its salinity as measured in wells initially increases (sometimes by as much as 300 - 400 µS/cm), because of the heavy loads of salt that are washed down into the wells. Later on, during a good rainy season ground water level keeps rising and salinity in wells falls again, as groundwater flows to the sea sub-terraneaously and is replenished by lower salinity water.

The salinity levels of wells on the island in the volcanic zones (Curaçao lava formation) are lower in the centre of the island and increase toward the coast. A study by Abtmaier (1978) indicates the following: the wells in the central areas are usually below 2000 µS/cm, while those nearer to the coast increase to values above 4000 µS/cm.

There are three main reasons for this increase:

- The salt spray from the sea; part of which is washed down to the groundwater level by rains. This salt spray is stronger near the coast.
- Water used for irrigation increases in salinity due to evaporation, and then flows back into the ground.
- In areas near the sea there can be intrusion of sea water if the water level is lowered too much by excessive pumping.

There is a notable difference between the lava formation in the NW part of the island and the lava formation in the SE part of the island. In the NW part more than 55% of the wells are between 1500 and 2250 µS/cm (203 wells measured), while 13% are above 3000 µS/cm. In the SE part of the island 45% of the wells are between 1500 and 2250 µS/cm (420 wells measured) while 20 % are above 3000 µS/cm. There is more influx of water from underground cesspits, which most houses use, into the groundwater, which will tend to lower salinity, but this part of the island is also more exposed to salt spray and there is more irrigation with well water, both factors which tend to raise salinity. From the above it can be seen that the impact of the salt spray on the salinity in wells is considerable even though its effects are hard to quantify precisely, since other factors are also at work.

The difference in salinity between the narrow coastal zone and the volcanic areas is not absolute; it is more a difference in degree.

Presence of Calcium in volcanic non-limestone areas in Curaçao

Inland in Curaçao there are also old limestone caps and limestone hills (such as for example the limestone cap on San Hirónimo/ Sint Hyronimus hill), where *Cerion uva* is more numerous than on the volcanic soils. Nevertheless *Cerion uva* is also present on volcanic soils and there is calcium present in these volcanic soils. The pillow lavas of the Curaçao lava formation are porous and many fissures and cracks are filled with carbonates (Abtmaier, 1978). Most if not all wells in the volcanic area contain significant amounts of calcium. Sambeek et al. (2000) give a mean value of 111 mg/l calcium for wells in volcanic areas, which can be seen to be quite high in comparison with the value of 150 mg/l which they give for wells in limestone areas. This is in accordance with the results obtained by Abtmaier

(1978), who found most wells in the volcanic area contained 100-200 mg/l of calcium. The values obtained by Abtmaier (1978) seem to be somewhat higher than those of Sambeek Eggenkamp and Vissers (2000). His measurements were taken during a period of very dry years. Although the pillow lavas and basalts of the Curaçao lava formation themselves contain some calcium, the high levels of calcium in these wells must have percolated down from the surface to the groundwater level. Such calcium is transported through the air as part of the salt spray coming from the sea and also as fine calcareous dust coming from limestone areas. Some may have washed down from higher limestone caps and to a lesser extent out of the mixed limestone, chert and mudstone of the Knip formation. Seawater contains about 416 ppm of calcium. A comparison of the percentage of calcium, sodium and chloride in seawater gives values of respectively 0.04, 1.08 and 1.94 %; the salt spray would presumably contain the same or a very similar ratio of these elements. However calcium salts are generally less soluble than sodium salts and will wash out off the soil less easily, so while compared to sodium and chlorine their concentration in the salt spray is low, the concentration of calcium will tend to increase in the soil.

Are *Cerion* obligate halophiles and calciphiles ?

Clench (1957) stated that *Cerion* are calciphiles and Mayr (1963) stated that they are are obligate halophiles. Woodruff (1978) disagreed and stated:

"…..Field observations over the last few years have shown that these beliefs are unfounded". Woodruff (1978) added "Even the most basic assertions that *Cerions* are halophiles (Mayr, 1963) or calciphiles (Clench, 1957) are contradicted by the occurrence of snails up to 15 km from the coast in Grand Bahama and in volcanic non-limestone areas in Curaçao".

These remarks have to be qualified; in the Curaçao volcanic non-limestone areas significant amounts of both salt and calcium are present. It can be concluded that the fact that *Cerion uva* is found inland on volcanic soils in Curaçao cannot be used to support the idea that it is neither halophilic nor calciphilic.

