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Antigonon Leptopus (Corallita) on St Eustatius: an Integrated Pest Management approach

Proposal for an Integrated Pest Management (IPM) approach

Remco Overeem and Marleen Riemens

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Plant Research International, part of Wageningen UR
Business Unit Agrosysteemkunde
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1. Introduction

Corallita (Antigonon leptopus) is a vine that is categorized as an invasive species of natural areas (Ernst and Ketner, 2007; Raju et al., 2001). The vine originates from Mexico and is cultivated in many tropical areas for its flowers (Burke and DiTommaso, 2011b). Corallita can become a serious pest, covering for example approximately 6% of the island Guam in 2011 (Reddy, 2011) and 33% of St Eustatius in 2014 (Berkowitz, 2014).

St Eustatius is a special municipality within the kingdom of The Netherlands. This island in the Caribbean region can roughly be divided in three parts. In the south east is the dormant volcano 'the Quill' with a hight of about 600 meter. In the north west is another nature reserve named Boven with peeks up to 250 meter. Thogether these regions are the Quill/Boven National Park (STENAPA, 2018). In between is the quite flat Cultuurvlakte were almost all inhabitants live (Figure 1).

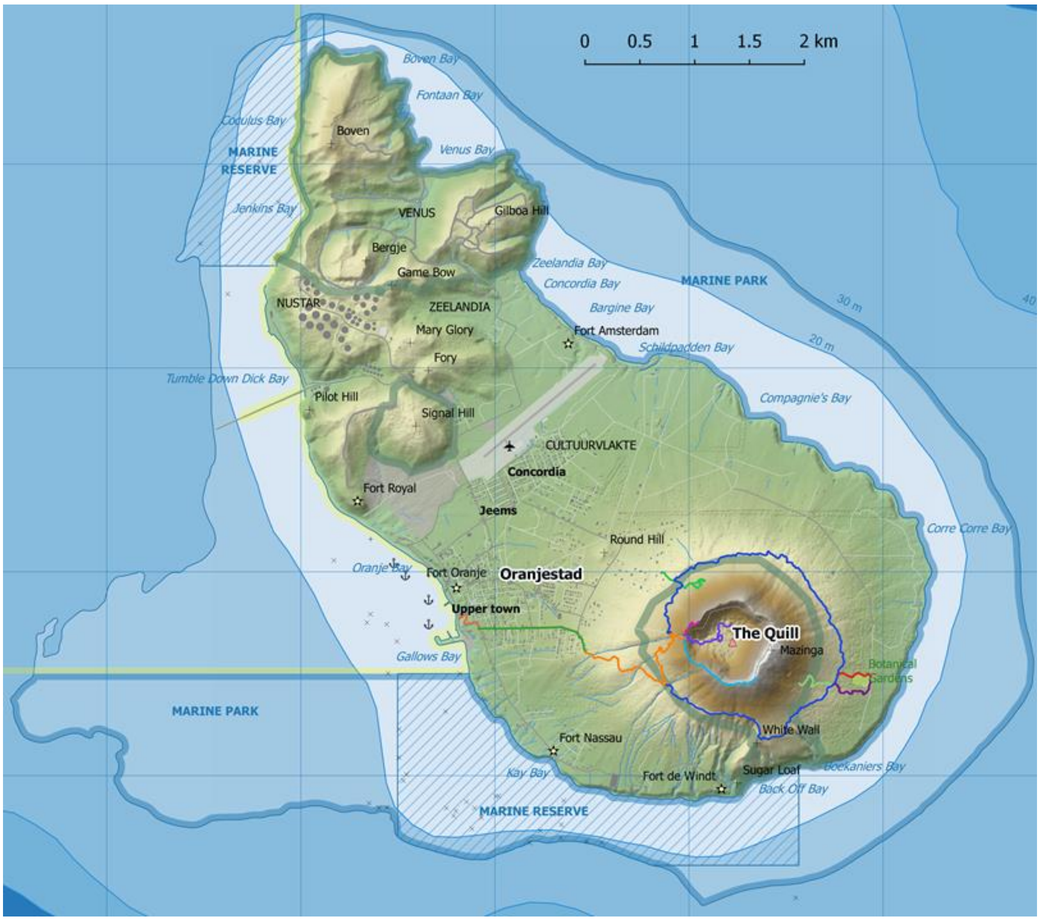

Figure 1. Map of St Eustatius. In the south east is the volcano the Quill and in the north west Boven, thogether the Quill/Boven National Park. In the middle the Cultuurvlakte with among others Oranjestad and the airport (Erren, 2017).

