Environmental Protection Authority
Te Mana Rauhī Taiao

APPLICATION FORM
Release

To obtain approval to release new organisms

(Through importing for release or releasing from containment)

Send to Environmental Protection Authority preferably by email (neworganisms@epa.govt.nz) or alternatively by post (Private Bag 63002, Wellington 6140)
Payment must accompany final application; see our fees and charges schedule for details.

Application Number

APP203631

Date

24 August 2018

Completing this application form

1. This form has been approved under section 34 of the Hazardous Substances and New Organisms (HSNO) Act 1996. It covers the release without controls of any new organism (including genetically modified organisms (GMOs)) that is to be imported for release or released from containment. It also covers the release with or without controls of low risk new organisms (qualifying organisms) in human and veterinary medicines. If you wish to make an application for another type of approval or for another use (such as an emergency, special emergency, conditional release or containment), a different form will have to be used. All forms are available on our website.
2. It is recommended that you contact an Advisor at the Environmental Protection Authority (EPA) as early in the application process as possible. An Advisor can assist you with any questions you have during the preparation of your application including providing advice on any consultation requirements.
3. 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. If you choose not to provide the specific information, you will need to apply for a waiver under section 59(3)(a)(ii) of the HSNO Act. This can be done by completing the section on the last page of this form.
4. Any extra material that does not fit in the application form must be clearly labelled, cross-referenced, and included with the application form when it is submitted.
5. Please add extra rows/tables where needed.
6. You must sign the final form (the EPA will accept electronically signed forms) and pay the application fee (including GST) unless you are already an approved EPA customer. To be recognised by the EPA as an “approved customer”, you must have submitted more than one application per month over the preceding six months, and have no history of delay in making payments, at the time of presenting an application.
7. Information about application fees is available on the EPA website.
8. All application communications from the EPA will be provided electronically, unless you specifically request otherwise.

Commercially sensitive information

9. 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.
10. Any information you supply to the EPA 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.

11. Once you have formally lodged your application with the EPA, any information you have supplied to the EPA about your application is subject to the Official Information Act 1982 (OIA). If a request is made for the release of information that you consider to be confidential, your view will be considered in a manner consistent with the OIA and with section 57 of the HSNO Act. You may be required to provide further justification for your claim of confidentiality.

Definitions

Containment	Restricting an organism or substance to a secure location or facility to prevent escape. In respect to genetically modified organisms, this includes field testing and large scale fermentation
Controls	Any obligation or restrictions imposed on any new organism, or any person in relation to any new organism, by the HSNO Act or any other Act or any regulations, rules, codes, or other documents made in accordance with the provisions of the HSNO Act or any other Act for the purposes of controlling the adverse effects of that organism on people or the environment
Genetically Modified Organism (GMO)	Any organism in which any of the genes or other genetic material: • Have been modified by *in vitro* techniques, or • Are inherited or otherwise derived, through any number of replications, from any genes or other genetic material which has been modified by *in vitro* techniques
Medicine	As defined in section 3 of the Medicines Act 1981 http://www.legislation.govt.nz/act/public/1981/0118/latest/DLM53790.html?src=qs
New Organism	A new organism is an organism that is any of the following: • An organism belonging to a species that was not present in New Zealand immediately before 29 July 1998; • An organism belonging to a species, subspecies, infrasubspecies, variety, strain, or cultivar prescribed as a risk species, where that organism was not present in New Zealand at the time of promulgation of the relevant regulation; • An organism for which a containment approval has been given under the HSNO Act; • An organism for which a conditional release approval has been given under the HSNO Act; • A qualifying organism approved for release with controls under the HSNO Act; • A genetically modified organism; • An organism belonging to a species, subspecies, infrasubspecies, variety, strain, or cultivar that has been eradicated from New Zealand; • An organism present in New Zealand before 29 July 1998 in contravention of the Animals Act 1967 or the Plants Act 1970. This does not apply to the organism known as rabbit haemorrhagic disease virus, or rabbit calicivirus A new organism does not cease to be a new organism because: • It is subject to a conditional release approval; or • It is a qualifying organism approved for release with controls; or

	• It is an incidentally imported new organism
Qualifying Organism	As defined in sections 2 and 38I of the HSNO Act
Release	To allow the organism to move within New Zealand free of any restrictions other than those imposed in accordance with the Biosecurity Act 1993 or the Conservation Act 1987
Unwanted Organism	As defined in section 2 of the Biosecurity Act 1993 http://www.legislation.govt.nz/act/public/1993/0095/latest/DLM314623.html?src=qs
Veterinary Medicine	As defined in section 2(1) of the Agricultural Compounds and Veterinary Medicines Act 1997 http://www.legislation.govt.nz/act/public/1997/0087/latest/DLM414577.html?search=ts_act%40bill%40regulation%40deemedreg_Agricultural+Compounds+and+Veterinary+Medicines+Act+_resel_25_a&p=1