Some of the larger indigenous land snails

Cerion

The genus *Cerion* belongs to the family Ceriidae (formerly Cerionidae) (Gastropoda, Stylommatophora, Pulmonata) and is hermaphroditic. The land snail *Cerion uva* (Linnaeus, 1758), is found on Aruba, Curaçao, Bonaire and Klein Bonaire, but not on Klein Curaçao which has no land snails (Wagenaar Hummelinck, 1940). The subspecies *Cerion uva desculptum* was described by Pilsbry and Vanatta (1896). Burrington Baker (1924a) describes several subspecies of *Cerion uva* from different localities on Curaçao. The Aruba *Cerion uva* were described as the subspecies *Cerion uva arubanum*, while those from Bonaire were considered *Cerion uva bonairensis*, Baker (1924). Harasewych (2014) has recently conducted DNA analysis of the various named subspecies and forms. This study concludes that *Cerion uva* on Aruba was most likely introduced from Curaçao. *Cerion uva* is endemic on Curaçao, Bonaire and Klein Bonaire. Four different sub-species are recognized (Western Curaçao, Eastern Curaçao, Ronde Klip Curaçao, Bonaire including Klein Bonaire). The genus *Cerion* is also found in South Florida, Bahamas, Turks and Caicos, Cuba, Cayman Islands, Hispaniola, Isla Mona, Puerto Rico and the Virgin Islands (Anegada and Necker). In these locations *Cerion* are nearly always restricted to a habitat close to the sea (Woodruff, 1978) and pers. comm. M.G. Harasewych, and are not found further inland. In Cuba *Cerion peracutum peracutum* (Clench and Aguayo, 1951) was encountered at a distance of about 1500 meters from the sea (Suárez Torres Hernandez Cobreiro and Fernández Velázquez, 2012). However in Curaçao and Bonaire *Cerion* are found inland, on volcanic non-limestone soils. They are however less numerous on these soils and are much more numerous on the limestone plateaus along the coasts. They are also commonly found on some inland limestone or limestone containing mountain tops, such as Tafelberg at Santa Barbara (195 m), the San Hirónimo (or Sint Hyronimus) table mountain (225 m) and Seru Gracia (297 m), to give a few examples on Curaçao.

Tudora

Tudora belong to the family Pomatiidae subfamily Annulariinae according to the taxonomy of Bouchet & Rocroi (2005) (Gastropoda: Caenogastropoda, Littorinimorpha, Littorinoidea). There are two sexes, males and females. The females are usually somewhat larger than the males. These snails have an operculum and only two tentacles.

The snail *Tudora megacheilos* (Potiez & Michaud, 1838) is endemic to Curaçao and Aruba. *Tudora rupis* (Burrington Baker, 1924b) is endemic to Curaçao; this species is found in the limestone rock areas both at the north coast and parts of the south coast and also on the Tafelberg at Santa Barbara. In Bonaire and Klein Bonaire the endemic *Tudora aurantia* (Wood, 1828) is found. *Tudora maculata* (Burrington Baker, 1924b) is another endemic on Bonaire, which is found on some limestone hills in central Bonaire and on Klein Bonaire. Burrington Baker distinguishes several subspecies of *Tudora megacheilos* and *Tudora rupis*. Wagenaar Hummelinck (1990) recognizes a smaller number of these subspecies. Up to now there has not been a modern re-evaluation of these *Tudora* subspecies, utilizing DNA analysis.

Tudora megacheilos is widespread on the island of Curaçao; it is also the land snail which is usually most common in gardens. During the dry season adult *Tudora* can often be found buried in the ground, usually at a depth of a few centimeters; when it rains they come out. They are also often seen on walls where they presumably get their calcium. Usually there are no algae growing on these walls, since the climate is very dry and most houses have roofs with large overhangs (3-4 ft). In gardens they are also found on the trunks of species of palm trees, which are not native to the island. The only native palm tree in Curaçao is a species of Sabal (cf. *Sabal causiarum*) growing in the Christoffel National Park. *Tudora megacheilos* has a marked preference for certain palms, but is not found on many other, sometimes very similar palms. It is especially fond of Royal palms, of which *Roystonea regia* and *Roystonea oleracea* (the "Cuban" and "Venezuelan" royal palms) are the most common on the island. These palms need well-irrigated gardens to flourish, *Tudora* occur predominantly on those palms which grow in grass lawns. On those *Roystonea* which stand quite dry *Tudora* are usually absent. The trunks are almost devoid of epiphytes because of the dry climate, thus the presence of the snails is not related to food. *Tudora megacheilos* is also often found on the trunks of *Dyopsis decary* (syn. *Dypsis decary*), a palm introduced from Madagascar and to a much lesser extent also on Manila palms (*Veitchia* sp.). In these cases there are sometimes green algae or mosses growing on parts of the trunk under the crown. The surface of these trunks is more porous than those of Royal palms and holds moisture. When it has rained *Tudora megacheilos* come out of the soil, climb the palm (Fig. 2) and seem to be grazing on algae growing on these trunks. It turns out that egg masses of *Tudora megacheilos* can be found on the trunks of *Roystonea* palms, the trunks have slightly grooved rings and eggs can be found attached in these grooves; either singly or in small clusters (Fig. 3a). They are attached to the palm with small tendrils. Other snails have been found to make attaching threads from which they can dangle or suspend themselves (Breure, 2011). It can be argued that there is no proof that the "eggs" seen in the picture are indeed egg masses; but these "egg masses" are never found on those palms where *Tudora* are not present. Comparison of the DNA of the egg masses and the adult snails could confirm this. These are definitely not feces; the feces of *Tudora* are long and very slender. In the morning dew or during rains the grooves in the palm trunk would collect some moisture but would quickly dry-out once the sunrises. These eggs are often (always?) fully exposed to the sun. This could be an advantage if light is needed for their development; however no data on the ontogenesis of these snails exist. Species of the closely related genus *Liguus* in Florida are known to need light for their development, and develop well under UV light lamps (Krull, 2006). After hatching, the young will presumably climb down or fall off the tree, and will start burrowing in soil and leaf litter. When they grow larger they will climb up on trees and rocks again; especially during wet periods. The leaf scars around the trunks are very smooth and may prevent many potential egg or snail predators from climbing up the trunks. Often the snails climb up very high in these palm trees, which is unusual for this species which normally is a sub-arboreal species (Fig. 3b). Thus these palms are very likely safe nursery areas. The impression is that the preference *Tudora* has for *Roystonea oleracea* is somewhat stronger than for *Roystonea regia*. *R. regia* has a smoother trunk with very shallow grooves; the grooves in *R. oleracea* are slightly deeper, can probably hold more moisture and could be preferable to anchor the eggs. The question then remains how an endemic snail could have developed such a preference for palms which were only introduced on the island quite recently, in the early 20th century. *Tudora* and its egg masses were also found on coconut palm (*Cocos nucifera*) trunks (another introduced palm). In Bonaire *Tudora* *aurantia* and its egg masses were also found on coconut palms. During the dry season *Tudora megacheilos* aestivate burrowed into the soil, they can then be found about one shell length or slightly deeper below ground. *Tudora rupis* also burrows.

