

**PRA template 3 (accidental introduction of potentially invasive species)**

**Pest Risk Analysis (PRA) for**

Name of organism: *Rhynchophorus ferrugineus* (Red palm weevil)

Territory: Cayman Islands Assessment Number: 002/2020

Date: 20/02/2020 Version: 1

PRA type: accidental introduction

**All sections should be completed. If not applicable indicate it**

**Part 1: Initiation**

**1.1 Summary of assessment results (max. 500 words)**

Give a brief summary of the risks of introduction, establishment, spread, impact and overall risk. Fill this part only in after you have completed all the PRA template.

A lot of research has recently become available on the biology of the Red palm weevil (*Rhynchophorus ferrugineus*), including the prevention of its introduction, containment and control. Some of this work is still ongoing, and a range of suggested control measures still require further trials before they can become more widely available. However, the information already available (including from PRAs that already exist for this species) is sufficient to make informed assessments with high confidence levels for most parts of this PRA. The bullet points below give a summary assessment of the PRA on *R. ferrugineus*:

- The species is highly invasive and has recently expanded beyond its natural range from southern and southeast Asia westwards, over vast areas of the Middle East and the Mediterranean basin.
- It also has become established on the islands of Aruba and Curacao. Although natural direct dispersal from these islands to the Cayman Islands is unlikely, it remains a long-term possibility that the species will use other islands or mainland Central America as stepping stones for further dispersal.
- Currently, the only major and likely pathway of introduction of *R. ferrugineus* is through the import of palm trees with a stem diameter >5cm.
- If the species were to be accidentally introduced to the Cayman Islands, the likelihood of establishment and rapid spread throughout the territory is high. This is mainly based on the wide availability of host plants for its development, combined with a suitable climate throughout the year, and its ability to rapidly self-disperse through flying adult weevils.
- Establishment would lead to highly negative impacts on ornamental palm trees. Many valuable old trees would be lost, and measures for containment and control of the pest, as well as for replacement of lost palm trees, would be costly.
- There is a significant risk that the endemic palm tree *Coccothrinax proctorii* would be threatened with extinction through the impact of *R. ferrugineus*.
- Biosecurity measures currently in place are not adequate to prevent the arrival of *R. ferrugineus* on the Cayman Islands, nor to contain its spread or successfully eradicate a newly established population. Implementing any of the measures outlined in more detail below - with the exception of restricting the trade of ornamental palm trees - would also be costly.
- In our view, the most efficient and least expensive way to effectively prevent the arrival of the Red palm weevil to the Cayman Islands would be to restrict the import of palm trees in any form other than

as seeds or small seedlings (stem diameter <5 cm). These restrictions should at least be applied to countries with records of the Red palm weevil and ideally extended to countries currently free of *R. ferrugineus*.

- This PRA only covers *R. ferrugineus*, but other species of the same genus potentially pose a similar threat to the Cayman Islands. In particular, a follow-on PRA to address risks associated with the closely related *R. palmarum* (South American Palm Weevil) is recommended (see comment at the end of this PRA).

## 1.2 Assessor details

Institution/Department:

Name and Job Title: Norbert Maczey, Vaughn Bodden, Kenisha Palmer, Pablo Gonzalez Moreno, Suzy Wood

Address:

Phone (office and/or mobile):

Email: n.maczey@cabi.org

## Part 2: Background

### 2.1 Aim of assessment

This section is intended to put the new organism(s) in perspective of the wider activities having led to conducting this PRA (e.g. previous horizon scanning, recent alerts or interceptions); all technical/scientific words must be explained

The Red palm weevil, *R. ferrugineus*, along with a closely related species, *R. vulneratus*, is an economically severe pest on palm trees. It originated from Southern and Southeast Asia but has recently spread westwards throughout the Mediterranean area and has recently become established on Aruba. The species has not arrived on the Cayman Islands as yet, but if accidentally introduced could become a threat to both ornamental and native palm species. This PRA looks at the likelihood of arrival, establishment and spread and how significant any negative impact of its introduction could become. The PRA aims to give advice on how the risks of introduction can be minimised and which mitigation measures should be put in place in case the species becomes established.

### 2.2 Identity

Identify the organism as fully as possible

**Scientific name (incl. taxonomic authority, date):** *Rhynchophorus ferrugineus* (Olivier, 1790)

**What is it? (max. 2 sentence description):** A large weevil or snout beetle

**English name(s):** Red palm weevil; Asiatic palm weevil; coconut weevil; red stripe weevil

**Family:** Curculionidae

**Synonyms:** *Curculio ferrugineus* Olivier, 1790; *Cordyle sexmaculatus* Thunberg, 1797; *Calandra ferruginea* Fabricius, 1801; *Rhynchophorus pascha v. papuanus* Kirsch, 1877; *Rhynchophorus indostanus* Chevrolat, 1882; *Rhynchophorus signaticollis* Chevrolat, 1882; *Rhynchophorus pascha v. cinctus* Faust, 1893; *Rhynchophorus ferrugineus v. seminiger* Faust, 1895; *Rhynchophorus signaticollis v. dimidiatus* Faust, 1895

**Other taxonomic remarks:** The taxonomy and classification of red palm weevils has undergone a number of changes in understanding and circumscription. The vast majority of publications presumably do refer to *R. ferrugineus* rather than the closely related *R. vulneratus*, as the former is by far the most widely invasive [https://en.wikipedia.org/wiki/Rhynchophorus\\_ferrugineus](https://en.wikipedia.org/wiki/Rhynchophorus_ferrugineus). Generally, two species of red palm weevil, *R. ferrugineus* and *R. vulneratus* are recognised, although for some time they were also treated as synonyms. Interestingly, the 'red palm weevil' species that appeared in the US was *R.*

*vulneratus* rather than *R. ferrugineus*, though the latter is the invading species in all of the other global introductions [https://en.wikipedia.org/wiki/Rhynchophorus\\_ferrugineus](https://en.wikipedia.org/wiki/Rhynchophorus_ferrugineus).

The genus *Rhynchophorus* contains ten species, of which seven, including *R. ferrugineus* and *R. vulneratus*, are known to attack palms (Booth *et al.*, 1990). A key to related genera and the revision of this species was provided by Wattanapongsiri (1966). Reginald (1973) suggested that *R. ferrugineus* is the typical *Rhynchophorus* species occurring worldwide. It is interesting to note that although the species has been continuously described under the author's name Olivier, some papers, especially those from the subcontinent, also indicate the author as Fabricius (Abraham *et al.*, 1989; Ramachandran, 1991; [www.cabi.org/isc/datasheet/47472](http://www.cabi.org/isc/datasheet/47472)).

### 2.3 Images of the species if available

If available, please provide pictures of different stages and habitats



Figure 1: adult Red palm weevil, source: <https://www.cabi.org/isc/datasheet/47472> (© Alan Roberts)

### 2.4 Existence of PRAs for this species

Please indicate if already PRAs for this species exist and which target areas and climatic conditions these cover (for suggestions of websites to check see guidance notes (e.g. [DoA Australia](#)))

A number of PRAs - publicly available on the internet - already exist for this species. A short PRA conducted by EPPO covers the Mediterranean region, another one China. One important document is a final project report on containment and eradication initiated by the EU. Defra (UK government) has also compiled a concise factsheet containing detailed information on detection and identification. Our PRA is largely based on the results provided in these studies and assessments. Links to individual documents mentioned here are given below.

[https://rnqp.eppo.int/recommendations/summarysheet\\_pest?pest=RHYCFE](https://rnqp.eppo.int/recommendations/summarysheet_pest?pest=RHYCFE)

<https://pra.eppo.int/pra/eee93e99-dedf-4b03-8d0e-71fec77a9dbd>

<https://planthealthportal.defra.gov.uk/assets/factsheets/Rhynchophorus-ferrugineus-Defra-PP-Factsheet-Oct-2016-FINAL3.pdf>

[https://www.researchgate.net/publication/301244029 Establishment and potential risks of a new invasive pest red palm weevil Rhynchophorus ferrugineus in China](https://www.researchgate.net/publication/301244029_Establishment_and_potential_risks_of_a_new_invasive_pest_red_palm_weevil_Rhynchophorus_ferrugineus_in_China)

### 2.4 Biology/Ecology

Please provide background information relevant to your application covering the bullet points in box below whenever applicable; see also guidance notes

- **growth form and size:**

Eggs are creamy white, oblong and shiny. The average size of an egg is 2.6 mm long and 1.1 mm wide (Menon & Pandalai, 1960). Eggs hatch in 3 days and increase in size before hatching (Reginald, 1973). The brown mouth parts of the larvae can be seen through the shell before eclosion. The larvae can grow up to 35 mm long and can be recognised by the brown head and white body. The body is composed of 13

segments. Mouthparts are well developed and strongly chitinized. The average length of fully-grown larvae is 50 mm and the mean width is 20 mm in the middle. When about to pupate, larvae construct an oval-shaped cocoon of fibre (Menon & Pandalai, 1960). The pupal case can range in length from 50-95 mm and in width from 25-40 mm. The prepupal stage lasts for about 3 days and the pupal period varies from 12-20 days. Pupae are first cream coloured but later turn brown. The surface is shiny, but greatly furrowed and reticulated. The average length of pupae is 35 mm and the average width is 15 mm. Adult weevils are reddish brown, about 35 mm long and 10 mm wide and are characterized by a long-curved rostrum (snout). Dark spots are visible on the upper side of the middle part of the body. The head and rostrum comprise about one-third of the total length. In the male, the dorsal apical half of the snout is covered by a patch of short brownish hairs, the snout is bare in the female, more slender, curved and a little longer than the male (Menon & Pandalai, 1960). Sacchetti *et al.* (2006) provides a description of the different stages of development of the weevil and a simplified key for the identification of *R. ferrugineus* and *R. palmarum* (source: <https://www.cabi.org/isc/datasheet/47472>).