1. Applicant details

1.1. Applicant

Company Name: (if applicable) New Zealand Forest Research Institute Limited (Trading as Scion)

Contact Name: Dr Toni Withers

Job Title: Senior Entomologist

Physical Address: Te Papa Tipu Innovation Park, 49 Sala St, Rotorua

Postal Address (provide only if not the same as the physical)**:** Private Bag 3020, Rotorua 3046

Phone (office and/or mobile): 07 3435721

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Email: toni.withers@scionresearch.com

1.2. New Zealand agent or consultant (if applicable)

Company Name: (if applicable)

Contact Name:

Job Title:

Physical Address:

Postal Address (provide only if not the same as the physical)**:**

Phone (office and/or mobile):

Fax:

Email:

2. Information about the application

2.1. Brief application description

Approximately 30 words about what you are applying to do

To release from containment a parasitoid wasp, *Eadya daenerys* (Hymenoptera: Braconidae) for biological control of the eucalyptus tortoise beetle, *Paropsis charybdis* (Coleoptera: Chrysomelidae), a pest of *Eucalyptus* trees in New Zealand.

2.2. Summary of application

Provide a plain English, non-technical description of what you are applying to do and why you want to do it

This application seeks permission to release from containment a potential biological control agent that has been assessed for control of the eucalyptus tortoise beetle. The eucalyptus tortoise beetle causes significant damage to susceptible species of eucalypts (gum trees) as both the adult beetle and the grubs (larvae) eat the newly produced leaves of host trees.

Eucalypts are an important component of our forestry industry, which is otherwise dominated by pine trees and Douglas fir. Gum trees are a valuable source of wood chips for making paper, cardboard and animal bedding; they are a solid wood resource for production of lumber; and some species produce such durable poles that may be able to be used directly without requiring preservative treatment. In the landscape gums provide shade, shelter, firewood, floral nectar resources for birds and bees, erosion control on steep land, and increased biodiversity. The total value of eucalypt forests has been estimated by Scion economists at $671 million (land value excluded).

The deliberate use of natural enemies to reduce pest populations is called biological control (biocontrol for short). Biocontrol can be a very effective and environmentally sustainable method of reducing the population growth rate of pests. When successful it has the best benefit:cost ratio of any pest management method, and is much better for the environment than the use of chemical insecticides.

Previous attempts at releasing biocontrol agents from Australia (where eucalyptus tortoise beetle has come from) have established populations of two egg parasite species (parasitoids), which have proven useful in reducing the second (summertime) generation of the pest. Currently the spring generation continues to go unchecked. We have been studying a specialist parasitoid from Australia that targets the spring-time generation by depositing eggs in the larvae of the beetle, where they then develop. First known as *Eadya paropsidis*, this parasitoid has now been renamed *Eadya daenerys*. When not attacked, around 90% of tortoise beetle larvae survive to adulthood. If each larva is attacked just once by *Eadya daenerys,* survival drops to less than 10%. In Australia *Eadya daenerys* can develop in *Paropsis charybdis* (the target pest in NZ), and three other eucalypt-feeding beetles from the closely related genus *Paropsisterna*, which are native to Tasmania and mainland Australia. New Zealand has no native beetles of this type, and no native eucalypts. The risks to non-target related native and beneficial beetles in New Zealand has been examined in laboratory tests and appears to be very low. Effective biocontrol by *Eadya daenerys* could prevent $7.2 million in losses per year from eucalyptus tortoise beetle affecting the growth and yield of susceptible *Eucalyptus* species. The potential economic benefits to New Zealand are why Scion wants to release *Eadya daenerys* in New Zealand to target the larval stages of the eucalyptus tortoise beetle.

2.3. Background and aims of application

This section is intended to put the new organism(s) in perspective of the wider activitie(s) that they will be used in. You may use more technical language but all technical words must be included in a glossary.