Drymaeus

The genus *Drymaeus* belongs to the family Bulimulidae (Gastropoda: Pulmonata).
In Curaçao *Drymaeus elongatus* (Röding, 1789) is found. In literature this snail on this island has variously been identified as *Drymaeus radiatus* (Bruguière, 1789) and also as *Drymaeus virgulatus* (Férussac, 1821). Another species *Drymaeus multilineatus* (Say, 1825) has formerly been reported from Curaçao (Burrington Baker, 1924a and Wagenaar Hummelinck, 1940). It was originally reported as an introduced species, only a few individuals were found; Hummelinck (1940) found a few in gardens. It is not known to occur on the island presently. Often introduced species which manage to establish a precarious foothold on the island are eliminated during extended periods of drought, which occur a few times during each century; a few examples are given in Van Buurt (2010).

Drymaeus elongatus is also found on Aruba, Curaçao and Bonaire; it is indigenous on these islands. In Curaçao some shells have been found in an archaeological excavation of buried shell middens of the pre-ceramic Archaic Indians, which date to about 4.500 BP (pers. comm. Claudia Kraan, NAAM - National Archaeological and Anthropological Museum). This species is only found in areas with undisturbed natural vegetation and is clearly dependent on a fairly limited selection of local plants (see Appendix I). Although it can also feed on a few introduced plant species, which grow in the wild, it is not generally found in gardens, which are usually planted almost exclusively with introduced plants. Thus it is not found in the inhabited areas.

Its presence on Aruba, Curaçao and Bonaire notwithstanding (which belong to the South-American faunistic realm), *Drymaeus elongatus* has a predominantly West Indian distribution. It is also found in Puerto Rico, Isla Mona, Vieques, Saint Thomas, Saint Johns, Tortola, Anegada, Saint Maarten/Saint-Martin, Saint-Barthelemy, Saint Croix, Saint Eustatius, Antigua and Barbuda. In the past it has also been reported from Basse-Terre, Guadeloupe, but has not been found on Guadeloupe

Fig. 2 -*Tudora megacheilos* moving around on the trunk of a (introduced) triangle palm *(Dypsis decary)* after rain.
Photo: Gerard van Buurt.

Fig. 3a - *Tudora megacheilos* on the trunk of *Roystonea oleracea*. Several eggs can be seen on the grooved part of the trunk. There is a small group of eggs on the left side of the picture above the *Tudora*. One of the eggs in this cluster is infected and is swollen and greenish. The little white bars in the white band are not eggs, but form part of the leaf scar, where previously the leaf was attached. Photo: Gerard van Buurt

Fig. 3b - *Tudora megacheilos* on the trunk of a *Roystonea regia*, on higher trees these snails sometimes climb even higher up. Photo: Gerard van Buurt

during more recent surveys (Bouchet and Pointier, 1998). It is presumed that its presence in Guadeloupe may have been based on a misidentification.

Unlike *Cerion* and *Tudora* which are terrestrial or sub-arboreal species, *Drymaeus elongatus* is arboreal and is found only on bushes and in trees. The distribution of *Drymaeus elongatus* in Curaçao is patchy and seems to be closely tied to the presence of an assortment of certain indigenous plants on which it is either feeding or otherwise dependent.