- **habitat:** Generally, the species is highly associated with the occurrence of its host plants, where it attacks the flowering stage, fruiting stage, and vegetative growing stage (see also <https://www.cabi.org/isc/datasheet/47472>).
- **lifecycle (e.g. reproduction and dispersal):** The biological aspects of *R. ferrugineus* have recently been studied by Justin *et al.* (2008), Abe *et al.* (2009), Prabhu *et al.* (2009), Salama *et al.* (2009) and Wang *et al.* (2009). Mating takes place at any time of the day, and males and females mate many times during their lifetime. The pre-oviposition period can range from 1-7 days. Oviposition is generally confined to the softer portions of the palm and continues for approximately 45 days. During this period, the weevil lays an average 204 eggs; the maximum number of eggs laid by a single female in captivity is 355 in 42 days and the minimum is 76 in 26 days (Menon & Pandalai, 1960). There is a short post-oviposition period of 10 days before the weevil dies. The female weevil lays its eggs in wounds along the trunk or in petioles, and also in wounds caused by the rhinoceros beetle, *Oryctes rhinoceros*. On hatching, the apodal larvae begin feeding towards the interior of the palm. In palms up to 5 years old the larvae may be found in the bole, stem or in the stem about 2-3 feet below the crown. As palms advance in age, the grubs are generally confined to the portions of the stem close to the growing point. In palms more than 15 years old, the larvae are generally found crown, in the crown and bases of leaf petioles. The larval period ranges from 36-78 days (average 55 days) (Nirula *et al.*, 1953). Jaya *et al.* (2000) recorded seven larval instars when *R. ferrugineus* was reared on sugarcane. When about to pupate, larvae construct an oval-shaped cocoon of fibre (Menon & Pandalai, 1960). The complete life cycle of the weevil, from egg to adult emergence, takes an average 82 days in India (Menon & Pandalai, 1960). After emergence from the pupal case the adult weevil remains inside the cocoon for 4-17 days (average 8 days) (Menon & Pandalai, 1960). According to Hutson (1933), the weevil becomes sexually mature during this period of inactivity. Weevils are active during day and night, although flight and crawling of weevils are generally restricted to the day time. Leefmans (1920) reported that weevils are capable of long flights and can find their host plants in widely distant areas; his studies suggested that weevils can detect breeding sites at distances of at least 900 m. Although Copeland (1931) suggested that the adult weevil does not feed on palms but visited them for oviposition only, it has been reported that the weevil definitely feeds and cannot live without food for more than 1 week. The longevity of the weevil ranges from 2-3 months, irrespective of the sex. In captivity, the maximum life span of the adult was 76 days for the female and 113 days for the male. It has been suggested that a single pair of weevils can theoretically give rise to more than 53 million progeny in four generations in the absence of controlling factors (Menon & Pandalai, 1960; Leefmans, 1920). In Egypt, El Ezaby (1997a) reported that the weevil has three generations per year, the shortest generation (first) of 100.5 days and the longest (third) of 127.8 days. The study also showed that the fatal (threshold) temperature of the egg was 40°C (source: <https://www.cabi.org/isc/datasheet/47472>).
- **hosts:** *Agave americana* (century plant), *Areca catechu* (betelnut palm), *Arenga pinnata* (sugar palm), *Borassus flabellifer* (toddy palm), *Brahea armata*, *Brahea edulis*, *Butia capitata*, *Calamus merrillii*, *Caryota cumingii*, *Caryota maxima*, *Caryota urens* (fishtail palm), *Chamaerops humilis* (dwarf fan palm), *Cocos nucifera* (coconut), *Corypha umbraculifera*, *Corypha utan* (gebang palm), *Elaeis guineensis* (African oil palm), *Howea forsteriana* (paradise palm), *Jubaea chilensis*, *Livistona chinensis* (Chinese fan palm),

*Livistona decora*, *Metroxylon sagu* (sago palm), *Phoenix canariensis* (Canary Island date palm), *Phoenix dactylifera* (date-palm), *Phoenix sylvestris* (east Indian wine palm), *Roystonea regia* (cuban royal palm), *Sabal* (palmetto-palm), *Sabal palmetto* (Cabbage palmetto), *Saccharum officinarum* (sugarcane), *Trachycarpus fortunei* (chinese windmill palm), *Washingtonia filifera* (desert fanpalm), *Washingtonia robusta* (mexican washington-palm) (source: <https://www.cabi.org/isc/datasheet/47472>).

- **host specificity:** There are some records from outside the Palm family (Arecaceae): *Agave americana* and *Saccharum officinarum* (sugarcane). Some non-palm ornamentals have also been reported to be attacked by the weevil (Menon & Pandalai, 1960). However, these don't seem to be main hosts of this species and it remains unclear if the weevil can fully develop inside them. With the exception of rattan (*Calamus merillii*) reported in the Philippines (Braza, 1988), *R. ferrugineus* is essentially a pest of palms. (source: <https://www.cabi.org/isc/datasheet/47472>).
- **associated pathogens, pests or parasites:** see below under biological control
- **other:** It is very difficult to detect *R. ferrugineus* in the early stages of infestation. Generally, it is detected only after the palm has been severely damaged. Careful observation may reveal the following signs which are indicative of the presence of the pest (Coconut Research Institute, 1987): Some holes in the crown or trunk from which chewed-up fibres are ejected. This may be accompanied by the oozing of brown viscous liquid. Another sign is a withered bud/crown. A crunching noise produced by the feeding grubs can be heard when the ear is placed to the trunk of the palm (source: <https://www.cabi.org/isc/datasheet/47472>).

## 2.5 What is the current distribution of the species

**Consider:** native range, history of introduction and invasion outside native range

According to Booth *et al.* (1990) *R. ferrugineus* occurs from Pakistan eastwards to Taiwan and the Philippines. It is now also found in Saudi Arabia and the United Arab Emirates. A specimen of *R. ferrugineus* was captured in a trap in Palestine. Flach (1983) reported that *R. ferrugineus* occurs together with *R. vulneratus* in the Philippines, but it is the exclusive species in India and Sri Lanka. Hartley (1977) reported the occurrence of *Rhynchophorus* in African oil palms but did not indicate the species. A record of *R. ferrugineus* in Queensland, Australia (CABI/EPPO, 2010; EPPO, 2014) published in previous versions of the Invasive Species Compendium (ISC) is invalid. Records of *R. ferrugineus* from Indonesia, Sabah and Sarawak (Malaysia), Singapore and Papua New Guinea published in previous versions of the ISC are now thought likely to be of *R. vulneratus* or *R. bilineatus* (CABI/EPPO, 2016). There is no evidence that records from Samoa, Solomon Islands and Vanuatu (EPPO, 2014) published in previous versions of the ISC are of *R. ferrugineus* (CABI/EPPO, 2016) (source: <https://www.cabi.org/isc/datasheet/47472>).

The species has become widespread in many southern European and North African countries. Records from America are so far restricted to Aruba (present, localized) and Curaçao (present) (source: <https://www.cabi.org/isc/datasheet/47472>). It was reported in the United States at Laguna Beach, CA late in 2010, but this was a misidentification of the closely related species, *R. vulneratus*, and this species did not become established ([https://en.wikipedia.org/wiki/Rhynchophorus\\_ferrugineus](https://en.wikipedia.org/wiki/Rhynchophorus_ferrugineus)).

## Part 3: Risk of accidental introduction, establishment and spread

### 3.1 Probability of entry introduction

3.1.1 Has the species been introduced into other countries and/or have multiple introductions been reported Please, check existing interception data in the territory

The species has been introduced to a number of countries within a short span of time, and it spread particularly rapidly throughout the Mediterranean. More worryingly for any British territory in the Caribbean is the fact that it has recently become established on Aruba and Curacao. However, so far, no positive interceptions have occurred during the current monitoring programme on Cayman.

It could be suggested that, since the weevil is present in almost all the major coconut-growing countries in the tropics, it does not pose any phytosanitary risk to these countries. However, information is not available on its quarantine status in the countries in which it is absent (source: <https://www.cabi.org/isc/datasheet/47472>).

### 3.1.2 What are the likely pathways for the accidental introduction of the species?

Consider whether the species or some of its life-stages can easily be overlooked?

Shipment of infested plants for planting of ornamental palm trees seem to be the main pathway (except plants in vitro) (EPPO PRA: <https://gd.eppo.int/taxon/RHYCFE/documents>). The early stages of a red palm weevil infestation are difficult to detect because the larvae feed within the plant; the plant does not show signs of damage during early infestation attack (EPPO 2008 in [https://www.ippc.int/static/media/uploads/resources/new\\_pest\\_response\\_guidelines\\_red\\_palm\\_weevil.pdf](https://www.ippc.int/static/media/uploads/resources/new_pest_response_guidelines_red_palm_weevil.pdf)). Esteban-Duran *et al.* (1998) suggested that *R. ferrugineus* is among the pests that could potentially be introduced to Spain and other countries of the European Union through imported vegetables (<https://www.cabi.org/isc/datasheet/47472>).

The importation of palm frond greenery as cut flowers is an unlikely pathway for the movement and entry of red palm weevil. Eggs may be deposited in the proximal end of the frond where young larvae feed before moving into the main part of the palm (Faleiro 2006; Salama *et al.* 2009). However, young *R. ferrugineus* in cut fronds are unlikely to be able to complete development before the frond dries to an unsuitable level, and are also unlikely to move to find a suitable host due to their limited mobility ([https://www.ippc.int/static/media/uploads/resources/new\\_pest\\_response\\_guidelines\\_red\\_palm\\_weevil.pdf](https://www.ippc.int/static/media/uploads/resources/new_pest_response_guidelines_red_palm_weevil.pdf)).

There don't seem to be any proven cases where the species has been able to invade as a stowaway not associated with palm trees. However, there have been five interceptions of unidentified *Rhynchophorus* spp. from baggage and cargo at US ports (PestID, 2009). Two were from Mexico, one from North Africa, one from Congo, and one from Ecuador. These very few interceptions indicate that the weevils in this genus may move in a limited manner as a hitchhiker ([https://www.ippc.int/static/media/uploads/resources/new\\_pest\\_response\\_guidelines\\_red\\_palm\\_weevil.pdf](https://www.ippc.int/static/media/uploads/resources/new_pest_response_guidelines_red_palm_weevil.pdf)).

The weevil can be spread over long distances in infested plants for planting of host palms (date palms, coconut and areca palms and many other palm species). However, the pest cannot complete its life cycle in palms with trunks/stipes less than 5 cm wide; these are very common in trade, and they are not considered to be an important pathway. On palms with trunks above this diameter (>5 cm) the life-cycle can be completed; these are usually shipped as bare-rooted plants with limited growing medium attached or potted plants in various sizes for ornamental purposes (source: [https://rnqp.eppo.int/recommendations/summarysheet\\_pest?pest=RHYCFE](https://rnqp.eppo.int/recommendations/summarysheet_pest?pest=RHYCFE)).