Nearly all major insect pests in NZ are exotic, i.e., from overseas. Despite strict biosecurity measures that target trade and tourism, exotic species continue to establish in NZ. Most exotic species are economically benign, but some have become significant pests in our primary industries. The eucalyptus tortoise beetle is one such invader, which currently costs the forest industry $1.0–$2.6 million/year in chemical control costs. In the absence of any chemical control, potential yield loss due to *P. charybdis* damage is estimated at $10 million per year (4.1 m^3 of wood production per hectare per year) in susceptible *Eucalyptus* stands. There are an estimated $402-$503 million worth of vulnerable *Eucalyptus* stands within the $671 million total value of the eucalypt plantation forest estate (Radics et al. 2018, Appendix One). Unmanaged, the eucalyptus tortoise beetle presents a significant risk to the productivity of these plantations and to the economic justification for establishing new forests that could expand New Zealand’s pulp and paper and solid wood industry in the future. This application targets this pest.

The pulp and paper industry in New Zealand grows shining gum (scientific name *Eucalyptus nitens* Deane & Maiden, Myrtaceae: Symphyomyrtus) for its fast growth rate and superior short fibre quality. This gum tree is native to Australia and is the favoured food of the eucalyptus tortoise beetle. The hardwood chips are either exported from the port of Southland for paper manufacture or used at Kinleith Mill as part of a pulp mix to manufacture packaging board called Kraft Liner Board, Kraft Top Line and Semi Chemical Fluting (Oji Fibre Solutions Ltd). Pulp producers supplement *E. nitens* plantations with other hardwood species, such as brown barrel gum (scientific name *Eucalyptus fastigata* Deane & Maiden), which is more resistant to eucalyptus tortoise beetle attack. However, *E. fastigata* is significantly slower growing. *Eucalyptus nitens* grows best in colder, higher elevation areas of NZ and pulp and paper plantations have been established in the central North Island, Southland, and southern Otago (Miller et al., 1992). In all these areas the eucalyptus tortoise beetle remains the most significant pest. Current pest management regimes include regular plantation health monitoring from the ground and via aerial surveys. Aerial spraying is triggered when damage from the eucalyptus tortoise beetle becomes visually severe, usually in December each year. For large-scale exotic forestry, aerial application of broad spectrum insecticide costs $160 per hectare per application

(Radics et al, Appendix One). The area treated in a given year will vary due to pest density, in 2017/18 it ranged from none sprayed in Southland (which was unusual) to the entire central North Island estate sprayed twice (R. Sherratt, G. Manley, pers. comm). On average one third of the plantation estate is sprayed per annum at a total combined cost of $1.0–$2.6 million/year. Insecticides are applied by aerial helicopter boom spraying with nozzles that deliver a very fine droplet. All companies apply a broad-spectrum insecticide containing the active ingredient alpha-cypermethrin (a synthetic pyrethroid) mixed with a spreader oil that is applied at a low volume (5 l/ha.). This method maximises canopy penetration, but carries a risk of spray drift due to the small droplet size. However, application of environmentally damaging insecticides is constantly under review for New Zealand forests certified by environmental schemes such as PEFC or FSC (Forest Stewardship Council) (Rolando et al., 2016). The ability to spray FSC certified forests with alpha-cypermethrin requires a derogation from FSC. In this case certified plantations use derogations as an emergency pest management measure to control eucalyptus tortoise beetle. This derogation requires FSC certified companies to continue researching alternative pest management solutions (Rolando et al., 2016).

Natural enemies (predators and parasitoids) are common everywhere. One species of natural enemy can reduce the population of its host insect by 100 to 1000-fold. Targeted use of natural enemies has been a successful pest management tool used for over 150 years. A single species of natural enemy can sometimes provide excellent control of a pest. However, stronger and more reliable control is achieved by the presence of several species of natural enemies – this mimics the natural situation where pests tend to have a suite of natural enemies in their region of origin. Classical biological control that establishes more than one natural enemy in the new country is an effective and environmentally sustainable way to control exotic pests.

Classical biocontrol is the preferred sustainable management option for eucalyptus tortoise beetle. For small growers such as farm foresters, or isolated, moderately sized plantations less than 20 ha in size, biological control is in fact the only option available. It is simply uneconomic for a small grower to use aerial spraying. Because of the fixed costs involved in getting a helicopter in the air, small area applications cost, at minimum, $340 per hectare (Radics et al. 2018, Appendix One). Chemical-based pest management is therefore not feasible for small growers, and even for large plantation managers cost:benefit analyses show it should be reserved for outbreaks of eucalyptus tortoise beetle threatening moderate to severe damage (Withers & Peters, 2017).