Corallita has been introduced on St Eustatius as a garden ornamentalin in 1907 (Ernst and Ketner, 2007). It has particularly spread since the 1980s, as development has increased and agriculture has decreased, which has led to more disturbed landscapes

and less clearing of fields, ideal conditions for Corallita to thrive (Berkowitz,2014; Ernst and Ketner, 2007).
The consequences of Corallita can be classified as ecological, technical and financial. Ecological effects are the smothering of native trees and shrubs, thereby outcompeting them for light (STENAPA, 2007; for example see Figure 2). As a result the habitat for native birds and the threatened Lesser Antillean Iguana is reduced, resulting in detrimental effects for these animals (Berkowitz et al., 2014). Technical problems involve the accessibility of former agricultural fields, roadsides and gardens. Moreover fences collapse by the weight of Corallita (Ernst and Ketner, 2007). Corallita is also overgrowing historical ruins and threatened the botanical garden and the Quill, which are all economic important places of St Eustatius (Berkowitz, 2014; Tieskens et al., 2014). Besides damage caused by this vine, control and eradication of Corallita is financially very costly.

Figure 2. Corallita smothering native vegetation on St Eustatius. Photo made by Joost van der Burg.

Ernst and Ketner (2007) had made several recommendations. Unfortunately very little has done so far, what resulted in a strong increase of area covered by Corallita (Berkowitz, 2014).
The European Commission (2009) has defined the eight principles of Integrated Pest Management (IPM) for the control of weeds, diseases and pests. In this study we explore how these principles can be used to design an effective management system for Corallita on St Eustatius. The eight principles are described below and their possible use for Corallita management will be described in the chapters indicated within the parentheses:

(1) Measures for prevention and suppresion (Chapter 2)
(2) Monitoring (Chapter 3)
(3) Threshold values as basis for decision-making (Chapter 4)
(4) Non chemical methods to be preferred (Chapter 5.1)
(5) Target specificity and minimization of side effects (Chapter 5.2)
(6) Reduction of use to necessary levels (Chapter 5.2)
(7) Application of anti-resistance measures (Chapter 5.2)
(8) Records, monitoring, documentation and check of success (Chapter 6).

The conclusions and recommendations will be summerized in chapter 7.

2. Prevention

Corallita is able to spread sexually through seed production and asexually via underground roots. The seeds are buyont and capable of spreading over large distances via water (Burke and DiTommaso, 2011b). Germition of seeds collected from plants was on average 57.5%. From seeds collected from the ground, 80% was rotten and/or invaded by insects or even completely empty. Moreover lifestock and insects are probably predators and not dispers Corallita: a previous feeding experiment on St Eustatius showed no viable seeds in the excretions of animals fed with Corallita fruit. Seedlings are therefore rarely found on St Eustatius (Ernst and Ketner, 2007) and the dispersal of Corallita therefore occurs probably mainly due to tuber and root parts.

The only known vector for long term dispersal are humans (Burke and DiTommaso, 2011b). The species has been introduced to the island intentionally as an ornamental. Burke and DiTommaso (2011a) compared the chloroplastic genome of Corallita of three sites of St Eustatius, two samples of each site. They found small genetic variation within one of the three sites, but relatively large differences between the samples of the three sites, suggesting that the population originates from different seed sources which have been introduced independently on the island. The physiological and ecological relevance of these differences are unknown.

The infection severity is concentrated at the south eastern half of the island (Figure 3). Further spread should be prevented. An important method to prevent spreading to new locations on the island is the stop of transport of soil containing any roots or tubers (Burke and DiTomasso 2011b). Moreover import of new Corallita seeds or plantmaterial should be prevented.
Currently existing hotspots of Corallita at the north eastern half of the island and/or in the neighbourhood of the national parks should be early detected and immediately eradicated. Secondly Corallita should be eradicated out of the village, which then, together with the airport, could serve as a barrier between the heavily infected area around the Quill and the clean area in the north west of the island. Monitoring and control methods needed for eradication of Corallita will be described in chapter 3 and 5 respectively.