Drymaeus elongatus is not found on the northern coast of the island even though some of the plants with which it is usually associated do occur in this area. This is almost certainly due to an excessive salt load in these areas. The northern coast consists of limestone plateaus, but this cannot be the reason *Drymaeus elongatus* is not found in these areas, since they are found and are sometimes quite abundant in calcareous areas on the south coast. Most of the plants with which it is associated are not found in the inhabited areas, while others are not completely absent but not very numerous. In some areas on the south coast *Drymaeus* are absent even though the plants associated with them are present. In such areas their absence could be explained by air pollution from the Curaçao refinery. In one particular case the western borderline of their occurrence seems to perfectly match a map of the air pollution footprint of the refinery (See map). However this does not constitute definite proof. A list of plants on which *D. elongatus* is regularly encountered is given in Appendix I; it can be seen that these are almost all indigenous plants. Burrington Baker (1924a) noted "Although it (*Drymaeus*) is certainly widespread in the undisturbed portion of the Dutch Leeward Islands, its remarkably discontinuous distribution, as already indicated, arouses the suspicion that its dissemination may be due to the agency of man". I believe this curious distribution of *Drymaeus* can be

largely explained by the effects of the salt spray. It can withstand some saltspray, but not too much.
Drymaeus are often found resting on twigs or leaves, usually in the shade but they can regularly also be found where they are fully exposed to the sun (Fig. 4). Here they can stay in the same position for many days and are probably aestivating. Apparently they can withstand overheating and are not vulnerable to predation. The same holds true for *Cerion* and *Tudora*. When they move they do so when it rains or right after rains (Fig. 5), usually when it is cloudy or at night. However the larger agglomerations of *Drymaeus elongatus*, which up to now were only found on the Wayaká tree (*Guaiacum officinale*) and the Surun (*Crateva tapia*) are always found in the shade. These are probably breeding aggregations (see Fig. 6).

A few *Drymaeus elongatus* were taken from the wild and released in a garden with several Wayaká (Lignum vitae - *Guaiacum officinale*) trees, on which these snails are commonly found in the wild. The snails were put on the tree, yet a few days later all had disappeared never to be found again. One juvenile *Drymaeus elongatus* was released on a candelabra cactus. During some, but not all subsequent nights it moved to a different position. During a cloudy morning it was found munching, which indicates it was feeding, on a fungus which was growing on the cactus and was photographed doing so (Fig. 7). The mouth of the animal was clearly moving and it made sweeping movements with its head, but the grazing trail was very vague. Nevertheless a grazing trail can be made out very vaguely and is also visible on the picture. It seems that the animal harvests only a thin top layer of the fungus. The fungus has not been identified, but it resembled and may have been a *Phyllosticta*, this is a type of fungus often found on cacti. This snail stayed on this cactus for about 11 days, after which time it was not found again.

Drymaeus elongatus also grazes on the leaves of some plants. Leaf damage likely to have been caused by *Drymaeus* has been observed on the tree *Crateva tapia* and on the vine *Serjania curassavica*. The epidermis of the leaves was abraded away, as if by a router, but the leaf veins remained intact (Fig. 8). This kind of damage is unlikely to have been inflicted by an insect and is more likely to have been caused by a snail. I have never seen this kind of damage in local horticulture. *Drymaeus elongatus* is the only snail on the island known to climb high up on these plants and is commonly found on both of these plants. Although *Drymaeus elongatus* were not actually seen grazing, they were found nearby the lesions on the same plant or on the same leaf.