Experts concluded that there is considerable uncertainty about the relative importance of plants for planting as a pathway compared to local spread ([https://rnqp.eppo.int/recommendations/summarysheet\\_pest?pest=RHYCFE](https://rnqp.eppo.int/recommendations/summarysheet_pest?pest=RHYCFE)).

However, this is probably not true for small islands, where the risk of invasion through natural spread from other territories is considerably lower.

For the USA, natural spread of the red palm weevil into the continental United States is considered unlikely. The closest populations of this pest to this country are in Aruba and the Netherlands Antilles, which would require a flight of over 1,100 miles. While red palm weevil flights of greater than 900 miles have been reported (EPPO 2008), the weevil would need to first establish in a closer location such as Central America, and continue multiple flights northward through Mexico and eventually into the United States. ([https://www.ippc.int/static/media/uploads/resources/new\\_pest\\_response\\_guidelines\\_red\\_palm\\_weevil.pdf](https://www.ippc.int/static/media/uploads/resources/new_pest_response_guidelines_red_palm_weevil.pdf)). Considering that the nearest population of the pest is still 1,400 km away from the Cayman Islands in Aruba, the likelihood of arrival through natural spread in the next few years is probably very low. However, long-term natural spread still remains a possibility through island hopping, particularly if any other island nearer to the Cayman Islands, whether through natural spread or accidental introduction, becomes invaded. The red palm weevil was probably brought into the Caribbean region with large *Phoenix* spp. date palms (>5 m tall) imported from Egypt. Due to the lack of phytosanitary regulations, similar *Phoenix* palms continue to enter Curacao for use, primarily in housing developments and hotel landscaping. The pest was probably

imported into Aruba from infested nursery stock obtained from Curacao. As in Curacao, Aruba does not have phytosanitary regulations in place to prohibit the importation of infested plant material nor regulatory measures to prevent movement within the country (Roda *et al.*, 2011).

Transport of seeds seems to be low risk, and countries like the USA and Australia continue to allow the import of seeds

([https://www.aphis.usda.gov/import\\_export/plants/plant\\_imports/federal\\_order/downloads/2010/Palm%20Pests\\_1-25-10.pdf](https://www.aphis.usda.gov/import_export/plants/plant_imports/federal_order/downloads/2010/Palm%20Pests_1-25-10.pdf); <https://www.agriculture.gov.au/biosecurity/legislation/permitted-arecaceae>).

### 3.1.3 What is the probability of the pest being associated with the pathway(s) at origin?

Please give any information available about: prevalence of pest in the source area; occurrence of life stage able to associate with consignment; volume and frequency of movement along the pathway; seasonal timing; pest management procedures applied at place of origin; for definition of probability see guidance notes 3.1.

There is no trading of live plants from Aruba or Curacao to the Cayman Islands, currently the Cayman Islands only import palms from the USA.

### 3.1.4 What is the probability of the pest surviving during transport?

**Consider:** speed and conditions of transport; duration and vulnerability of life cycle; previous interceptions of the pest; prevalence of pest; commercial procedures during transport (e.g. refrigeration)

According to a recent PRA for China the survival rate of the pest in transportation is regarded as high. Here it is estimated to be more than 40% during transportation, but no references about timing and/or distance are provided (<https://asplantprotection.org/wp-content/uploads/2018/07/122-130.pdf>).

### 3.1.5 What is the probability of the pest evading existing biosecurity procedures? **Consider:**

inspection methods and quality control; certification schemes; chemical treatment

It is difficult to identify the early stages of infection (<https://asplantprotection.org/wp-content/uploads/2018/07/122-130.pdf>). While *R. ferrugineus* is a relatively large insect, usually >25 mm (~1 in) long, as stem borer its larval stages are concealed and difficult to detect. The female lays eggs in wounds or soft tissue of the plant and after hatching the larvae burrow into the stem, creating large galleries that eventually weaken and destabilize the tree. The damage caused by the larvae is only visible long after infestation, and by the time the first symptoms of the attack appear, they are so serious that they generally result in the death of the tree

([https://www.aphis.usda.gov/import\\_export/plants/plant\\_imports/federal\\_order/downloads/2010/Palm%20Pests\\_1-25-10.pdf](https://www.aphis.usda.gov/import_export/plants/plant_imports/federal_order/downloads/2010/Palm%20Pests_1-25-10.pdf)).

### 3.1.6 What is the probability of transfer from entry point to a suitable host or habitat?

**Consider:** dispersal mechanisms, including vectors; number of destinations; proximity to suitable hosts; seasonality

Self-dispersal within the environment is through adult flight, and the pest can find its host plants in widely separated areas. Studies suggested that they can detect breeding sites (cut tissue, wounds etc.) at distances of at least 900 m (EPPO, 1997). Marked beetles were found five days after release up to 7 km away from the place where they were released (EU, 2011). The complete life cycle from egg to adult emergence, takes an average of 82 days in India and adults live 2-3 months, with up to three generations a year possible (EPPO, 1997) ([https://rnqp.eppo.int/recommendations/summarysheet\\_pest?pest=RHYCFE](https://rnqp.eppo.int/recommendations/summarysheet_pest?pest=RHYCFE)).

In the case of the Cayman Islands the probability of transfer to a suitable host needs to be considered high for adult beetles hatching from untreated imported palm trees. Suitable climatic condition allowing adult beetles to be active all year round, and the self-dispersal capacity of the *R. ferrugineus* is high enough to reach any part of the territory including the smaller islands through the dispersal flight of a single individual. There are ornamental and native palms across all three islands. The weevil is more likely to be imported into Grand Cayman, natural dispersal to the smaller isles, Little Cayman and Cayman Brac, would have to occur across 96 km of ocean. Human-mediated dispersal from imports into Grand Cayman and then onto the Little Cayman or Cayman Brac is therefore more likely than natural dispersal.

## Summary probability of accidental introduction

|  |   |  |   |                                 |                                      |
|--|---|--|---|---------------------------------|--------------------------------------|
| Probability of introduction in next 10 years | Very unlikely <input type="checkbox"/>              | Unlikely <input type="checkbox"/>          | Moderately likely <input checked="" type="checkbox"/> | Likely <input type="checkbox"/> | Very likely <input type="checkbox"/> |
| Confidence                                   | High confidence <input checked="" type="checkbox"/> | Medium confidence <input type="checkbox"/> | Low confidence <input type="checkbox"/>               |                                 |                                      |

### 3.2 Probability of establishment

3.2.1 Does the territory provide suitable climatic and habitat conditions for the species to **survive and reproduce** under natural conditions unassisted or without human interference (e.g.

**cultivation, gardens)? Consider:** climate similarity between the species global range and the PRA area, availability of the habitat conditions required by the species based on its behaviour elsewhere; identify/name specifically the climate/habitat it might survive? Which land-cover? Justify why and provide landmarks as examples; for definition of human interference see guidance notes 3.2.1

- **Survival:** *R. ferrugineus* is likely to survive all year round in all parts of the Cayman Islands where palms grow, both in ornamental plantings and in any natural habitats. The endemic *Coccoloba* has an island wide distribution on Grand Cayman and ornamental palms are common.
- **Reproduction (self-sustaining population):** The life cycle of *R. ferrugineus* ranges from 45-139 days, depending on the climate, which allows for several generations in a year ([https://www.aphis.usda.gov/import\\_export/plants/plant\\_imports/federal\\_order/downloads/2010/Palm%20Pests\\_1-25-10.pdf](https://www.aphis.usda.gov/import_export/plants/plant_imports/federal_order/downloads/2010/Palm%20Pests_1-25-10.pdf)). Recently, *R. ferrugineus* has spread over a wide geographical area in a very short time period, indicating a high ability to reproduce under a relatively wide range of climatic conditions.

3.2.2 How likely can the species survive and reproduce indoors or similar habitats (e.g.

polytunnels, gardens, urban area)? **Consider:** availability of the habitat conditions required by the species based on its behaviour elsewhere; identify/name specifically the conditions it might survive?

- **Survival:** n.a.
- **Reproduction (self-sustaining population):** n.a.

3.2.3 **(only for pests and diseases)** If hosts or vectors are required, are these available in the PRA

**area? Consider:** abundance of hosts and alternate hosts or vectors and how these are distributed in the PRA area; geographic proximity of hosts to pathway destinations; presence of other suitable species that could be new hosts; compare the known distribution of the pest with ecoclimatic zones in the PRA area; soil factors for soilborne pests; survival strategies; survival in protected cultivation

Any ornamental palm trees, naturalised stands of introduced palms, or stands of native and/or endemic palms are at risk of being infected by the Red palm weevil. If rapid response measures are applied to ornamental palms where infection has been detected at an early stage, the spread of the weevil can possibly be contained. Even then, smaller naturalised tree stands may provide a reservoir for continued spread throughout the Cayman Islands. The endemic *Coccoloba* palm is abundant throughout all three islands mainly in coastal shrubland and dry shrubland habitats. Palms are a common ornamental plant across Grand Cayman – less so in Cayman Brac and Little Cayman but still present. There are naturalised stands of a few palm species on Grand Cayman, particularly coconut tree stands. None or very few naturalised stands exist on the two smaller islands but coconut trees occur on the coast of both.