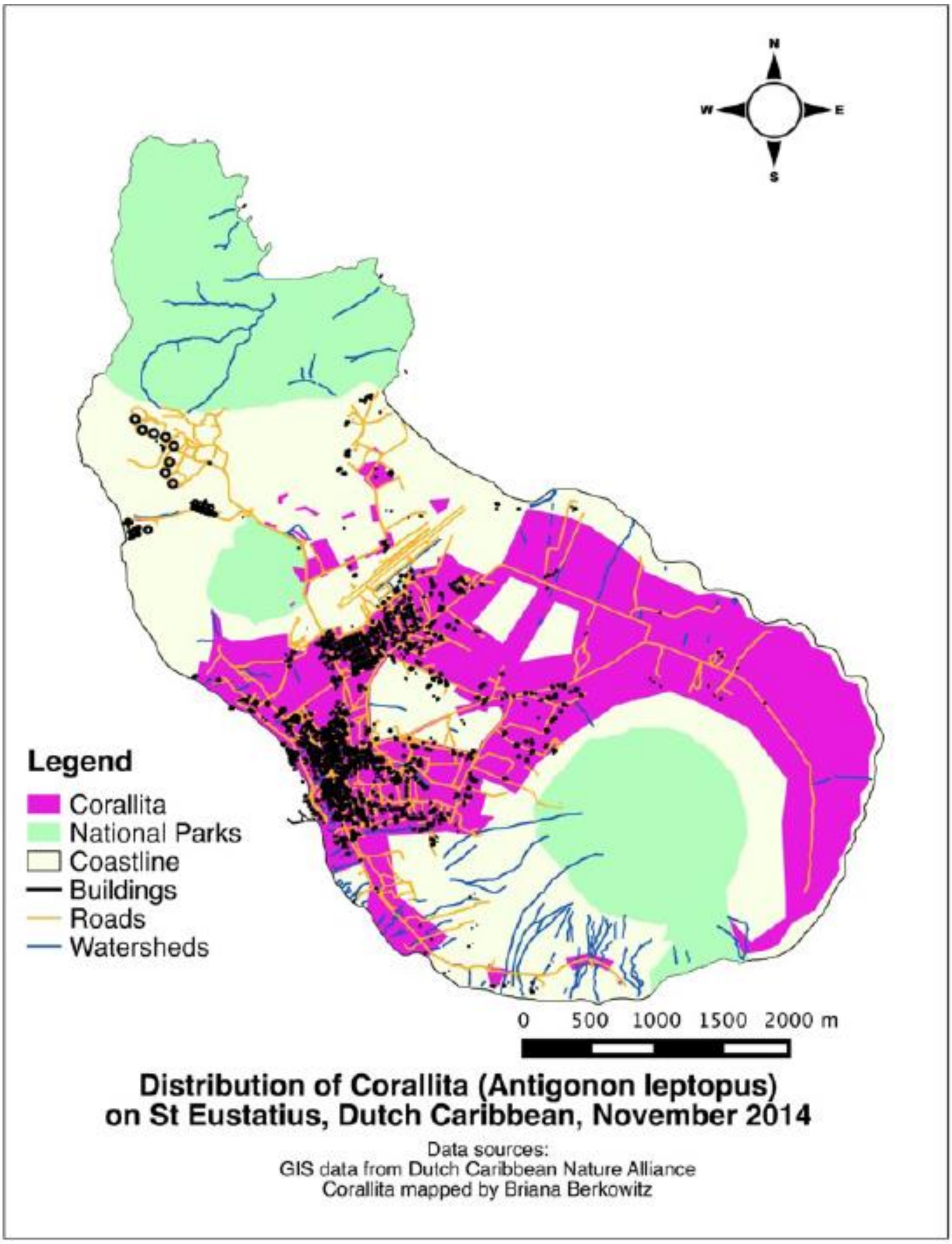

Figure 3. Distibution of Corallita on St Eustatius on November 2014 (Berkowitz, 2014)

3. Monitoring

Monitoring and registration is a key element of integrated pest management. Based on the field data and the economical aspects of control, decisions can be made, a year round planning can be made, and, after execution of control, a check can be made whether control was efficient. Regular checks of possible habitats, early detection of new infestations or early regrowth after control, combined with a quick removal of the observed plants, will usually lead to a cost effective control solution for invasive species. Besides the registration of the presence of plants, it is also favourable to monitor the effectiveness of the control actions.

Objective monitoring during the season, gives the opportunity to:

- Setting goals for a specific area;
- Making inferred conclusions on the efficacy of control strategies;
- Assessing the cost efficacy of control methods based on economic values;
- Relating the effect monitoring to the habitat traits (e.g. nutrient levels, shading, moisture levels, and so on).

Two studies previously monitored the distribution of Corallita on St Eustatius and mapped the distribution of corallita on a topographical map (Berkowitz, 2014; Ernst and Ketner, 2007). The map of Berkowitz (2014) is shown in Figure 3 and the map of Ernst and Ketner (2007) in Appendix I. Comparison of both maps reveals a strong increase of surface of the island were Corallita is present from 15-20% in 2007 till 33% in 2014. Both Berkowitz (2014) and Ernst and Ketner (2007) emphasized the importance of monitoring Corallita distribution on St Eustatius. Nevertheless to our knowledge currently such a monitoring and registration system does not exist at the moment.