The introduced land snails

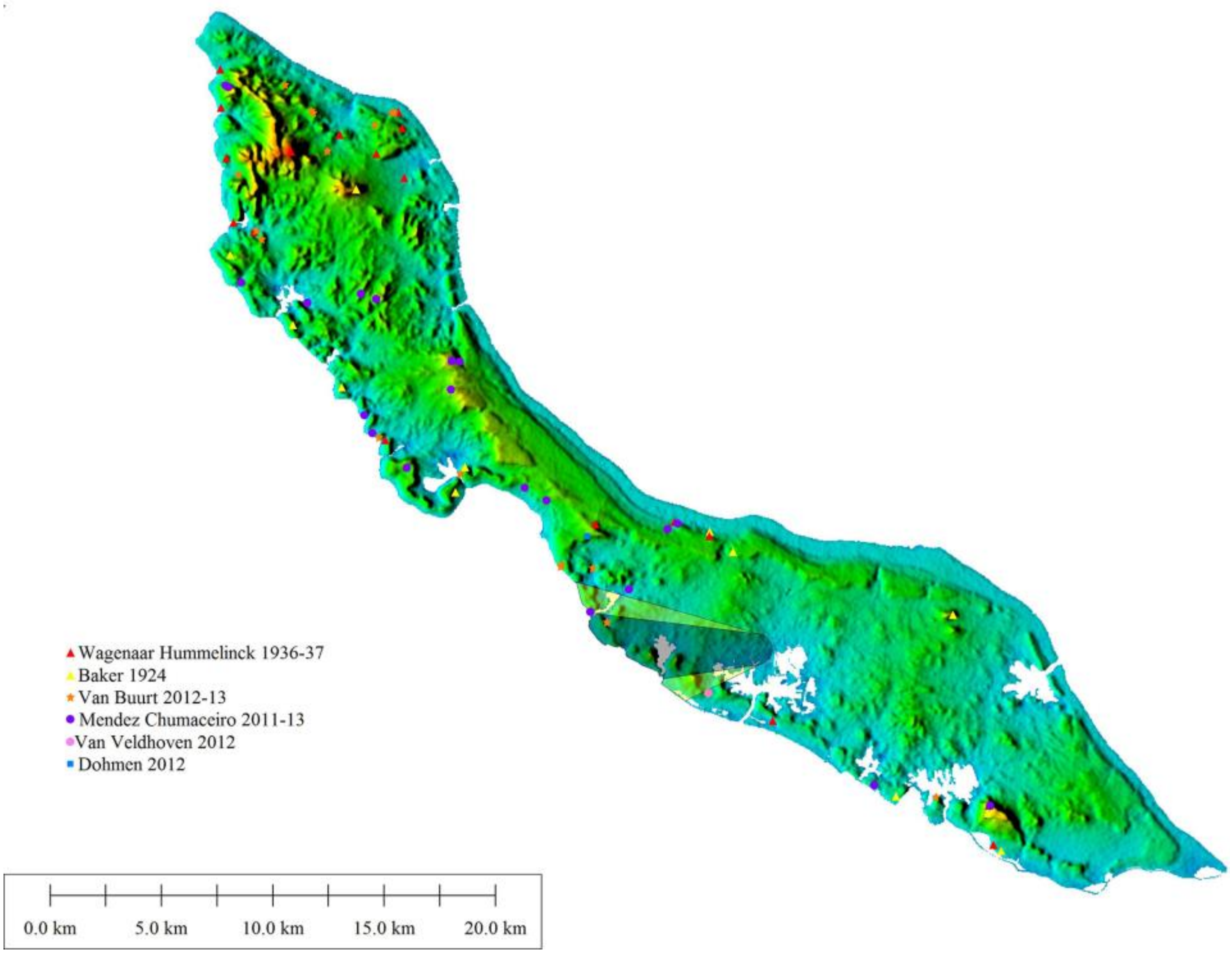
Bulimulus

Bulimulus guadalupensis (Fig. 9) was introduced in Curaçao from Saba in 1972 (Breure, 1975). It is nowadays found in many gardens in the eastern part of Curaçao. There may have been later introductions with nursery plants also. However it has not established itself outside of gardens, in the bush (locally called mondi), which is probably too arid.

Cnemidophorus murinus, a fairly large teiid lizard has been observed feeding on *Bulimulus* in Curaçao. Some adult *Bulimulus guadalupensis*, which I released in my garden were wiped out almost

Fig. 4 - *Drymaeus elongatus* on twig of *Crossopetalum rhacoma*, where it will soon be fully exposed to the sun.
Photo: Gerard van Buurt

Fig. 5 - *Drymaeus elongatus* moving around on a branch of the Kamalia (*Coccoloba swartzii*), after a short rain.
Photo: John G.M. Dohmen



Map 1 - **Distribution of *Drymaeus elongatus* in Curaçao**

Drymaeus elongatus is absent from the Lower and Middle plateau and all along the North coast. This is probably related to excessive levels of salt in the air. On the northern part of the island, in areas near the sea, the *Drymaeus* are often found on the leeward side of hills or in gullies. Some were encountered on trees and candelabra cactus growing right behind a steep cliff; sheltering them from the sea winds (Fig.12). Somewhat further downwind from the same cliff they were absent on similar vegetation. In the western part of the island some *Drymaeus* were found on the exposed windward side of a hill, not too far from the coast. This would seem to contradict the whole idea of their distribution being affected by excessive salt spray. The prevailing winds are however almost due east or slightly south east. Thus here they do not travel the shortest route from the coast, but cross a considerable distance overland coming from the east. There is a very good inverse match between the high wind energy areas in Curaçao and the distribution of *Drymaeus*. High wind energy and salt spray in the air are undoubtedly highly correlated (the high wind energy map cannot be reproduced in this article since it is copyrighted). Neither is *Drymaeus* found in the inhabited areas in Middle Curaçao. The main reason is undoubtedly that in this area there is hardly any undisturbed original vegetation left. Most of the plants with which *Drymaeus elongatus* is associated are either not found in this area or are quite scarce. Air pollution is very likely an additional factor explaining their absence. This could affect them either directly or indirectly by killing off lichen and algal growth on trees; which they utilize as food. The presence of the black rat (*Rattus rattus*) in the inhabited areas could be an additional contributing factor explaining their absence. *Drymaeus elongatus* is also known from the eastern part of Curaçao, but this area has not been sampled, since it is privately owned land and the owner does not want biologists roaming around on his land, (rightly) fearing that the results of their studies could be used to restrict land use. Nevertheless it seems safe to assume that in this area, it is present only along the south-eastern coast where it is protected by hills that block the easterly winds and that if data were available they would simply extend the present line of dots in the Fuik bay area somewhat to the east, along the wind shadow of the coastal hills. In the middle of the island the Refinery aerial plume pollution can be seen. The SO2 and soot data were provided by Milieudienst Eilandgebied Curaçao (Curaçao Island Environmental Service). These data also indicate the direction of the prevailing winds. The darker shaded area contains 65 % of the pollution measured; the lighter shaded areas contain 10-12%. The earliest records for *Drymaeus* are by Burrington Baker who visited Curaçao in 1920 and 1922 (Burrington Baker, 1924a). The data by Wagenaar Hummelinck were collected in 1936-37. All other data: 2011-13. The refinery started operations in May 1918. Thus the earliest records for *Drymaeus* do not predate the refinery; however in the early days the refinery was much smaller and its chimneys were not as high and its pollution did not carry as far. The one *Drymaeus* location which is situated at the edge of the aerial pollution plume; just within the 65 % area of air pollution is situated in a steep gully between hills, where it would be at least partially protected.