Furthermore, pest management using broad spectrum insecticides is incompatible with biological control. Parasitoids and predators tend to be highly susceptible to synthetic pyrethroids such as alpha-cypermethrin (Loch, 2005). Scion has evaluated alternative targeted chemicals that might control eucalyptus tortoise beetle without affecting biological control agents. To date no economically viable chemical alternative has been identified for use in New Zealand that controls all life stages of the pest as well as providing significantly better environmental protection for non-target organisms, including aquatic life (Withers et al., 2013).

Despite the on-going threat of arrival of other pests and diseases of eucalypts (Withers, 2001), the eucalyptus tortoise beetle remains the most serious plantation pest limiting the planting of sub-genus Symphyomyrtus eucalypts in NZ today (Lin et al., 2017; Murray et al., 2008). Eucalyptus tortoise beetle arrived in New Zealand in Lyttelton in 1916, and within decades, attempts at biological control had been initiated. Early attempts failed when imported insects were heavily hyperparasitised or could not be reared in the laboratory successfully so were never released into the environment (Bain & Kay, 1989). Some control of eucalyptus tortoise beetle was eventually achieved in most parts of New Zealand following the successful introduction in 1987 of the egg parasitoid *Enoggera nassaui* Girault (Hymenoptera: Pteromalidae). However, *Enoggera nassaui* does not adequately attack the first generation of eggs laid in spring after adults emerge from over-wintering sites. It was suspected that New Zealand *E. nassaui* may not be cold-adapted, as the founding population was sourced from the hot dry climate of Western Australia. In 2000 a second strain of *E. nassaui* was introduced from sub-alpine sites in Tasmania (Murphy & Kay, 2004), but this has not improved spring parasitism rates (Pugh et al. 2018, Appendix Two). The recent self-introduction (Murray et al., 2008) of *Neopolycystus insectifurax* Girault (Hymenoptera: Pteromalidae), a competitor of *E. nassaui*, has significantly improved late season (summer generation) control of the pest but it is seldom present in the spring generation. More concerning is the effect of the specialist hyperparasitoid *Baeoanusia albifunicle* Girault (Hymenoptera: Encyrtidae), which could reduce the abundance *E. nassaui*. The negative impacts of *B. albifunicle* have not yet been as severe as was predicted (Murray & Mansfield, 2015) and the combined effects of the two egg parasitoids continue to exert partial control of the summer generation of eucalyptus tortoise beetle (Pugh et al. 2018, Appendix Two).

The New Zealand Farm Forestry Association (NZFFA), SouthWood Exports Ltd (SWEL), and Oji Fibre Solutions NZ Ltd urged Scion to continue searching for a more effective biological control agent to manage the eucalyptus tortoise beetle problem. Currently there are no parasitoids present in New Zealand that attack the larval stage. This means that any eggs that evade the two egg parasitoids or generalist predators, such as ladybirds or pentatomids, will successfully complete the larval stage of the life cycle. Tortoise beetle larvae feed voraciously for three weeks before pupating in the leaf litter or topsoil, and emerging as adults. Young adult females also feed voraciously for two weeks to gain the nutrients required to mature their ovarioles. Hence, the best new biological control agents would be those that attack the pest's early larval life-stages. Tachinid flies were introduced from Tasmania to control the larval stage in the 1970s but failed to establish (Bain & Kay 1989). It is now universally accepted that tachinid flies are not host-specific enough to make them a safe biological control agent. This led to our focus on the host-specific larval endoparasitoid, *Eadya daenerys*, whose main host in Tasmania is *Paropsisterna agricola* (Chapuis)(Coleoptera: Chrysomelidae) a pest in *E. nitens* plantations (Rice, 2005). Field research revealed *P. charybdis* is another field host of this parasitoid (Peixoto et al., 2018). *Paropsis charybdis* is a much larger beetle than *Pst. agricola*, and the *E. daenerys* that utilise *P. charybdis* emerge even larger than those from *Pst. agricola* (Smart, 2016), a promising sign. This application is the culmination of seven years of research and an investment of over $2 million by Scion and our collaborators into this parasitoid species. Modelling suggests biological control with *E. daenerys* could prevent $7.2 million in yield losses per year for the current 60-75% of *Eucalyptus* spp. stands that are susceptible to the pest in New Zealand. We are therefore applying for permission to release *E. daenerys* as a biological control agent to manage the eucalyptus tortoise beetle in New Zealand and protect this resource valued at $402-$503 million.

3. Information about the new organism(s)

3.1. Name of organism

Identify the organism as fully as possible

Non-GMOs - Provide a taxonomic description of the new organism(s).

Both -

- Describe the biology and main features of the organism including if it has inseparable organisms.