Above the importance of a monitoring and registration system was described. Berkowitz (2014) and Ernst and Ketner (2007) both performed field surveys to map distribution of Corallita among St Eustatius. Berkowitz (2014) surveyed by truck and walked main and secondary roads and recorded locations where Corallita was found with GPS coordinates. Ernst and Ketner (2007) used a topographical map, but did not describe how they performed the field survey. Ernst and Ketner (2007) also used aerial photos made by KLM Aerocarta in 1991. Corallita was hardly identifiable on these pictures, but these photos were useful for orientation. According to these authors it was possible to recognize Corallita on Google Earth images. A major downside of this methodology is the dependency of clear weather. When the islands are covered by clouds, the vegetation will not be visible. Finally for a new mapping based on Google Earth researchers are dependend on an update of these pictures, which might not always fit with the desired moment of mapping.
Haber et al. (n.d.) compared the map and manual mapping method of Berkowitz (2014) with a semi-automated map, made based on a WorldView-2 satellite image. The semi-automated map had similar accuracy, a lower percentage false positives and is quickly and easily repeatable. Disadvantages of this method are that much more resources

and expertise are needed, a higher percentage false negatives and Corallita cannot be identified on places where it is growing under other plants. When regularly an overview of the entire island will be made, the semi-automated mapping method of Haber et al. (n.d.) might be a good alternative. Berkowitz (2014) recommended to map the distribution of Corallita on the entire island every five years. Because of the rapid expansion of the area covered with Corallita, this frequency may be too limited to record the changes in distribution of Corallita. A higher frequency would be advised. Besides this monitoring of the entire island, monitoring of (treated) spots is needed, but this will all occur on small scale and needs detailed assessment on efficacy and growth stage. Therefore field surveys are to be preffered above the semi-automated mapping method of Haber et al. (n.d.). Google Earth and aerial photos might give some additional information, but field surveys remain necessary.

It is recommended to determine also the density and frequency of Corallita per location to gain insight in the infection severity (Berkowitz, 2014). The maps of Berkowitz (2014) and Ernst and Ketner (2007) namely only give insight in the presence or absence of Corallita per location. The effect of infection severity on monitoring frequency of the entire island as well as of isolated spots, needs to be investigated. Besides mapping the distribution among the entire island, Ernst and Ketner (2007) advised to monitor some locations more frequently, approximately every two months. These locations include isolated spots or spots from which Corallita could spread into the National Parks and places where Corallita is not present yet, but were chances were high that it will appear. For both types some locations are listed below, according to Ernst and Ketner (2007).
Isolated or critical spots:

- Around the Telecom board
- Along the paths near the entrance to the Quill
- End of bird trail, Botanical Garden
- Isolated habitats near Fort deWindt
- Various isolated habitats in Zeelandia (e.g. along the road, outside the garden of Nicole Esteban, downhill of the house of Wendy Collins and other).

Suggested sites for monitoring the presence/absence of Corallita in an early warning system:

- (New) building sites
- Along the border of the Quill sector of the National Park, where the chances are high that Corallita will appear, because of transport of fruits, small tubers or cuttings.
- In the Boven sector of the National Park.
- Beyond the Botanical Garden, passed the present border of Corallita.
- On the compound of the Oil Terminal.
- Locations between Fort de Windt and Oranjestad.

It should be noted that the recommendation to monitor these specific sites dates from eleven years ago and therefore probably needs an update. Nevertheless these sites might serve as starting point. Once a control program for Corallita is started, structural adjustment of critical hotspots and other specific sites to monitor is necessary.

4. Threshold values

Especially in agriculture treshold values might be usefull to determine from which infection severity cost for control methods are lower than reduction of profits caused by the invasive plant. For Corallita on St Eustatius this is not the case. Every single new Corallita plant will contribute to the growth of the population and the development of Corallita as a pest. Moreover, it would be more time consuming to determine infection severity than to remove such a single plant. So the threshold value for Corallita is one. Every new plant on at a new location should be immediately removed.

5. Control methods

The control of invasive species varies from “doing nothing” to the use of mechanical, chemical and/or biological control methods. Doing nothing is not a realistic option on St Eustatius. Between 2007 and 2014 almost nothing was done to controle the dispersal of Corallita, resulting in an almost doubled distribution area of Corallita (Berkowitz, 2014). Control methods are therefore needed to stop further dispersal and reduction of infected area. The possible mechanical and chemical control methods for invasive species will be discussed with relevance to Corallita in paragraphs 5.1 and 5.2 respectively. Biological control methods for Corallita were not found and will therefore not be discussed.