#### Summary probability of establishment

|  |   |  |  |                                 |   |
|--|---|--|--|---------------------------------|---|
| Probability of establishment in the wild | Very unlikely <input type="checkbox"/>              | Unlikely <input type="checkbox"/>          | Moderately likely <input type="checkbox"/> | Likely <input type="checkbox"/> | Very likely <input checked="" type="checkbox"/> |
| Confidence                               | High confidence <input checked="" type="checkbox"/> | Medium confidence <input type="checkbox"/> | Low confidence <input type="checkbox"/>    |                                 |   |



### 3.3 Probability of spread

3.3.1 What is the potential spread in the territory? **Consider:** rate and distance of spread elsewhere; natural barriers in PRA area, the occurrence of a dispersal vector or commodity; see also guidance notes 3.3.1

- **self-dispersal:** Adult red palm weevils have a high dispersal capability. Assessments during a European research project showed that flight was very variable between individuals and age was strongly correlated to frequency of flight, which occurred from 2-97 days of age, with 96% of flights being undertaken by 13-19 day old adults. Weevils aged up to 2 months could cover a distance of 10 km within a single flight, and 20% of weevils were still able to perform long flights after 2 months of age. Overall, 41% of flying individuals were able to cover a mean distance of 5 to 10 km per flight. One individual flew 48 km in a single flight and one covered a distance of 250 km during its life. Mated males performed more flights and flew longer distances than virgin ones, which together with a longer life than females, make them an overlooked risk as they can signal palms to other weevils by the pheromone they emit (<https://cordis.europa.eu/project/id/289566/reporting>).
- Dispersing adults can find their host plants in widely separated areas. Studies suggested that they can detect breeding sites (cut tissue, wounds etc.) at distances of at least 900 m (EPPO, 1997). Marked beetles were found five days after release up to 7 km away from the place where they were released (EU, 2011). The complete life cycle from egg to adult emergence, takes an average of 82 days in India and adults live 2-3 months, with up to three generations a year possible (EPPO, 1997) ([https://rnqp.eppo.int/recommendations/summarysheet\\_pest?pest=RHYCFE](https://rnqp.eppo.int/recommendations/summarysheet_pest?pest=RHYCFE)).
- **direct transport by humans:** unlikely direct transport, but picking up and movement of a large attractive beetles can't be excluded; mostly through active transport of palm trees
  - **transport via vehicles (e.g. boat, cars, including tyres):** unlikely
  - **wind drift or via driftwood:** possible (wind drift), but probably less important than active dispersal flights (heavy insects)
  - **water:** very unlikely
  - **transport via animals (e.g. berries digested by birds, seeds stuck to wool, etc.):** unlikely
  - **transport with vectors:** not applicable
  - **other:** none at this stage
  - **how rapidly would the organism spread by natural means?:** Within a year spread throughout the territory is feasible

#### Summary probability of spread

|  |   |  |  |   |  |
|--|---|--|--|---|--|
| How quickly can the species spread (excluding deliberately assisted by humans) | Less than 10 m/year. Can't occupy suitable habitats within next 100 years<br>Very slowly <input type="checkbox"/> | Between 10 and 100 m per year. Suitable habitats are likely to be occupied between 50 and 100 years<br>Slowly <input type="checkbox"/> | Between 100 and 500 m per year. Suitable habitats are likely to be occupied between 50 and 100 years<br>Moderate pace <input type="checkbox"/> | > 500 m per year Can occupy suitable habits throughout the territory within 5 to 20 years<br>Quickly <input type="checkbox"/> | Can occupy suitable habits throughout the territory within 5 years<br>Very quickly <input checked="" type="checkbox"/> |
| Confidence   | High confidence <input checked="" type="checkbox"/>   | Medium confidence <input type="checkbox"/>   | Low confidence <input type="checkbox"/>  |   |  |

## Part 4: Economic and environmental risks

It is important to look at the potential magnitude of the consequences, and to look at distribution effects (who bears risks). Consider potential maximum impact.

Please, **complete this section referencing supporting material**. Please, cite the material in the text and provide a description of where the information in the application has been sourced in the list of references (e.g. from in-house research, independent research, technical literature, community or other consultation, and provide that information with this application). If the information available is scarce, include information about related species (e.g. same genus or family) clearly indicating that it does not correspond to the organism being assessed.

#### 4.1 Risks recorded from outside the territory, which are applicable to the territory

4.1.1 Is the species listed in the following Plant Protection organizations and Invasive lists and if so, what is its status?

##### America

**COSAVE:** yes/☐ A short PRA for Paraguay from 2007 is issued on the COSAVE website

**NAPPO:** yes/☐ APHIS has issued a detailed PRA for the species:

[https://www.aphis.usda.gov/import\\_export/plants/plant\\_imports/federal\\_order/downloads/2010/Palm%20Pests\\_1-25-10.pdf](https://www.aphis.usda.gov/import_export/plants/plant_imports/federal_order/downloads/2010/Palm%20Pests_1-25-10.pdf)

**OIRSA** yes/no

##### Europe

**EPPQ:** yes/☐ listed in plant import guidelines:

[https://www.eppo.int/media/uploaded\\_images/RESOURCES/eppo\\_publications/td\\_1061\\_plants\\_for\\_planti ng.pdf](https://www.eppo.int/media/uploaded_images/RESOURCES/eppo_publications/td_1061_plants_for_planti ng.pdf); and on quarantine alert list: [https://www.eppo.int/ACTIVITIES/plant\\_quarantine/alert\\_list](https://www.eppo.int/ACTIVITIES/plant_quarantine/alert_list)

**EC Plant Health Directive** (Council Directive 2000/29/EC): yes/no

##### Africa

**ARC:** yes/no (page currently not running fully)

##### Others:

**CABI CPC** yes/☐ full datasheet

**CABI ISC** yes/☐ full datasheet

**GISD** yes/no

**PIER:** not listed

**Other information relevant for the territory (e.g. regional, national...)**

4.1.2 Is there any negative impact of the species on the economy, environment or public health recorded from any parts of its current distribution? Please provide a summary of the available information

The impact of *R. ferrugineus* is a worldwide problem and the economic impact of *R. ferrugineus* to palms around the world is devastating. The impact on the economy in invaded countries in particular is regarded as very high. Not only does it result in a need to replace ornamental palm trees, but the impact on production of dates and coconuts is regarded as very high. In addition, the impact on cultural values, specifically in Saudi Arabia where date palms are of high cultural value, is equally high (<https://cordis.europa.eu/project/id/289566/reporting>).

Approximately 30% of the world's date production comes from the Gulf region of the Middle-East. Recent statistics shows that red palm weevil infestation may cause severe economic losses ranging between 1 and 5%, accounting for 5.18 to 25.92 million USD, respectively, with indirect losses increasing this figure several fold. The estimated cost saving of the curative treatment of palms in the early stage of attack is USD 20 to 104 million for 1 and 5% infestation levels, respectively (El-Sabea *et al.*, 2009). Menon & Pandalai (1960) suggested that *R. ferrugineus* is a serious pest of coconut palms in India and Sri Lanka. Ganapathy *et al.* (1992) observed *R. ferrugineus* damage in 34% of coconut groves in Cochin, India. Dhileepan (1991) reported that the weevil is a major pest of oil palms in Kerala. Flach (1983) suggested that *R. ferrugineus* along with *R. vulneratus* are major pests of the sago palm in Sarawak. A relatively recent record of *R. ferrugineus* in India as a pest on oil palm (Misra, 1998) poses serious implications to some countries in South-East Asia (e.g. Malaysia, Indonesia) where oil palm is a major economic crop. In most European countries, the target of red palm weevil infestation is mainly the ornamental palms ruining the aesthetic beauty of parks and roads. Overall, red palm weevil damage to any type of palm accounts for losses of millions of dollars. Although there are no specific studies on the economic impact of the problems due to *R. ferrugineus* on coconut and sago palms for a long time, estimates place annual losses due to these invasive species in the multi-billion Euro range. The direct costs include the value of the destroyed trees and their potential (date) crops, the cost of trapping and other quarantine methods, and the huge budgets allocated to the various chemical treatments. The indirect costs are also substantial. The most significant of these is the restricted movement of trees, resulting in drastic cuts in trading not only among countries but also between different regions of the same country (<https://cordis.europa.eu/project/id/289566/reporting>).

It is thought that the effects of this pest and the measures required to eradicate and control them are having significant, and potentially devastating, impacts on the palm tree populations and landscape in the Mediterranean basin. The numerous nurseries throughout the Mediterranean basin that supply exotic palms are of great economic value. In Spain alone, over 50,000 palm trees have been destroyed in the fight against the red palm weevil between 1996-2010 and > 90% of these occurred between 2005 and 2010. However, the eradication and control of *R. ferrugineus*, especially over large areas, is hampered by the huge costs required and budget limitations, which are compounded by the difficulties in the eradication on private properties, resulting in re-infestation of 'cleaned' areas (<https://cordis.europa.eu/project/id/289566/reporting>).

For the USA palm trees are of huge economic importance. In 2007, the gross sales for palms from nurseries in the USA were 203 million USD, predominantly in Florida and in California (<https://cordis.europa.eu/project/id/289566/reporting>).

Little information is available about the environmental impact of *R. ferrugineus* within its introduced range and in particular on populations of native and endemic palm species. There is, however, great concern that the palms, *Phoenix canariensis* and *P. theophrasti* native to the Canary Islands and Crete respectively, as well as palm groves such as those of Elche in Spain, a UNESCO World heritage site, will eventually succumb to infestations of these pests (<https://cordis.europa.eu/project/id/289566/reporting>).

## 4.2 Economic and socioeconomic effects

4.2.1 Could the species have any negative effect on economic activities in the territory? Please include any information about specific assessments from areas outside the PRA area including experiences with closely related species with relevance for the area of interest (**consider:** reduction in crop yield or quality; reduction in prices or demand, including export markets; increase in production costs (including costs of control); vectoring of other pests of economic importance; extent of phytosanitary regulations imposed by importing countries)

- agriculture: There is no large-scale productions but one or two small companies harvest coconuts to sell products in grand Cayman and these could be heavily impacted on after the introduction of the Red Palm Weevil. **Even though there are no large established farms, there are a few small farms and a Coconut palm is almost in every backyard. The Beacon of Hope Foundation has imported a machine to produce local coconut oil. Sugar cane is also a secondary host, if established in Sugar canes will affect backyard growers and juice vendor.**
- livestock: n.a.
- fisheries: n.a.
- aquaculture: n.a.
- forestry: n.a.
- tourism: **The aesthetics of dying palm trees and an overall loss of palm trees may impact negatively on tourism.** It is recognised that palms provide significant cultural services, e.g. in the form of palms in urban environments, lining streets and town squares, in public parks and private gardens, and other popular tourist areas, which would be costly to replace. Placing an economic value on such services is very challenging for economists (<https://cordis.europa.eu/project/id/289566/reporting>). Loss of palm trees would also affect the Annual Coco Fest
- recreational potential: Similar to tourism, usage of recreational areas on the Cayman Islands by residents may change. Palms in some ways provide shaded areas and their loss would especially affect the beach areas, parks and backyard hammocks where the tourist and local relax in shade.
- infrastructure: n.a.
- employment rates: There will be the risk that the few commercial importers of palm trees on the Cayman Islands could lose their business in order to prevent the introduction of the Red palm weevil. Equally, there are two plant nurseries that produce only palms. The introduction of the Red Palm Weevil would risk the loss of their employees.
- other: Costs for eradication and containment measures; costs for replanting palm trees; old specimen trees themselves have a high monetary value, in particular if they impact on the value of the property they are standing on, or are part of the view from other properties.