Fig. 6 - Large agglomeration of *Drymaeus elongatus* on a Wayaká (Lignum vitae) tree *(Guaiacum officinale).* This is probably a breeding aggregation. Photo: Michèle van Veldhoven

Fig. 7 - Juvenile *Drymaeus elongatus* munching on a fungus on a cactus, very faint grazing tracks are visible. Photo: Gerard van Buurt

immediately by these lizards. This is unusual since indigenous land snails such as *Cerion uva* and the *Tudora* species generally do not seem to fall prey to this lizard and also seem to be relatively invulnerable to birds (see discussion below).

The *Cnemidophorus murinus* lizard is commonly found almost everywhere, but it will not be present,

Fig. 8 - Leaf of the vine *Serjania curassivica* (Fam: Sapindaceae) which has been grazed by *Drymaeus elongatus*. A large *Drymaeus elongatus* was encountered nearby this leaf, on this vine. Photo: Gerard van Buurt

or its presence in gardens will be much reduced when dogs are kept. In irrigated gardens there will also be much more vegetation and ground cover where such snails can hide. This could be an additional factor explaining the absence of *Bulimulus guadalupensis* in the bush. In an arid environment with less vegetation and ground cover such snails would be very vulnerable to predation by such teiid lizards. In Puerto Rico a very similar teiid lizard (*Ameiva exsul*) is a common predator of *Bulimulus guadalupensis* (Lewis, 1989).

Zachrysia

Zachrysia provisoria is present in Curaçao (identification by: Ad Hovestadt, the Netherlands). It was first found in the Dominguito area, around 2002, and has now spread to other areas nearby (Damacor, Toni Kounchi, Mahaai, Semikok), it is also found in the Groot Piscadera area, where it has been present for several years now. These snails have not been reported previously from Curaçao. These snails are considered a major horticultural pest in the Caribbean and Florida (Auffenberg and Stange 1993). It has not yet been determined whether they can survive outside of gardens in the dry Curaçao climate and whether they will become a threat to native plants. Several snails were found that had apparently been killed and eaten by birds. Very likely the predator was the tropical mockingbird (*Mimus gilvus*), although the local troupials (*Icterus* spp.) could also be involved.

Achatina

On the 16th of January 2013 the giant African snail, *Achatina fulica* (= *Lissachatina fulica*) was first found on Curaçao by Mr. Manuel Boot. Although an effort was immediately undertaken to extirpate it, this has not been successful. It seems that it is now established in the Oud Jan Thiel residential area (pers. comm. Manuel Boot, Vitis gardening company) and is slowly spreading. It is now clear that it is here to stay. We have no idea how it arrived. It could have been introduced with garden plants, come from a yachting harbor not too far away or may have been introduced as a pet. We cannot say yet whether it will be able to survive in the wild outside of gardens and whether it will be able to penetrate into the bush. Since this snail is adapted to dry areas, this could very well turn out to be the case.

Discussion

Possible use of wax compounds on succulent plants as high-energy food

It looks like some of these landsnails scrape of a thin layer of wax from succulent plants. This has been observed in *Bulimulus guadalupensis* and *Cerion uva* (see Figs. 9-11). It may also be the case in *Drymaeus elongatus*, but was not as clearly visible. With *Tudora* this has not been noted. *Cerion uva* living on the cactus *Stenocereus griseus* were found to have white feces (see Fig. 11), which were waxy to the touch. Since these animals do not feed frequently, such feces are however not regularly found. It is known that during the dry season such animals can aestivate during very long periods (Anderson and Sinn, 2000).