5.1 Mechanical control

Weeds can be controlled through mechanical methods that are generally based on three mechanisms: cutting, uprooting and burying weeds. Mechanical weed control methods have a high capacity and have in general low costs which makes them attractive. However, they are also not very selective, and application in natural areas may sometimes impossible due to accessibility of the area and other vegetation. Timing and intensity of the operation determines their selectivity, together with weed and total vegetation growth stage.
Just cutting or burning Corallita has a minor effect, because the plant soon resprouts from the underground roots and tubers (Ernst and Ketner, 2007; Muniappan et al., 2002). Burning is always accompanied by fire hazard, for what reason cutting is a better option. Because of regrowth from roots and tubers, cutting of plants should always occur in combination with removal of these underground parts, or treatment with systemic herbicides. If Corallita is grown in trees, the stems needs to be pulled from the crown. To prevent Corallita growing again in trees, the crowns can be pruned up making it more difficult for Corallita to reach the branches (Ernst and Ketner, 2007). Pruning up trees at the edge of a forest in combination with removing shrubs a few meters in front of the forest might make it more difficult for Corallita to enter the forest. The cutted plant parts of Corallita together with eventually harvested roots and tuber have to be burned to prevent regrowth out of plant parts, or sowing from seeds still hanging on the plants (Ernst and Ketner, 2007).

In gardens and private grounds, cutting Corallita and harvesting the roots and tubers is a suitable method to keep it back (Berkowitz, 2017). It is important to remove Corallita plants as soon as possible because the number of tubers per square meter increases soon up to several hunderd, ranging in weigth from less than 1 till 300g. Tubers were found till a depth of two meter below soil surface (Ernst and Ketner, 2007). For larger plants it is therefore probably needed to repeat the removal of tubers some times because it is very likely that some tubers remain in the ground.
Inhabitants were informed about the threats of Corallita and also about possible controle methods (STENAPA, 2007). Nevertheless the coverage with Corallita increased also in the urban areas (Berkowitz, 2014). So just informing the inhabitants is

not sufficient to stimulate them to control Corallita in their own garden. Therefore other positive and/or negative tools and actions are needed to stimulate the inhabitants from St eustatius to remove Corallita from their gardens.

On a large scale it is not feasible to harvest all roots and tubers manually, while it becomes to costly to do it mechanically. In the latter case namely infected areas have to be excavated till a depth of two meter and all soil has to be sieved. Moreover in several places this is not possible because of the other vegetation.
Besides the urban areas, the areas covered by Corallita can be roughly divided in forest areas and areas with shrubs, herbs and pastures. These latter areas with shrubs, herbs and pastures are in the Cultuurvlakte and are suitable for (limited) cultivation (Veenenbos, 1951). The best option would be to remove all vegetation of these areas and sow grass on it, or reintroduce agriculture or horticulture on these areas (Burg et al., 2012). When grass will be sown, Guinea grass (*Panicum maximum*) is a good competitor of Corallita according to an inhabitant of St Eustatius (Ernst and Ketner, 2007). However, as far as known no scientific research has been done to proof this, neighter compared this race with other grass races. It would therefore be better to first investigate which species and race of grass is the best competitor of Corallita on St Eustatius before the vegetation of this area is replaced by grass.
In case of grass it has to be regularly mowed or intensively grazed. The frequency of mowing is unknown. For the Japanese knotweed for example twice per month has to be mown, resulting in a maximum plant length of 15cm. At this size the roots put a lot of energy in the shoot, but did not receive significant amounts back (Groot and Oldenburger, 2011). Further research is needed to clarify the optimum mowing frequency for Corallita on St Eustatius. With mechanically mowing caution has to be taken to prevent for spreading with the machinery of plants parts that can regrowth at a new location.
Ernst and Ketner (2007) observed, spread over 11 days, in total 16½ hour grazing cattle. Only incidentally cows and goats were observed eating Corallita leaves and pigs digging up and eating the tubers. This might however be influenced by the year, because in that year sufficient rainfall occurred and therefore also sufficient other vegetation was available (Ernst and Ketner, 2007). Weiss et al. (2010) compared Saint Croix White hair lambs with fed with a diet containing 4% Corallita and a diet containing 25% Guinea grass. The lambs did ate the diet including Corallita, but this diet lowered weight gains compared to the diet containing Guinea grass. So cows, goats, sheeps and pigs eat Corallita, but prefer other vegetation. Whether grazing is effective in controlling Corallita on St Eustatius needs therefore to be investigated.

According to Burg et al. (2012) in some cases plastic sheets could be effective to smother Corallita plants. This might be supported by the fact that Corallita does not tolerate shade (Burke, 2011). The effectivity and feasibility of this method probably strongly depends on the infection severity with Corallita and the size, geomorphology, vegetation and cultivation and of the area.

5.2 Chemical control

Areas where it is not possible to harvest roots include forests, stony land, ruins and along roads and other pavements. For these areas currently chemical methods are the only known possibility to control Corallita.

Ernst and Ketner (2007) investigated the effect of two herbicides on Corallita: Garlon (active ingredient triclopyr) and glyphosate. Garlon is not allowed to use anymore since 2012 (Ctgb, 2011) and will therefore not be discussed in this report.