Taxonomy

- Class: Insecta: Hymenoptera: Braconidae: Euphorinae
- Species (and strain if relevant): *Eadya daenerys* Ridenbaugh, 2018
- Common name(s): none
- Type of organism: Invertebrate

In-depth field collecting and molecular phylogenetic research on Tasmanian eucalypt-feeding tortoise beetles and their parasitoids (Peixoto et al., 2018) revealed that *Eadya paropsidis* Huddleston and Short (the original name the new organism into containment permit was issued under, NOC1000162) is actually a larger species than the one studied by Rice (2005). *Eadya paropsidis* can now be separated by physical morphometric, and molecular (CO1) analysis from the proposed newly described biological control agent, *Eadya daenerys* Ridenbaugh (Ridenbaugh et al., 2018). Every adult female *Eadya* that has been introduced into containment in New Zealand under NOC1000162 has been examined and identified as *Eadya daenerys*. Tasmanian specimens from the Rice (2005) and Smart (2017) field research were also confirmed as *Eadya daenerys*, in addition to specimens collected by Riek in ACT and NSW on mainland Australia, confirming the species is not just geographically limited to Tasmania (Ridenbaugh et al., 2018).

Eadya daenerys is a medium-sized (body length 5.8mm, ovipositor length 0.82 mm) black braconid wasp with a red-orange head except for the antenna, apex of mandible, and ocellar triangle, which are black. The pronotum is black except for the anterior dorsal margin, which is orange. The propleuron is orange, and the mesothorax and legs are black (Ridenbaugh et al., 2018). Another diagnostic feature, in combination with colour, is the lack of a transverse carinae in the propodeum, which can be difficult to see in photographs but is distinct under a microscope.

Host relationships

The host relationships among Tasmanian *Eadya* species have been determined from laboratory and field research conducted in young *Eucalyptus nitens* plantations infested with leaf beetles (Table 1) (Peixoto et al., 2018). *Eadya daenerys* was the most commonly collected species in all years, during November and December (summarised in Ridenbaugh et al, 2018 and Pugh et al, Appendix Two), and its most common field host in Tasmania was *Pst. agricola* (Table 1). We are certain weevils (Coleoptera: Curculionidae) are not hosts because while *Eadya daenerys* were being collected in 2015-2016, eggs and larvae of *Gonipterus spp.* were also collected from the same trees and reared. No *Eadya* were ever recovered from any *Gonipterus* spp larvae (A. Garcia, and NM deSouza, pers comm).

Table 1. Parasitoid-host relationships confirmed by molecular methods (from Peixoto et al 2018) by *Eadya* species from multiple field locations between 2011-2017 collections and rearing and with names subsequently assigned by (Ridenbaugh et al., 2018).

Eadya daenerys (sp. n 3)	***Eadya paropsidis***	***Eadya annleckiei (sp. n 1)***	***Eadya spitzer (sp. n 2)***
-	-	-	*P. aegrota ellioti*
-	*P. atomaria (syn P. reticulata)*	-	-
Pst. agricola	-	-	-
P. charybdis	*P. charybdis*	*P. charybdis*	*P. charybdis*
-	*P. tasmanica*	-	-
Pst. bimaculata		-	-
Pst. nobilitata	-	*Pst. nobilitata*	-
-	-	*Pst. selmani*	-
-	-	*Pst. variicollis (syn P. obovata)*	-