In oceanic food chains waxy compounds play an important role (Benson and Lee, 1975). The cutin layer of succulents such as cactus consists of biopolymers (Kolattukudy, 2002), which would constitute an excellent high carbon energy compound if utilized as food. It would also be very useful for animals which only eat after rains and which sometimes have to survive very long extended dry periods by aestivation. On some photographs it seems as if a very thin layer of the waxy surface layer has been scraped and harvested (see Figs. 9-11). This would be consistent with the earlier observation, described above, where a *Drymaeus elongatus* was only harvesting a thin top layer of a fungus. From the listing in Appendix I it can be

Fig. 9 - *Bulimulus guadalupensis* on *Aloë vera*. It looks like the wax around the animal is smoother and has been "shaved". Both the *Bulimulus* and the *Aloë* have been introduced on the island. Photo: Carel P. de Haseth

Fig. 10 - *Cerion uva* on *Stenocereus griseus* candelabra cactus, there are “scratch” marks on the cactus around the *Cerion.* Photo: Gerard van Buurt

Fig. 11 - *Cerion uva* with whitish feces on a *Stenocereus griseus* candelabra cactus, it can also be noted that there is a clear zone around the mouth of the animal. Photo: Gerard van Buurt

noted that many of the plants on which *Drymaeus elongatus* is regularly found are succulents which have a waxy cuticle.

Predation

Cerion uva is exceptionally well armored. Quenson and Woodruff (1997) describe crab predation on *Cerion* in the Bahamas and the Florida Keys. Of the main predators on *Cerion* they describe, landcrabs and rats, which are also present in Curaçao. In Curaçao dead *Cerion* and *Tudora* were found with lesions which were probably caused by crabs. In Curaçao the principal predators would very likely be larger hermit crabs (*Coenobita* sp.), which can roam quite far inland; however these have become much less common than in the past and Quenson and Woodruff do not mention them in their study. Gecarcinus land crabs and other land crabs living near the coast, such as *Cardisoma guanhumi*, both mentioned by Quenson and Woodruff, are present in Curaçao. Quenson and Woodruff mention the Norway rat (*Rattus norvegicus*) as a major *Cerion* predator near inhabited areas in the Bahamas. In Curaçao this rat is much less common than the black rat (*Rattus rattus*), it is practically only found in the harbor area. The black rat is seldom found in the mondi (bush), is clearly associated with human habitation and is unlikely to be a major *Cerion* predator in Curaçao. In Papiamentu, the local language of Curaçao, *Cerion uva* is called kokolishi di kalakuna, meaning “turkey shell” (Coomans 1967). In the past they were fed to turkeys and were even exported to Germany in large burlap sacks for this purpose (Boeke, 1907). Large birds such as turkeys, chicken, Guinea fowl and peacocks can eat snails such as *Cerion* and *Tudora*. However these are not natural predators and do not roam around in the wild.

Little is known about predation on *Drymaeus elongatus*. Since it is an arboreal snail crabs are probably not a major predator (although hermit crabs sometimes do climb into trees). In or near inhabited areas the black rat (*Rattus rattus*) could be a major predator, its presence might be an additional reason why *Drymaeus elongatus* is not found in the inhabited areas. Seaman (1959) mentions the White-crowned pigeon (*Patagioenas leucocephala*, formerly *Columba leucocephala*) as a predator on *Drymaeus elongatus* in St. Croix. In Curaçao similar sized pigeons exist. Once an empty *Drymaeus elongatus* shell was found with a comma like lesion that could have been made by a bird. Townsend et al. (2005) mention predation on *Drymaeus multilineatus* by the Green iguana (*Iguana iguana*) in the Florida Keys. We have never noted predation on *Drymaeus elongatus* by green iguanas in Curaçao, although such iguanas are plentiful.

Zoogeography

Wagenaar Hummelinck (1940) considered *Cerion*, *Tudora* and also *Microceramus*, to be old West-Indian elements in the Curaçao fauna. In those days their presence would be explained by invoking old land bridges such as the Aves rise. Their presence harks back to a time when the islands Aruba, Curaçao and Bonaire were situated much closer to the Greater Antilles. Nowadays such ideas are supported by models of continental drift and movement of ocean plates. Several such models nowadays exist, which - although they may differ from each other in various important respects - generally support the idea that Aruba, Curaçao and Bonaire were once situated much closer to the

Greater Antilles. The genus *Cerion* is also found in South Florida, Bahamas, Turks and Caicos, Cuba, Cayman Islands, Hispaniola, Isla Mona, Puerto Rico and the Virgin Islands (Anegada and Necker); a fossil representative of this genus has been found on Saint Croix.

This disjunct distribution has *raised* many questions (FAHY, 1996). *Tudora* and Microceramus are mainly West-Indian genera with some South American representatives. The genus *Drymaeus* is of South American origin with some West-Indian representatives. *Drymaeus elongatus* is found in Puerto Rico and the northern Lesser Antilles and in Aruba, Curaçao and Bonaire. This raises the question whether it should be considered a West-Indian element in the fauna of Aruba, Curaçao and Bonaire or whether it is a South-American faunal element in the West-Indies. It also raises the questions whether it is an "old" or a "new" element and how to explain this somewhat disjunct distribution. BURRINGTON BAKER (1924a) states:

"The remarkably discontinuous distribution of *D. virgulatus* (*D. elongatus*) gives rise to the suspicion that it has been introduced into Curacao by commerce; it is noteworthy that this species also occurs in St. Martin and St. Eustatius, two of the islands of the northern Lesser Antilles, which are also part of the Netherlands Colony of Curacao". He refers to (cf. VERNHOUT, l. c., p. 184). The remarkably discontinuous distribution Burrington Baker refers to is its distribution in Curaçao, which can now be explained in large part by the effects of salt spray. This discontinuous distribution made Burrington Baker conclude that the species must have been introduced. The reference to its occurrence in St. Martin and St. Eustatius seems to have been added almost as an afterthought. Burrington Baker does not raise the possibility that such an introduction could have taken place in the reverse direction, which is entirely logical since he did not believe it to be indigenous in Curaçao. In my opinion *Drymaeus elongatus* is definitely not an introduced species in Curaçao (as explained earlier). This leaves the question of how to explain its discontinuous distribution in the Caribbean.

Drymaeus elongatus is also found on Aruba and Bonaire but not on Klein Bonaire and Klein Curaçao

Fig. 12 - Edge of a cliff at Savonet; the base of this cliff is about 20 meters above sea level and forms the edge of a hill of about 40 meters high, which in this area runs in a North-Southerly direction. *Drymaeus* are found on the vegetation in the right (Western) side of the picture; even though this location is very near to the sea. Standing where the picture was taken, one can hear the waves crashing on the coast about 250 meters to the North-East. The hill is sheltering the *Drymaeus* vegetation from the prevailing Easterly sea winds. Somewhat further downwind from this same cliff, *Drymaeus* are absent on similar vegetation. Photo: Gerard van Buurt

(Wagenaar Hummelinck, 1940). Its absence on Klein Bonaire could be due to the small size of the islet (7 km2). Suitable habitat could be lacking entirely or may be too small to sustain a population. Salt spray is not particularly strong on this islet. The channel between the islet and the main island, although quite narrow is still a barrier, some species could not cross it. In the previous interglacial the island was fully submerged.

Most of the indigenous land snails are very small (Burrington Baker, 1924a). A similar pattern, with small snails predominating in the fauna of land snails, is found on oceanic islands in the Pacific Ocean (Vavoglyi, 1975). These snails, or their ancestors must have arrived by oceanic dispersal; such small snails are less likely to have survived a sea voyage and have probably been transported by birds. *Tudora*, *Cerion* and *Drymaeus* are somewhat larger than the other indigenous snails, of these *Drymaeus* is the largest. However many much smaller juveniles can be found and for an arboreal snail like *Drymaeus*, it seems likely that it must have arrived transported by birds. Likewise the somewhat larger size of *Cerion* and *Tudora* compared to other Curaçao land snails does not exclude the possibility of the arrival of juveniles or eggs of these species by aerial dispersal. Apart from size, for aerial transportation weight would be an important consideration.

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Appendix I

List of plants on which *Drymaeus elongatus* is regularly encountered

Boraginaceae

Watakeli - *Bourreria succulenta*

Burseraceae

Takamahak - *Bursera tomentosa* (*Drymaeus* is quite frequently found on these trees. Burrington Baker (1924) calls this species *Bursera gummifera*).

Cactaceae

Kadushi - *Cereus repandus*

Datu - *Stenocereus griseus*

Infrou - *Opuntia caracassana* (formerly: *Opuntia wentiana*)

Tuna - *Opuntia elatior* (introduced plant normally found in gardens, some grow in the wild)

Caesalpiniaceae

Palu Brasil (Dye wood) - *Haematoxylum brasiletto* (*Drymaeus* is quite frequently found on these trees)

Watapana - *Caesalpinia coriaria*

Capperaceae

Surun - *Crateva tapia* (this plant is distributed all over South and Central America, with the exception of Chile. It is native in Curaçao where it is not very numerous but can be found in the wild in humid areas, near dams and waterflows. This tree seems to be a "magnet" for *Drymaeus*. It is also found in Bonaire where it has the name Ishiri, an indigenous name. In Aruba this tree is very rare, which can be explained by the fact that Aruba has a more arid climate).

Celastraceae

Plaka Chikitu - *Crossopetalum rhacoma*

Euphorbiaceae

Lòki-Lòki - *Phyllanthus botryanthus*

Fabaceae

Indigo - *Indigofera tinctoria* (introduced plant commonly growing in the wild, *Drymaeus* found on indigo only once)

Guttiferae (Clusiaceae)

Kuchua, **Kachiu** - *Clusia rosea*

Mimosaceae

Wabi – *Acacia tortuosa* (not very common on this tree)

Polygoniaceae

Kamalia, Dreifi shimaron - *Coccoloba swartzii*

Rubiaceae

Lumbra blanku - *Erithalis fruticosa*

Palu di lele - *Randia aculeata*

Sapindaceae

Behuku - *Serjania curassavica*

Verbenaceae

Flor di sanger - *Lantana camara*

Zygophyllaceae

Wayaká (Lignum vitae) - *Guaiacum officinale* (*Drymaeus* is quite frequently found on these trees, sometimes in large groups)

Folia conchyliologica

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