4.2.2 Are there any risks of impacts on cultural valuable species, habitats, landscapes, practices or other values? Please include any information about specific assessments from areas outside the PRA area including experiences with closely related species with relevance for the area of interest

- competition with or impact on cultural valuable species: For Europe it is recognised that palms provide significant cultural services, e.g. in the form of palms in urban environments, lining streets and town squares, in public parks, heritage palm groves and private gardens (<https://cordis.europa.eu/project/id/289566/reporting> . The same can be assumed for the Cayman Islands. Of course, placing an economic value on such services is challenging.
- impact on historically valuable practices: Yes, the endemic *Coccothrinax* or the silver thatch palm is used in traditional basket, hat, rope, etc. making. The species is also the national tree of the Cayman Islands.
- change of landscape: In an environment where the landscape is heavily dominated by palm trees such as that of the Cayman Islands, the potential loss of these trees will undoubtedly lead to a significant change in the landscape in parts of the territory. Palms are in particular a dominant feature of dry shrubland habitats
- value of landscape for recreation: Similar to the above, the loss of palm trees in some parts of the territory will result in a diminished value for recreation (changed landscape, loss of shade).
- other: *Coccothrinax proctorii*, the Cayman thatch palm or Silver Thatch Palm is endemic to the Cayman Islands and is currently not listed as a primary host of the red Palm Weevil. If the pest impacts heavily on this endemic palm species this could affect the local culture as well.

### Summary economic and socioeconomic impacts

Make sure the summary score is well linked with the information reported above so the scoring is fully justified (for more information risk levels see guidance notes)

|                              |   |  |   |   |                                     |
|------------------------------|---|--|---|---|-------------------------------------|
| Risk of socioeconomic impact | Very small <input type="checkbox"/>                 | Small <input type="checkbox"/>             | Medium <input type="checkbox"/>         | Large <input checked="" type="checkbox"/> | Very large <input type="checkbox"/> |
| Confidence                   | High confidence <input checked="" type="checkbox"/> | Medium confidence <input type="checkbox"/> | Low confidence <input type="checkbox"/> |   |                                     |

### 4.3 Impact on public health

4.3.1 Could there be any impact on public health? **Consider:** Can the species be disease-causing or be a parasite, or be a vector or reservoir for human diseases?

There is a low risk of increased exposure to harmful chemicals if the use of pesticides to control *R. ferrugineus* increases. Infested trees would have to be cut down, shredded/chipped or burnt. Additional exposure to dust or smoke if the incinerator is not operational.

### Summary public health impact

|                                 |  |   |   |                                |                                     |
|---------------------------------|--|---|---|--------------------------------|-------------------------------------|
| Risk of impact on public health | Very small <input type="checkbox"/>      | Small <input checked="" type="checkbox"/>             | Medium <input type="checkbox"/>         | Large <input type="checkbox"/> | Very large <input type="checkbox"/> |
| Confidence                      | High confidence <input type="checkbox"/> | Medium confidence <input checked="" type="checkbox"/> | Low confidence <input type="checkbox"/> |                                |                                     |

### 4.4 Impact on animal health

Could there be any impact on animal health? **Consider:** Can the species be disease-causing or be a parasite, or be a vector or reservoir for animals?

None at this stage

### Summary animal health impact

|                                 |   |  |   |                                |                                     |
|---------------------------------|---|--|---|--------------------------------|-------------------------------------|
| Risk of impact on animal health | Very small <input checked="" type="checkbox"/>      | Small <input type="checkbox"/>             | Medium <input type="checkbox"/>         | Large <input type="checkbox"/> | Very large <input type="checkbox"/> |
| Confidence                      | High confidence <input checked="" type="checkbox"/> | Medium confidence <input type="checkbox"/> | Low confidence <input type="checkbox"/> |                                |                                     |

#### 4.5. Environmental and ecosystem effects

4.5.1 Are there any threats to native or endemic species? Indicate direct effects on native species; note any aspects related to pollination of native species should be covered in the following question (**consider**: threat to endangered species; impact on keystone species; changed community structure; hybridization with native species)

The online checklist of plants for the Cayman Islands ([http://www.caymanflora.org/QEIf flora/ge\\_list/genus lt.html](http://www.caymanflora.org/QEIf flora/ge_list/genus lt.html)) lists the following species belonging to the palm family (Arecaceae): *Coccothrinax proctorii* (endemic), *Cocos nucifera* (naturalised), *Phoenix dactylifera* (introduced), *Roystonea regia* (native), and *Thrinax radiata* (native)

The introduction of *R. ferrugineus* would pose a significant risk for the survival of *Coccothrinax proctorii*, a palm species endemic to the Cayman Islands. *Thrinax radiata* and *Roystonea regia* are both native and likely to be negatively impacted by the introduction of the red palm weevil. *Cocos nucifera* is not native but can be considered as 'naturalised' and have become a common feature of coastal habitats.

There is also the possibility that the loss, in particular of old trees, could impact on native and endemic plants and animals relying on introduced palms as a substitute habitat. Reptiles such as the sphaero geckos, endemic anolis lizards, dwarf ground boas, all use palm trees as a habitat for shelter and hunting. Some bird species do use old palms for nesting (e.g. barn owl). There are deadwood beetles and termites that live and feed on palms on the islands.

4.5.2 What is the level of potential negative impact on ecosystem services in the PRA area? (**consider**: provisioning services (freshwater, wood and fibre, fuel); regulating services (soil formation, natural hazards, water and air quality); cultural services (aesthetic, educational, recreational, spiritual); supporting services (nutrient cycling, habitat stability; pollination) see also guidance notes 4.5.2

Increased use of insecticides to control the Red palm weevil may impact negatively on populations of native insects, including pollinating bees and wasps, as well as on soil biodiversity and water quality on the Cayman Islands. This is especially the case if these need to be used in otherwise primary habitat if the pest species invaded there.

#### Summary environmental impact

|                              |   |  |   |   |                                     |
|------------------------------|---|--|---|---|-------------------------------------|
| Risk of environmental impact | Very small <input type="checkbox"/>                 | Small <input type="checkbox"/>             | Medium <input type="checkbox"/>         | Large <input checked="" type="checkbox"/> | Very large <input type="checkbox"/> |
| Confidence                   | High confidence <input checked="" type="checkbox"/> | Medium confidence <input type="checkbox"/> | Low confidence <input type="checkbox"/> |   |                                     |

### Part 5: Pest risk management

#### 5.1 Prevention

5.1.1 Which measures **already** in place are suitable to minimise the risk of introduction and establishment **Consider**: inspection of commodities; trapping, disrupting specific pathways, etc.

- **pre-border**: Palms are only imported from the USA under compliance agreement treatment and would not be allowed from infested areas. None specific for RPW since it is not reported in the USA.
- **at the border**: 100% visual inspection upon arrival are in place but this might not be enough to prevent introduction of RPW
- **post-border**: Only Monitoring for symptoms in place, but no specific prevention measures)

5.1.2 Which measures **not yet** in place are suitable to minimise the risk of introduction and establishment **Consider:** inspection of commodities; trapping, disrupting specific pathways, etc.

- pre-border:** Shipment of in vitro plants and palm seeds are apparently safe (EPPO PRA, USDA factsheet, Giblin-Davis *et al.* 2013). Equally, the import of plants with stem diameters <5cm and the import of fruits are deemed to be safe (Giblin-Davis *et al.* 2013).  
 An assay studied the feasibility of a quarantine treatment for Canary Islands date palms. Palms were naturally infested and placed in a sealed container. Infested palms were exposed to aluminium phosphide for 48 h. The infested and treated palms were inspected for the presence of all stages of *R. ferrugineus*. Treatment completely eliminated all live stages of *R. ferrugineus* (i.e. 100 % efficacy) and no phytotoxic effects of aluminium phosphide were observed for up to 1 year after exposure to aluminium phosphide. This treatment, which could be easily applied in sealed containers used to prepare and ship palms overseas, could therefore be recommended to significantly reduce the enormous risks that palm imports currently bring worldwide (<https://cordis.europa.eu/project/id/289566/reporting>). The introduction of *R. ferrugineus* to many countries through the trade of adult palms indicates that the best method for preventing introduction of this pest is to prohibit importation of all host species (with the exception of seeds and possibly in vitro reared seedlings and young plants with a small stem diameter below 5cm). This measure has, for example, been put in place for the USA, in order to prevent the entry of *R. ferrugineus*, but also of closely related species such as *R. palmarum*, the South American palm weevil, which could pose an even greater risk for the **Caymans**, as it is already much more widespread regionally. ([https://www.aphis.usda.gov/import\\_export/plants/plant\\_imports/federal\\_order/downloads/2010/Palm%20Pests\\_1-25-10.pdf](https://www.aphis.usda.gov/import_export/plants/plant_imports/federal_order/downloads/2010/Palm%20Pests_1-25-10.pdf)). It would be a challenge for DOA to simply only allow the import of seeds/small seedlings, because the Dept of Planning requires plants of certain size to be including in building plans and the local supply is not enough then the demand for import is always there. As a result pre-border phytosanitary mitigations would be the more feasible than small seedlings
- at the border:** ‘Palm Protect’ developed detection techniques for use at trade points and open areas. For detection of individual palms in quarantine/at trade point two protocols were successfully demonstrated based on olfaction and acoustics. Dogs were trained to detect infestations of both the red palm weevils, and the accuracy of detection was high but depended on the palm host. Acoustic monitoring was able to detect *R. ferrugineus* larvae inside young palms shortly after infestation, and long before any visual symptoms appear (<https://cordis.europa.eu/project/id/289566/reporting>). Equally the treatment with aluminium phosphide described above under ‘pre-border’ treatment could be applied at the border itself. The DOA has Phostoxin available but so far this was never used and recommended as a fumigant for live plants. The efficacy would need to proven for phytotoxicity. If yes, then it would be possible
- post-border:** In open areas, the use of attractants and traps and a location aware/decision support system can be deployed. This has already been trialled and tested for Europe. Here, baited traps were found to be useful as a monitoring tool for *R. ferrugineus*, using Picusan® as an effective lure for both palm plantations and urban areas. A location aware system (CPLAS) and decision support system was developed for use in urban and agricultural areas. This is a useful tool for the management of red palm weevil, providing information and classification of on infestations symptoms, risk assessment and control recommendations (<https://cordis.europa.eu/project/id/289566/reporting>). However, much of the containment efforts in place for larger countries in the Mediterranean may not be very effective, a spread and establishment of the weevil on small island systems will quickly cover the whole area.  
**Monitoring for RPW** It is one of the planned surveys to confirm its absence on Cayman and this was to start in late 2019 but was disrupted due to staff changes. The apparatus is on hand and things being equal will be done this year.