<u>Biology</u>

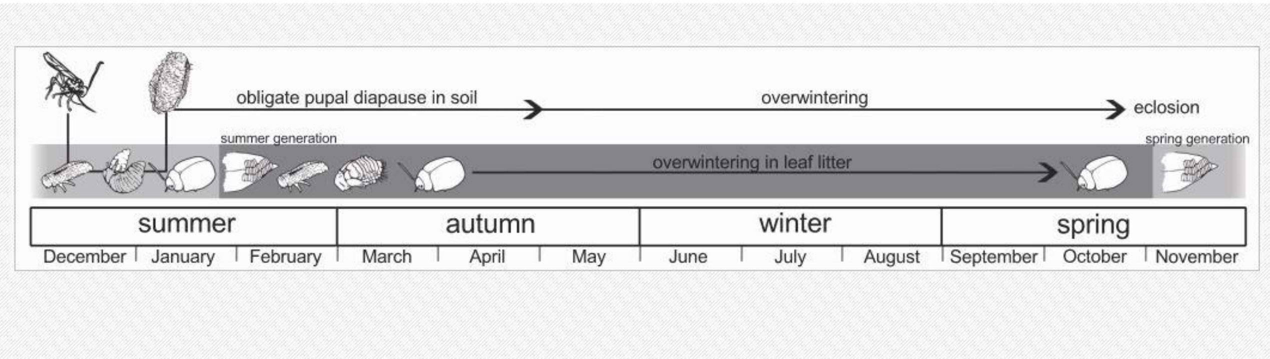
Parasitoids are typically very small species of wasps (Hymenoptera), and are completely harmless to humans. Koinobiont parasitoids lay eggs in their hosts, with which they have evolved a close species-specific relationship. The parasitoid eggs hatch, overcome the immune system of their host, and the immature stages consume the host insect internally before emerging to pupate within a spun cocoon. Adults emerge from the cocoon and begin the cycle again. Once a host larva has been located and rapidly approached, *E. daenerys* oviposits small (0.3 mm) hydropic eggs (eggs that lack yolk and absorb nutrients from the host) directly into the haemocoel of its host. These eggs hatch in approximately five days at 22 ˚C (Rice, 2005; Rice & Allen, 2009). First instar larvae have a well-developed set of mandibles, and a hook, which are presumably used for fighting with competing parasitoids within the host. *Eadya daenerys* has a mean fecundity (estimated by instantaneous egg load) of 975 eggs ± 68 SE. Field-collected females have an average lifespan in the laboratory of 13.6 days ±1.1 SE (n = 28, range = 2 – 24) (Rice, 2005), but this extends to over 40 days if held in laboratory conditions between 10-14˚C (G. Allen, unpublished data).

Eadya daenerys prefer to oviposit in early stage larval hosts, although they can attack and develop in all instars of *Pst. agricola* (A. Rice and G. Allen, unpublished data). Older host larvae appear more effective at defensive behaviour, in which they evert their dorsal glands and thrash at the parasitoid (T. Withers, pers. obs.).

Eadya daenerys larvae develop in 25 days at 18˚C (Rice & Allen, 2009). Like all insects, development rates are temperature-dependent and rates increase with increasing temperatures. The lethal maximum temperature for *E. daenerys* development is unknown. Mature parasitized host larvae drop to the ground to excavate a chamber in the soil and pupate, and this is where the *E. daenerys* larva emerges from the host and spins a silken cocoon within which it pupates (Rice, 2005). This aspect of the life cycle has been difficult to replicate in the containment laboratory. Dissection of cocoons at different times after spinning revealed that maturation into an adult occurs over approximately the first 40 days (G. Allen, unpublished data). Adults then undergo a period of extended obligate diapause over winter and emerge the following spring (Rice & Allen, 2009). Field monitoring has confirmed that *E. daenerys* is univoltine in Tasmania (Smart, 2016), which is expected as the similar species *E. paropsidis* Huddleston & Short is also univoltine and only attacks the spring generation of *Paropsis atomaria* Ol. in mainland Australia (Tanton & Epila, 1984). A CLIMEX™ climate comparison between Tasmania and New Zealand (Figure 1) shows *E. daenerys* sourced from Tasmania will be well matched to New Zealand and phenologically will overlap with the spring generation of *P. charybdis* in New Zealand (Pugh et al. 2018, Appendix Two).

Eadya daenerys has no inseparable organisms. It is known to be hyper-parasitised by *Perilampus tasmanicus* Cameron (Hymenoptera: Perilampidae). *Perilampus tasmanicus* has been reared from larvae of *P. atomaria* where it parasitizes both *Eadya* spp. and at least one of three species of tachinid flies in the Australian Capital Territory (Tanton & Epila, 1984). *Perilampus tasmanicus* has also been reared from *Pst. agricola* larvae infested with *Eadya* sp. in Tasmania (G. Allen, pers. comm). *Perilampus tasmanicus* is not present in New Zealand.

Figure 1. Lifecycle of *E. daenerys* in relation to *P. charybdis* in NZ



There are 130 species of Braconidae in New Zealand (MacFarlane et al., 2010). Eighteen species are listed as having been imported into New Zealand as beneficial biocontrol agents, including *Cotesia urabae*, the parasitoid of the gum leaf skeletoniser; *Cotesia rubecula*, the parasitoid of the white butterfly; and *Cotesia plutellae*, the parasitoid of the diamondback moth. New Zealand has no native parasitoids in the genus *Eadya*.