Ernst and Ketner (2007) performed three experiments differing from four till six months each in length. Regrowth was checked every two till seven weeks. Glyphosate was effective in killing the shoot and the roots and tubers. These authors investigated both foliage and stump treatment. Stump treatment was slightly more effective, but much more time consuming. Moreover, with foliage treatment it is easy to check if the treatment was applied in the right manner because of the yellow colourization and wilting of the leaves after a few days. Ernst and Ketner (2007) therefore advised a foliage treatment with glyphosate. However there is no clarity about the concentration. With 100% glyphosate[1] almost all shoots, roots and tubers were killed and only incidental regrowth occurred (Ernst and Ketner, 2007). These authors also investigated glyphosate concentrations of 12.5, 25, 50 and 75% and found that the regrowth increased when the concentration decreased. For the 50% and 75% treatment they did not describe whether the tubers were killed or not, but they indicated that concentrations of 12.5 and 25% tubers were not killed and repeat of treatment was necessary. Nevertheless, without mentioning any reason, these authors advised to spray with glyphosate concentrations of 25%.

Ernst and Ketner (2007) also advised to perform next experiments of about one year with different concentrations of glyphosate to investigate the effect on the tubers and roots and on regrowth. In our opinion one year is short, especially when low dosages of herbicides will be used. It is therefore recommended continue the expirements till one year after the last regrowth was observed.

From a resistance management point of view, it is advised to not use a single mode of action; the use of herbicides with different modes of actions will slow down a possible resistance development in Corallita towards glyphosate. On top of that, there is a strong public debate about the position of glyphosate on the market and sole dependency on this product is not to be advised. So further research should not only focus on dosages, but also on different types of herbicides. Moreover very little is known on herbicidal effectivity in relation to mode of action and size and plant growh stage of Corallita. Ernst and Ketner (2007) advised to spray Corallita when the plants reached a length of 30 till 40cm. However, a thorough study on the optimum plant growth stage and size can potential reduce the amount of required herbicide. Finally the effect of type and dosage of the herbicides, Corallita growth stage and size and mode of action on the environment needs to be included in the experiments.

[1] The 100% glyphosate treatment is pure, undiluted agent. There are however many agents with the active ingredient glyphosate and they made not clear which one they used. So the amount of active ingredient per surface unit or applied volume remains unclear. Possibly Ernst and Ketner (2007) did wrote these information in their appendix VI entitlet 'Fact sheets; Glyphosate and Garlon', but no acces to the appendices could be obtained.

Among the areas were chemical methods are the only known possibility to control Corallita, the critical spots as described in chapter 3 needs to have highest urgency. Control of these spots cannot wait till the above described experiments are finished and a advice can be given. Therefore it will be advised to cut of Corallita plants at these areas and after regrowth of 30 till 40cm to spray these plants with 100% glyphosate, a concentration which was proven by Ernst and Ketner (2007) to kill both the plant and roots and tubers. Alternatively, lower dosages can be used when more frequently applied. The exact frequency is unknown.

The with Corallita infected areas at the west, north and east side of the Quill consists of forest. At the south side of the Quill the infection severity is lower, but there are much more watersheds. In these areas the only feasible option is to cut of the Corallita plants and to spray the regrowth with herbicide. It is important to use precision equipment in these areas that allows treatment on single spots. However there should be waited with spraying till the above described experiments are finished and the most target specific herbicide can be choosen and applied in the lowest effective dosage on the smallest possible plant to reduce the side effects to a minimum. Except for the critical spots, it is for the same reason also recommended to wait with spraying in the urban areas till these experiments are finished. Finally herbicides probably always have (small) negative side effects, but it is important to keep in mind that a total coverage with Corallita will kill all other vegetation and is therefore probably much more harmful.

6. Records, monitoring, documentation and check of success

In the previous chapter different control methods were discussed. After performance of a control method it is important to monitor the effect of the treatment to be able to repeat the treatment if necessary. This monitoring has to be done by field survey as discussed in chapter 3. Below a scheme is presented based on Ernst and Ketner (2007) which can be used to monitor the effect of the treatment. Adaptation of this scheme based on the recommended experiments as discussed in the previous chapter is probably needed.

1. Cut down Corallita.
2. Remove tubers or spray when regrowth reached a length of 30 till 40cm (3 or 4 weeks after cutting).
3. In case of spraying check 1 week later if the herbicide is applied in the correct manner. That appears out of yellowing and wilting of the leaves. If not, repeat spraying.
4. Check two months later for regrowth.
    - If that appears repeat step 2 till 4.
    - If that not appears check two month later again etc.
5. When after 12 months still no regrowth has appeared, a spot can considered to be clean.