**Summary efficacy prevention measures**

|  |   |  |  |                                 |                                      |
|--|---|--|--|---------------------------------|--------------------------------------|
| Probability of current prevention measures being effective | Very unlikely <input type="checkbox"/>              | Unlikely <input checked="" type="checkbox"/> | Moderately likely <input type="checkbox"/> | Likely <input type="checkbox"/> | Very likely <input type="checkbox"/> |
| Confidence   | High confidence <input checked="" type="checkbox"/> | Medium confidence <input type="checkbox"/>   | Low confidence <input type="checkbox"/>    |                                 |                                      |

|  |   |  |  |                                 |   |
|--|---|--|--|---------------------------------|---|
| Probability of suitable future prevention measures being effective | Very unlikely <input type="checkbox"/>              | Unlikely <input type="checkbox"/>          | Moderately likely <input type="checkbox"/> | Likely <input type="checkbox"/> | Very likely <input checked="" type="checkbox"/> |
| Confidence   | High confidence <input checked="" type="checkbox"/> | Medium confidence <input type="checkbox"/> | Low confidence <input type="checkbox"/>    |                                 |   |

## 5.2 Control

5.2.1 What existing control measures available in the territory for the control of other pests can provide adequate control to mitigate the risks described above? **Consider:** cultural practices e.g. irrigation, planting, harvesting methods etc.; pest control programmes; natural enemies; please link to effectiveness, practicality, costs, negative consequences and acceptability

- eradication: Some measures are in place to destroy infected material whenever intercepted.
- containment to prevent further spread: no specific measure in place from the Department of Environment, but regulations exist to prevent the movement of infested materials and destruction of infested materials can be adopted.
- mechanical/chemical control: Chemical methods used for other pest can be adopted, Landscapers have injections available and root drench.
- biological control: Not available on Cayman at this point.

5.2.2 What additional control measures currently not available in the territory can provide adequate control to mitigate the risks described above? **Consider:** cultural practices e.g. irrigation, planting, harvesting methods etc.; pest control programmes; natural enemies; please link to effectiveness, practicality, costs, negative consequences and acceptability

- eradication: In many areas, particularly larger countries (as in the Mediterranean), eradication of *R. ferrugineus* is deemed unlikely and containment is seen as more realistic (<https://cordis.europa.eu/project/id/289566/reporting>). It is still not clear under which circumstances eradication using the methods currently applied in Europe for containment of *R. ferrugineus* might be possible on relatively small island systems. Localised eradication of a small starter population, restricted to only few infested plants, may be possible. Eradication has been cited for California, USA, but this has been shown to be of a closely related species and before it could become properly established (<https://www.cabi.org/isc/datasheet/47472>). However, a successful eradication programme of the red palm weevil was undertaken in the Canary Islands to protect the native *P. canariensis* after this insect was detected in resorts of Fuerteventura and Gran Canaria in 2005. This included a ban on the importation of any palms from outside the islands, and a programme of work including monitoring for the pest; inspection of palm trees and nurseries; accreditations for transplants and movement of palm trees; elimination of infected trees; plant health treatments and mass trapping; and an awareness campaign including a web site; talks and seminars, and courses, newsletters and leaflets. In 2007 an outbreak was reported on Tenerife, but since 2008 no additional weevils have been detected (<https://cordis.europa.eu/project/id/289566/reporting>).
- containment to prevent further spread: No effective methods are currently available once the pest becomes established. Buffer zone of 10km is suggested for EU, but this is unrealistic for small islands ([https://ec.europa.eu/food/sites/food/files/plant/docs/ph\\_biosec\\_red\\_palm\\_weevil\\_brochure\\_en.pdf](https://ec.europa.eu/food/sites/food/files/plant/docs/ph_biosec_red_palm_weevil_brochure_en.pdf)).
- mechanical/chemical control: An injection device specifically for palm trees that quickly and efficiently delivers insecticide into the palm's trunk, with minimal damage to palm tissues, has been developed. Stipe injection resulted in a better distribution and higher persistence of pesticide compared with frond injection and crown spraying, suggesting that stipe injection could be a good alternative for the control of *R. ferrugineus*. A relatively wide range of further containment and control approaches have been looked into with varying success (<https://www.cabi.org/isc/datasheet/47472>).
- biological control: Control methods include mass trapping and attract and infect procedures, using a Picusan® trap and entomopathogenic fungi. In field trials, the attract and infect device was found to be more effective at protecting palms than trapping alone. Between 40 and 80% of the adults captured with infective traps were infected with fungi, and traps remained effective for over 75 days. Moreover,

infected adults were able to move distances over 300 m from the trap, helping to spread fungi to other weevils. Only 42% of the sentinel palms in the centre of infective trap plots were infested by weevils, compared to 100% infestation in mass trapping plots (<https://cordis.europa.eu/project/id/289566/reporting>; <https://secure.fera.defra.gov.uk/palmprotect/index.cfm?sectionid=31>). Different strains of entomopathogenic fungi from *R. ferrugineus* from around the Mediterranean basin have been identified. Laboratory, semi-field, and field assays for one of these strains of *Beauveria bassiana* have demonstrated the potential that entomopathogenic microorganisms have for controlling these palm pests. Overall, a number of different biological control agents have been found for *R. ferrugineus*, but so far no highly efficient approach has been fully developed (<https://www.cabi.org/isc/datasheet/47472>).

### Summary efficacy of current control measures from 5.2.1

|   |   |  |  |                                 |                                      |
|---|---|--|--|---------------------------------|--------------------------------------|
| Probability of control measures being effective | Very unlikely <input type="checkbox"/>              | Unlikely <input checked="" type="checkbox"/> | Moderately likely <input type="checkbox"/> | Likely <input type="checkbox"/> | Very likely <input type="checkbox"/> |
| Confidence                                      | High confidence <input checked="" type="checkbox"/> | Medium confidence <input type="checkbox"/>   | Low confidence <input type="checkbox"/>    |                                 |                                      |

### Summary efficacy of proposed control measures from 5.2.2

|   |   |  |  |                                 |   |
|---|---|--|--|---------------------------------|---|
| Probability of suitable future control measures being effective | Very unlikely <input type="checkbox"/>              | Unlikely <input type="checkbox"/>          | Moderately likely <input type="checkbox"/> | Likely <input type="checkbox"/> | Very likely <input checked="" type="checkbox"/> |
| Confidence  | High confidence <input checked="" type="checkbox"/> | Medium confidence <input type="checkbox"/> | Low confidence <input type="checkbox"/>    |                                 |   |

### Other information

Add here any further information you wish to include in this application including if there are any ethical considerations that you are aware of in relation to your application

This PRA covers *R. ferrugineus*, currently the most invasive species of palm weevil. However, a number of other species of the genus impact on palm trees, notably *Rhynchophorus palmarum* (South American Palm Weevil), which is already much more widespread in the Caribbean region. A lot of information in this PRA is also applicable to *R. palmarum*, and the measures for prevention and control should be largely the same for this species. However, there may be some significant differences regarding its host spectrum and it is recommended to look into this, as well as the pathways specific to *R. palmarum*, in a separate PRA. In particular it is recommended to assess whether there are any imports of palm trees (or other host plants on which *R. palmarum* might be able to develop) from countries free of *R. ferrugineus* but where *R. palmarum* has already established.

### Is there a need for a more detailed PRA or for more detailed analysis of particular sections of the PRA? (For completion by the Biosecurity group only!)