- **Could the organism form an undesirable self-sustaining population? If not, why not?**

Yes. This application is to release a biological control agent that is intended to establish a self-sustaining population to control the eucalyptus tortoise beetle. Subject to EPA approval, the releasing and establishment of a new predator or parasitoid is actually the intent of all new biocontrol programmes. However, we do not envisage ever importing a potential biocontrol agent without having built a prima facie case, through existing knowledge, that the potential benefits to NZ would outweigh the possible environmental costs. We do not believe that *E. daenerys* will become undesirable, as the risk to native and beneficial non-target species is demonstrably low. These risks are outweighed by the benefits of improved biological control of the eucalyptus tortoise beetle. More information on our rationale is provided in section 5.

- **How easily could the new organism be recovered or eradicated if it established an undesirable self-sustaining population?**

It is likely that biocontrol agents would disperse over a wider area in order to become undesirable, and eradication would be possible only by the application of broad-spectrum insecticides over a wide area. Eradication would then probably prove to be impractical or undesirable, but this would be considered on a case-by-case basis. Eradication of the new biocontrol agent may prove to be more environmentally damaging than any undesirable impact it could be having.

3.2. Regulatory status of the organism

Is the organism that is the subject of this application also the subject of:

An innovative medicine application as defined in section 23A of the Medicines Act 1981?

☐ Yes ☒ No

An innovative agricultural compound application as defined in Part 6 of the Agricultural Compounds and Veterinary Medicines Act 1997?

☐ Yes ☒ No

4. Māori engagement

Discuss any engagement or consultation with Māori undertaken and summarise the outcomes. Please refer to the EPA policy ‘Engaging with Māori for applications to the EPA’ on our website (www.epa.govt.nz) or contact the EPA for advice.

The Te Papa Tipu Innovation Park sits on Ngati Tuteata and Ngati Te Taeotu tribal whenua (lands). The marae, Hurunga Te Rangi, is located at Ngapuna, Rotorua and the resident kaumatua, Mr George Mutu (Koro George) has an on-going relationship with Scion. Scion meets with Koro George and other hapu representatives on a regular basis. Scion initiated engagement at the marae in July 2015 and began discussions about *E. daenerys* as a potential biological control agent of eucalyptus tortoise beetle. These, and subsequent discussions, have informed our research and this application.

Table 2: Summarised pre-application consultation with Maori conducted to date:

Maori Engagement in relation to Paropsis Biological Control Project			
DATE	Where held	With whom (numbers)	Topic
October 2014	His home at Mourea	Willy Newton and his wife (2)	*Paropsis* and leaf spots damaging *Eucalyptus* on trust property. Gained access to trust property State Highway 33, Okere Falls
February 2015	Scion, Rotorua	Kaumatua George Mutu (1)	Discussed research planned at Scion, and requested an invitation to speak at the marae about biological control research
14 May 2015	Scion, Rotorua	Kaumatua George Mutu (1)	Discussed research planned at Scion, and requested an invitation to speak at the marae about biological control research
5 July 2015	Hurunga Te Rangi Marae	Hurunga Te Rangi elders including Kaumatua George Mutu (16)	Toni Withers, Nelson Meha and Russell Burton to hui – spoke on biological control research underway at Scion. Provided a Scion contact point for further questions and offered to host a group visit to our facilities at Scion. Question asked: what impact would eating the *Eadya* wasp have on native insectivorous birds like piwakawaka?
7 August 2015	Auckland Airport Marae	Better Border Biosecurity Biosecurity Hui (50)	John Charles spoke on behalf of Toni Withers (sick), about how we conduct biosafety testing to address risks of new species to the NZ biota
12 Sept 2015	At Scion, Rotorua	Sastri Nuri Paengaroa B trustee (1)	Impact of leaf diseases and *Paropsis* on their *E. nitens* plantation
17 Nov 2015	Paengaroa B block SH 5	Sastri Nuri and Paengaroa B trustees (3)	Observed in field the *E. nitens* plantation and impact of *Paropsis* and leaf spots on the growth of the trees
8 March 2016	Scion, Rotorua inside containment facility	Te Taumata o Ngati Whakaue (12)	What is biological control and how do we conduct biosafety testing to assess safety of *Eadya*. Questions included “Will the wasps sting?: “Will they become pests?” and “Can you get rid of them if they do become pests?”