For the areas with shrubs, herbs and pastures in the Cultuurvlakte it was advised to sow grass, or start agriculture or horticulture. When grass is sown, mowing or intensively grazing by cattle should be continued for several years. In case of grazing it is important to check every two months if no spots with Corallita remain which were not eaten by the cattle. These spots should be mowed and surveyed two months later again.

7. Conclusions and recommendations

The implementation of the proposed methods to control Corallita on St Eustatius has to be divided in two phases.
In **phase 1** Corallita has to be eradicated from the critical spots as described in chapter 3. Moreve inhabitants of St Eustasius have to be stimulated to control the plant in their gardens and private grounds as soon as possible.
In the mean time experiments should be set up to answer the questions concerning the frequency of monitoring (see chapter 3) the type and dosage of the herbicides, mode of action, Corallita growth stage and size and the effect on the environment (see paragraph 5.2). The results of these experiments should be combined with the scheme of chapter 6 to a suitable protocol. Moreover research should be done to make clear which grass species and varieties are the best competitors of Corallita. The optimum mowing frequency and effectivity of grazing needs also to be investigated (see paragraph 5.1).

When the experiments of phase 1 succesfully are finished, **phase 2** can be started. If needed the eradication of Corallita from the critical spots and pivate grounds should be continued.
The areas with shrubs, herbs and pastures in the Cultuurvlakte should be cleaned from all vegetation and the most competitive grass variety have to be sown. Secondly Corallita has to be eradicated, according to the protocol obtained in phase 1, out of the areas were it is not possible to harvest roots including forests, stony land, ruins and along roads and other pavements. Together this is a large area and removing Corallita will be labour-intensive. It is therefore recommended to divide these areas in smaller parts. The size of a part should be determined based on the percentage of coverage with Corallita and availability of money and employees and/or volunteers. When eradication of a part is (almost) finished, eradication of the next part can be started. It is recommended to start with the urban area to create a buffer zone between the highly infected area surround the Quill and the (almost) clean northern part of the Island (see also chapter 2). Concerning the remaining parts surround the Quill it is recommended to first eradicate Corallita from light infected areas, because in that way a fast reduction of the total area wer Corallita is present can be reached. Moreover the damage to underlying vegetation in heavily infected areas as for example in Figure 2 is probably so serious that replanting of native vegetation is unavoidable.

Especially the first removal of Corallita of highly infected areas is very labour-intensive. Unemployment and poverty are serious problems on St Eustatius (Refunjol and Franssen, 2018). Therefore for this task maybe unemployed people can be hired or employed. If limited money is available possibly a team of volunteers from St Eustatius can be created for this taks which only will occur when with a new part is started. Another possibility is to search for people outside of the island.

Besides afformentioned control methods it is important that no new Corallita plants will be introduced on St Eustatius. Moreover the transport of soil containing any roots or tubers on the island should be prevented.

The above mentioned recommendations need to have high priority and to be turned in effective and feasible policy. In our opinion this has been the biggest obstacle for controlling of Corallita on St Eustatius. Despite in several reports usefull recommendations were done (e.g. Berkowitz, 2014; Burg et al., 2012; Ernst and Ketner, 2007) little follow up was made. According to Refunjol and Franssen (2018) this is linked to the bad governance of the government of St Eustasius. Based on their report recently the local government has been dissolved and replaced by a government commissioner of the Minister of internal affairs and kingdom relations of The Netherlands (Knops, 2018a; Knops, 2018b). Despite other troubles on the island this government commissioner could, in collaboration with STENAPA[2], give high priority to Corallita and turn the recommendations in effective and feasible policy.

The above mentioned control methods and recommendations for experiments need high priority. Besides these topics more interessing questions exist. These questions are of lower priority, but might be relevant for (long term) control of Corallita. Below these questioned are briefly mentioned.

- What is the annual growth cycle of Corallita in St Eustatius? And how is this related to the climate? Based on these information the protocol for control of Corallita can be optimized.
- The areas were Corallita is present were roughly based on digital vegetation-, cultivation- and geomorphology maps divided in forest areas, areas with shrubs, herbs and pastures, private grounds, stony lands, ruins and areas along roads and other pavements. More detailed information about these areas would allow more precision mode of action. Which vegetation, cultivation, soil and geomorphology types can be distinguished for regions were Corallita is present.
- The Quill and the Cultuurvlakte consists of a sandy loam soil, while the north west part of the island consists out of stony rough land and loam soils (Koomen et al., 2012). On the north west part of St. Eustatius almost no Corallita was found. This can have a historical cause, but could also be influenced by soil type because Corallita prefers sandy soils (Burke, 2011). What is the relevance of soil type on the dispersal of Corallita on St Eustatius?
- Why is Corallita not a pest in its native region in Mexico?
- What are natural enemies of Corallita?
- Corallita has pink flowers, but also a white-flowered cultivar exists which is commonly not invasive (Burke and DiTommaso, 2011b). Why is the pink-flowered cultivar commonly invasive while the white-flowered is not?
- Burke and DiTommaso (2011a) found genetic differences between Corallita populations on St Eustatius (see also chapter 2). What is the physiological and ecological relevance and the importance for control methods of the genetic differences between the Corallita populations of different sites of the island?