No  Yes

If yes, please forward to FERA or NNSS or others

### References and information sources consulted

Online resources



- APHIS, USDA (2010) Federal Import Quarantine Order: Palm Pests *Rhynchophorus ferrugineus* Olivier (Red palm weevil), *R. palmarum* Linnaeus (Giant Palm Weevil), and *Bursaphelenchus cocophilus* Cobb (Red Ring Nematode). -  
[https://www.aphis.usda.gov/import\\_export/plants/plant\\_imports/federal\\_order/downloads/2010/Palm%20Pests\\_1-25-10.pdf](https://www.aphis.usda.gov/import_export/plants/plant_imports/federal_order/downloads/2010/Palm%20Pests_1-25-10.pdf)
- Bertone, C., Michalak, P.S., Roda, A. (2011) New Pest Response Guidelines - Red palm weevil - *Rhynchophorus ferrugineus*. USDA, 122p.  
[https://www.ippc.int/static/media/uploads/resources/new\\_pest\\_response\\_guidelines\\_red\\_palm\\_weevil.pdf](https://www.ippc.int/static/media/uploads/resources/new_pest_response_guidelines_red_palm_weevil.pdf)
- CABI, Invasive Species Compendium (2020) *Rhynchophorus ferrugineus* (red palm weevil).  
<https://www.cabi.org/isc/datasheet/47472>
- Dembilio, O., Audsley, N., Cohen, Y., Colazza, S., Isidoro, N., Karamaouna, F., Kontodimas, D., Navarro-Llopis, V., Peri, E., Quesada-Moraga, E., Riolo, P., Rochat, D., Soroker, V., Jacas J.A. Review of control methods against the palm borers *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae) and *Paysandisia archon* (Burmeister) (Lepidoptera: Castniidae). 39p.  
<https://secure.fera.defra.gov.uk/palmprotect/index.cfm?sectionid=31>
- DoA, Australia (2020) Permitted Arecaceae (palm) Seeds List. -  
<https://www.agriculture.gov.au/biosecurity/legislation/permitted-arecaceae>
- EPPO (2020) EPPO Global Database - *Rhynchophorus ferrugineus*(RHYCFE).  
<https://gd.eppo.int/taxon/RHYCFE/documents>
- EPPO (2020a) Regulated non-quarantine pest Project - *Rhynchophorus ferrugineus* (RHYCFE)  
[https://rnqp.eppo.int/recommendations/summarysheet\\_pest?pest=RHYCFE](https://rnqp.eppo.int/recommendations/summarysheet_pest?pest=RHYCFE)
- EPPO (2020b) EPPO Platform on PRAs - PRA for *Rhynchophorus ferrugineus*.  
<https://pra.eppo.int/pra/eee93e99-dedf-4b03-8d0e-71fec77a9dbd>
- European Union (2011) The insect killing our palm trees - EU efforts to stop the Red palm weevil. – 32p.  
[https://ec.europa.eu/food/sites/food/files/plant/docs/ph\\_biosec\\_red\\_palm\\_weevil\\_brochure\\_en.pdf](https://ec.europa.eu/food/sites/food/files/plant/docs/ph_biosec_red_palm_weevil_brochure_en.pdf)
- Malumphy, C., Eyre, D. Anderson, H. (2016) Plant Pest Factsheet - Red palm weevil - *Rhynchophorus ferrugineus*. DEFRA. <https://planthealthportal.defra.gov.uk/assets/factsheets/Rhynchophorus-ferrugineus-Defra-PP-Factsheet-Oct-2016-FINAL3.pdf>
- Palm Protect (2016) Final Report Summary - PALM PROTECT (Strategies for the eradication and containment of the invasive pests *Rhynchophorus ferrugineus* Olivier and *Paysandisia archon* Burmeister). 22p. -  
<https://cordis.europa.eu/project/id/289566/reporting>
- Queen Elizabeth II Botanic Park (2020) Flora of the Cayman Islands – The flora list. -  
[http://www.caymanflora.org/QEIIflora/ge\\_list/genus\\_lt.html](http://www.caymanflora.org/QEIIflora/ge_list/genus_lt.html)
- Rui-Ting, J., Aziz, A. (2011) Establishment and potential risks of a new invasive pest, red palm weevil *Rhynchophorus ferrugineus* in China. - Arab J. Pl. Prot. 29(1): 122-130.  
[https://www.researchgate.net/publication/301244029\\_Establishment\\_and\\_potential\\_risks\\_of\\_a\\_new\\_invasive\\_pest\\_red\\_palm\\_weevil\\_Rhynchophorus\\_ferrugineus\\_in\\_China](https://www.researchgate.net/publication/301244029_Establishment_and_potential_risks_of_a_new_invasive_pest_red_palm_weevil_Rhynchophorus_ferrugineus_in_China) or  
<https://www.agriculture.gov.au/biosecurity/legislation/permitted-arecaceae>
- Wikipedia (2020) *Rhynchophorus ferrugineus*. [https://en.wikipedia.org/wiki/Rhynchophorus\\_ferrugineus](https://en.wikipedia.org/wiki/Rhynchophorus_ferrugineus)

## References

- Abe F, Hata K, Sone K, 2009. Life history of the red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Dryophoridae), in southern Japan. Florida Entomologist, 92(3):421-425. <http://www.fcla.edu/FlaEnt/>
- Abraham VA, Koya KMA, Kurian C, 1989. Integrated management of red palm weevil (*Rhynchophorus ferrugineus* F.) in coconut gardens. Journal of Plantation Crops, 16(Supplement):159-162

- ALA, 2016. *Rhynchophorus ferrugineus*. In: Atlas of Living Australia, <http://biocache.ala.org.au/occurrences/230cca74-ca88-4d39-9a93-b9990abd1874>
- Booth RG, Cox ML, Madge RB, 1990. IIE guides to insects of importance to man. 3. Coleoptera. Wallingford, UK: CAB International
- Braza RD, 1988. Asiatic palm weevil destroys rattan too. Canopy International. 13(6):6
- CABI, EPPO, 2010. *Rhynchophorus ferrugineus*. [Distribution map]. In: Distribution Maps of Plant Pests, Wallingford, UK: CABI. Map 258 (3rd revisio.
- CABI, EPPO, 2016. *Rhynchophorus ferrugineus*. [Distribution map]. In: Distribution Maps of Plant Pests, Wallingford, UK: CABI. Map 258 (4th revisio.
- Copeland EB, 1931. The coconut. London, UK: Macmillan and Co., Ltd
- Dhileepan K, 1991. Insects associated with oil palm in India. FAO Plant Protection Bulletin, 39(2-3):94-99
- El-Ezaby FA, 1997. Injection as a method to control the Red Indian date palm weevil *Rhynchophorus ferrugineus*. Arab Journal of Plant Protection, 15(1):31-38; 17 ref
- El-Sabea AMR, Faleiro JR, Abo-El-Saad MM, 2009. The threat of red palm weevil *Rhynchophorus ferrugineus* to date plantations of the Gulf region in the Middle-East: an economic perspective. Outlooks on Pest Management, 20(3):131-134. <http://www.pestoutlook.com>
- EPPO, 2014. PQR database., Paris, France: EPPO. <http://www.eppo.int/DATABASES/pqr/pqr.htm>
- Esteban-Duran J, Yela JL, Beitia-Crespo F, JimTnez-Blvarez A, 1998. Exotic curculionids susceptible to being introduced into Spain and other countries of the European Union through imported vegetables (Coleoptera: Curculionidae: Rhynchophorinae). Boleti^n de Sanidad Vegetal, Plagas, 24(1):23-40; 26 ref
- Faleiro JR, 2006. A review of the issues and management of the red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Rhynchophoridae) in coconut and date palm during the last one hundred years. International Journal of Tropical Insect Science, 26(3):135-154. [http://journals.cambridge.org/download.php?file=%2FJTI%2FJTI26\\_03%2FS1742758407203340a.pdf&code=1deb83cc2eaac3c89ea5704c1f57a0b3](http://journals.cambridge.org/download.php?file=%2FJTI%2FJTI26_03%2FS1742758407203340a.pdf&code=1deb83cc2eaac3c89ea5704c1f57a0b3)
- Flach M, 1983. The sago palm. In: FAO Plant Production and Protection Paper, 85 pp.
- Ganapathy T, Rajamanickam K, Raveendran TS, Lourduraj AC, Kennedy FJS, 1992. Status of coconut cultivation in Pollachi tract. II Prevalence of pests and diseases Indian Coconut Journal (Cochin), 23(3):4-6
- Giblin-Davis, R.M., Faleiro, J.R., Jacas, J.A., Peña, J.E., Vidyasagar, P.S.P.V. (2013) Biology and Management of the Red palm weevil, *Rhynchophorus ferrugineus*. - In: CAB International 2013. Potential Invasive Pests of Agricultural Crops (ed. J. Peña). 1-34.
- Hutson JC, 1933. The red weevil of coconut. Dept. Agric. Ceylon. Leaflet No. 22
- Jaya S, Suresh T, Sobhitha-Rani RS, Sreekumar S, 2000. Evidence of seven larval instars in the red palm weevil, *Rhynchophorus ferrugineus* Oliv. reared on sugarcane. Journal of Entomological Research, 24(1):27-31; 14 ref
- Justin CGL, Leelamathi M, Thangaselvabai T, Johnson SBN, 2008. Bioecology and management of the red palm weevil, *Rhynchophorus ferrugineus* Oliv. (Coleoptera: Curculionidae) on coconut - a review. Agricultural Reviews, 29(2):117-124
- Leefmans S, 1920. De Palmsnuitkever (*Rhynchophorus ferrugineus* Olivier). Mededelingen van het Instituut voor Plantenziekten, No. 43, Department van Landbouw, Nigverheld en handel Batavia
- Menon KP, Pandalai KM, 1960. Pests. In: The Coconut palm. A Monograph. Inrankulam, South India: Indian Central Committee, 261-265
- Misra RM, 1998. Insect pests of oil palm (*Elaeis guineensis* L.) from India and their management. Indian Journal of Forestry, 21(3):259-263

- Nirula KK, Anthony J, Menon KPV, 1953. The red palm weevil and its control. Proc. 40th Session Indian Sci. Cong., 147-148
- Prabhu ST, Patil RS, 2009. Studies on the biological aspects of red palm weevil, *Rhynchophorus ferrugineus* (Oliv.). Karnataka Journal of Agricultural Sciences, 22(3):732-733.  
<http://203.129.218.157/ojs/index.php/kjas/article/viewFile/1243/1187>
- Pullen, K. R., Jennings, D., Oberprieler, R. G., 2014. Annotated catalogue of Australian weevils (Coleoptera: Curculionoidea). Zootaxa, 3896, 1-481. <http://www.mapress.com/zootaxa/2014/f/z03896p481f.pdf>
- Ramachandran CP, 1991. Effects of gamma radiation on various stages of red palm weevil, *Rhynchophorus ferrugineus* F. Journal of Nuclear Agriculture and Biology, 20(3):218-221
- Reginald C, 1973. Principal Insect Pests. In: Coconuts. Tropical Agriculture Series, London, UK: Longmans
- Roda A, Kairo M, Damian T, Franken F, Heidweiller K, Johans C, Mankin R, 2011. Red palm weevil (*Rhynchophorus ferrugineus*), an invasive pest recently found in the Caribbean that threatens the region. Bulletin OEPP/EPPO Bulletin, 41(2):116-121.  
[http://onlinelibrary.wiley.com/journal/10.1111/\(ISSN\)1365-2338](http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1365-2338)
- Roda A, Kairo M, Damian T, Franken F, Heidweiller K, Johans C, Mankin R (2011) Red palm weevil (*Rhynchophorus ferrugineus*), an invasive pest recently found in the Caribbean that threatens the region. Bulletin OEPP/EPPO Bulletin. 41 (2), 116-121.  
[http://onlinelibrary.wiley.com/journal/10.1111/\(ISSN\)1365-2338](http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1365-2338) DOI:10.1111/j.1365-2338.2011.02446.x
- Sacchetti P, Camèra A, Granchietti A, Rosi MC, Marzialetti P, 2006. Identification, biology and spread of the Red palm weevil *Rhynchophorus ferrugineus* (Olivier) in Italy. (Identificazione, biologia e diffusione del curculionide delle palme, *Rhynchophorus ferrugineus* (Olivier).) Informatore Fitopatologico, 56(6):35-40
- Salama HS, Zaki FN, Abdel-Razek AS, 2009. Ecological and biological studies on the red palm weevil *Rhynchophorus ferrugineus* (Olivier). Archives of Phytopathology and Plant Protection, 42(4):392-399.  
<http://journalsonline.tandf.co.uk/link.asp?id=300198>
- Wang Feng, Ju RuiTing, Li YueZhong, Xu Ying, Du YuZhou, Zhou JianMing, 2009. Lab observation for biological characteristics and morphology of *Rhynchophorus ferrugineus*. Chinese Bulletin of Entomology, 46(4):556-560. <http://www.ilib.cn/P-kczs.html>
- Wattanapongsiri A, 1966. A revision of the Genera *Rhynchophorus* and *Dynamis*. Department of Agricultural Science Bulletin. Bangkok, Thailand

## Appendices and referenced material (if any) and glossary (if required)

In case this is an application made for the deliberate introduction of a species/commodity it is recommended that you contact a member of the biosecurity group as early in the application process as possible. Biosecurity can assist you with any questions you have during the preparation of your application including providing advice on any consultation requirements.

Unless otherwise indicated, all sections of this form must be completed for the application to be formally received and assessed. If a section is not relevant to your application, please provide a comprehensive explanation why this does not apply.

Commercially sensitive information must be included in an appendix to this form and be identified as confidential. If you consider any information to be commercially sensitive, please show this in the relevant section of this form and cross reference to where that information is located in the confidential appendix.

Any information you supply to biosecurity prior to formal lodgement of your application will not be publicly released. Following formal lodgement of your application any information in the body of this application form and any non-confidential appendices will become publicly available.

## Information resources

This list of online resources may help the applicant to gather information about the organism being assessed. In bold are key databases with relevant information about invasive species. The other resources provide information about the description, distribution, and habitat the species. It is recommended to check additional resources about the species from within its native range (e.g. local floras).

### Global

**CABI, 2016. Invasive Species Compendium. Wallingford, UK: CAB International. [www.cabi.org/isc](http://www.cabi.org/isc)**

**ISSG, 2015. Global Invasive Species Database (GISD). Invasive Species Specialist Group of the IUCN Species Survival Commission. <http://www.issg.org/database/welcome/>**

ILDIS, 2005. International Legume Database and Information Service: World Database of Legumes (version 10). Reading, UK: School of Plant Sciences, University of Reading. <http://www.ildis.org/>

Missouri Botanical Garden, 2015. Tropicos database. St. Louis, Missouri, USA: Missouri Botanical Garden. <http://www.tropicos.org/>

USDA-ARS, 2015. Germplasm Resources Information Network (GRIN). Online Database. Beltsville, Maryland, USA: National Germplasm Resources Laboratory. <https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearch.aspx>

WCSP, 2015. World Checklist of Selected Plant Families. London, UK: Royal Botanic Gardens, Kew. <http://apps.kew.org/wcsp/home.do>

### Asia

Flora of China Editorial Committee, 2015. Flora of China. St. Louis, Missouri and Cambridge, Massachusetts, USA: Missouri Botanical Garden and Harvard University Herbaria. [http://www.efloras.org/flora\\_page.aspx?flora\\_id=2](http://www.efloras.org/flora_page.aspx?flora_id=2)

Flora of Pakistan, 2015. Flora of Pakistan/Pakistan Plant Database (PPD). Tropicos website. St. Louis, Missouri and Cambridge, Massachusetts, USA: Missouri Botanical Garden and Harvard University Herbaria. <http://www.tropicos.org/Project/Pakistan>

### Africa

**Invasive Species South Africa, 2015. Plants A-Z: Flora that is invasive in South Africa. South Africa: Invasive Species South Africa. <http://www.invasives.org.za/invasive-plants.html>**

Madagascar Catalogue, 2015. Catalogue of the Vascular Plants of Madagascar. St. Louis, Missouri, USA and Antananarivo, Madagascar: Missouri Botanical Garden. <http://www.tropicos.org/project/mada>

PROTA, 2015. PROTA4U web database. Grubben GJH, Denton OA, eds. Wageningen, Netherlands: Plant Resources of Tropical Africa. <http://www.prota4u.org/search.asp>

### Americas

**I3N-Brasil, 2015. Invasive alien species database. Florianópolis - SC, Brazil: Horus Institute for Environmental Conservation and Development. <http://i3n.institutohorus.org.br>**

Catalogue of the Vascular Plants of Ecuador, 2015. Catalogue of the Vascular Plants of Ecuador . St. Louis, Missouri, USA: Missouri Botanical Garden. <http://tropicos.org/Project/CE>

Flora Mesoamericana, 2015. Flora Mesoamericana. St. Louis, Missouri, USA: Missouri Botanical Garden. <http://www.tropicos.org/Project/fm>

Flora of North America Editorial Committee, 2015. Flora of North America North of Mexico. St. Louis, Missouri and Cambridge, Massachusetts, USA: Missouri Botanical Garden and Harvard University Herbaria. [http://www.efloras.org/flora\\_page.aspx?flora\\_id=1](http://www.efloras.org/flora_page.aspx?flora_id=1)

FLEPPC, 2013. List of Invasive Plant Species. List of Invasive Plant Species. Fort Lauderdale, Florida, USA: Florida Exotic Pest Plant Council. <http://www.fleppc.org/list/list.htm>

Forzza RC, Leitman PM, Costa AF, Carvalho Jr AA, et al., 2015. List of species of the Flora of Brazil (Lista de espécies Flora do Brasil). Rio de Janeiro, Brazil: Rio de Janeiro Botanic Garden. <http://floradobrasil.jbrj.gov.br>

Instituto de Botánica Darwinion, 2015. Flora del Conosur. San Isidro, Argentina: Instituto de Botánica Darwinion. <http://www2.darwin.edu.ar/Proyectos/FloraArgentina/BuscarEspecies.asp>

Peru Checklist, 2015. The Catalogue of the Flowering Plants and Gymnosperms of Peru. St. Louis, Missouri, USA: Missouri Botanical Garden. <http://www.tropicos.org/Project/PEC>

USDA-NRCS, 2015. The PLANTS Database. Baton Rouge, USA: National Plant Data Center. <http://plants.usda.gov/>

Vibrans H, 2015. Malezas de México (Weeds of Mexico). <http://www.conabio.gob.mx/malezasdemexico/2inicio/home-malezas-mexico.htm>

#### **Caribbean**

Acevedo-Rodríguez P, Strong MT, 2012. Catalogue of the Seed Plants of the West Indies. Smithsonian Contributions to Botany, 98:1192 pp. Washington DC, USA: Smithsonian Institution. Online version at <http://botany.si.edu/Antilles/WestIndies/catalog.htm>

Broome R, Sabir K, Carrington S, 2007. Plants of the Eastern Caribbean. Online database. Barbados: University of the West Indies. <http://ecflora.cavehill.uwi.edu/index.html>

Kairo M, Ali B, Cheesman O, Haysom K, Murphy S, 2003. Invasive species threats in the Caribbean region. Report to the Nature Conservancy. Curepe, Trinidad and Tobago: CAB International, 132 pp. [http://www.issg.org/database/species/reference\\_files/Kairo%20et%20al,%202003.pdf](http://www.issg.org/database/species/reference_files/Kairo%20et%20al,%202003.pdf)

#### **Europe**

**DAISIE, 2015. Delivering Alien Invasive Species Inventories for Europe. European Invasive Alien Species Gateway.** [www.europe-aliens.org/default.do](http://www.europe-aliens.org/default.do)

**EPPO, 2014. PQR database. Paris, France: European and Mediterranean Plant Protection Organization.** <http://www.eppo.int/DATABASES/pqr/pqr.htm>

Royal Botanic Garden Edinburgh, 2015. Flora Europaea. Edinburgh, UK: Royal Botanic Garden Edinburgh. <http://rbg-web2.rbge.org.uk/FE/fe.html>

#### **Oceania**

Council of Heads of Australasian Herbaria, 2015. Australia's virtual herbarium. Australia: Council of Heads of Australasian Herbaria. <http://avh.ala.org.au>

**HEAR, 2012. Alien species in Hawaii. Hawaii Ecosystems at Risk. Honolulu, USA: University of Hawaii.** <http://www.hear.org/AlienSpeciesInHawaii/index.html>

**New Zealand Department of Conservation, 2015. Common Weeds in New Zealand. Wellington, New Zealand: Department of Conservation.** <http://www.doc.govt.nz/conservation/threats-and-impacts/weeds/common-weeds-in-new-zealand/>

PIER, 2015. Pacific Islands Ecosystems at Risk. Honolulu, USA: HEAR, University of Hawaii. <http://www.hear.org/pier/index.html>

University of Queensland, 2013. Weeds of Australia. Biosecurity Queensland Edition. Australia: University of Queensland. <http://keyserver.lucidcentral.org/weeds/>

Wagner WL, Herbst DR, Lorence DH, 2015. Flora of the Hawaiian Islands website. Washington DC, USA: Smithsonian Institution. <http://botany.si.edu/pacificislandbiodiversity/hawaiianflora/index.htm>

Wagner WL, Herbst DR, Tornabene MW, Weitzman A, Lorence DH, 2015. Flora of Micronesia website. Washington DC: Smithsonian Institution. <http://botany.si.edu/pacificislandbiodiversity/micronesia/index.htm>

Wagner WL, Lorence DH, 2015. Flora of the Marquesas Islands website. Washington DC, USA: Smithsonian Institution. <http://botany.si.edu/pacificislandbiodiversity/marquesasflora/index.htm>

#### **Taxonomy and Names**

Stevens PF, 2015. Angiosperm Phylogeny Website. St. Louis, Missouri, USA: Missouri Botanical Garden. <http://www.mobot.org/MOBOT/research/APweb/>

The Plant List, 2013. The Plant List: a working list of all plant species. Version 1.1. London, UK: Royal Botanic Gardens, Kew. <http://www.theplantlist.org/>

#### **Biology: Chromosome Numbers**

IPCN Chromosome Reports, 2015. Index to Plant Chromosome Numbers (IPCN), Tropicos website. St. Louis, Missouri, USA: Missouri Botanical Garden. <http://tropicos.org/Project/IPCN>