[2] St Eustatius National Parks (STENAPA) is a non governmental, not for profit foundation with a mandate for environmental protection on St Eustatius (STENAPA, 2018).

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Appendix I Distribution map of Corallita on St Eustatius in 2007.

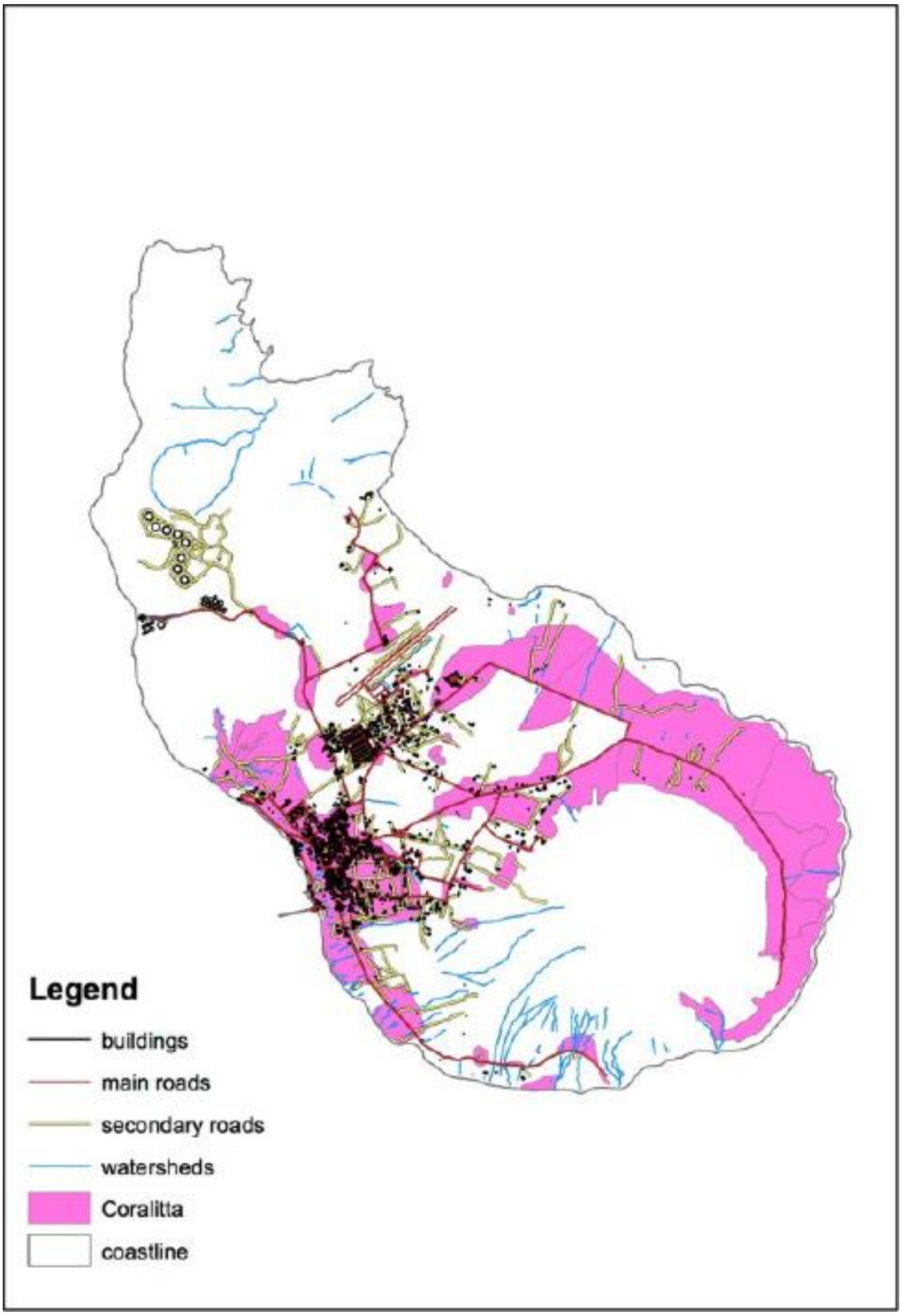

Figure 4. Distibution of Corallita on St Eustatius in 2007 (Ernst and Ketner, 2007)