23 August 2016	Selwyn Insley	Hurunga Te Rangi Hapu representative (1)	Discussion on how to progress future engagement with Hurunga Te Rangi on biological control. Agreed to host a hui for marae members at the Scion containment facility
9 February 2017	Bev Purdie	Manawhenua Ki Mohua (1)	Emailed our proposal to search for native beetles in Kahurangi National Park for host testing against *Eadya*
10 March 2017	Nelson	Manawhenua Ki Mohua monthly meeting	Greg Napp (DOC) presented our proposal to search for native beetles in Kahurangi National Park for host testing against *Eadya*. They were supportive and the permit was granted.
30 March 2017	Scion, Rotorua	Hui for Hurunga Te Rangi members (1)	Scion hosted the hui at the Scion containment facility to discuss *Paropsis* and GWA biocontrol projects. Poor attendance, postponed.
April 3, 2017	Whangarei Forum North	Northland Maori Forestry Forum (~100)	Vicky Hodder presented on Scion's research including the *Paropsis* biocontrol project, and handed out leaflets
26 October 2017	Ngai Tahu	30 minute presentation to the HSNO Komiti (6)	Toni Withers presented at the HSNO Komiti at Ngai Tahu, on the *Eadya* proposal. They urged Scion to test as many native beetles as possible
Feb 2018	Mailing list	Preapplication consultation mailed out (22 iwi groups)	Replies received seeking additional information from Joey Tahana, Ngati Pikiao Environmental society. We replied that this committee no longer has this particular role, and explained the risks of *Eadya*
April 2018	Mailing list	Preapplication complete data summary mailed out to (22 iwi groups)	Nick Hume, Wairarapa Moana Inc. Trust, requested more info about potential interactions with bees. We replied they may interact occasionally within flowers, but little else.
12 April 2018	You-tube Video	Video about Paropsis biocontrol released on Scion You-Tube site	https://youtu.be/ASu-DDIlo-g 84 views and 5 likes to 1st July 2018
May 23 2018	Te herenga Regional Hui	Te Manuka Tutahi, Whakatane, opportunity to speak on biocontrol project proposed by Scion (20)	Questions included wider impacts of biocontrol on species in the food web. Why can't birds control the *Paropsis* beetle? How do we avoid making the same mistakes as in the past, bringing in rabbits, stoats, weasels etc.? Why would we care about the health of an Australian tree? Will the parasitoid spread myrtle rust? Do eucalypt plantings increase the risk of spreading myrtle rust to native trees?

			You have shown native beetles did get impacted, how will you know they won't start preferring that beetle rather the *Paropsis*? When all the *Paropsis* are gone, what will they feed on then? Another wasp, haven't we already got enough wasps stinging us?
28 May 2018	Thomas Malcolm	Te Turi Whakamataki	Sent copy of pre-application and complete data. Acknowledgement that he has sent it on to the executive
July 2018	Dawn Paewhenua	Te Pumautanga o Te Awara Trust	Acknowledged receipt of proposals and alert to change of mail box

Summarised outcomes:

During our face-to-face meetings and other forms of engagement (Table 2), Māori expressed a general concern about the risks of biological control as a management tool. Introducing an exotic organism into New Zealand does not sit comfortably alongside the deep connection they feel between humans and the natural world as kaitiakitanga. Māori have experienced and are concerned by the significant degradation of the environment since European colonisation. Parallels were drawn by some between the current proposal to introduce "yet another species claiming it will be beneficial" and the history of past, irresponsible introductions of exotic organisms. Examples given during consultation were possums, rabbits, stoats, snails, and numerous ornamental plants that have since become environmental weeds. No specific written views from iwi or hapu or other Māori interest groups were received despite extensive communication of our proposal to 22 different groups with recognised interests in forestry (Table 3). Several common threads were expressed verbally by Māori during our face-to-face meetings. These included:

- Many iwi have a strong desire to develop their lands and build the Māori economy. Forestry is a significant part of this vision, and if this introduction makes eucalypt trees more profitable to grow then this could be beneficial.
- Many iwi have an active interest in the manuka honey industry, and sought assurance that the biological control proposal was compatible with this. As gum trees are winter flowering they hold value in feeding bees through the winter when manuka is not flowering.
- Many Māori are opposed to the use of pesticides on their own land and elsewhere. This view is formed from the potential harmful effects on human health and non-target organisms. Spraying forestry plantations with a generalist insecticide is not something that they support. If the introduction of a biological control agent could prevent or reduce the need for spraying then this would be viewed as a very beneficial outcome.

- Some preferred a future vision where native forest giant species (e.g. totara, rimu) were grown instead of Australian *Eucalyptus* species as a sustainable supply of future timber needs. However some iwi hold assets that include *Eucalyptus* plantations (e.g. Tūhoe Manawarū).
- The most common concern raised by the proposal was whether this wasp could “sting people”, and would become a nuisance like the German wasp. Assurance was always given that parasitoids cannot sting people and will not form colonies as they are not vespulids.
- One query was whether the proposed biocontrol agents would be harmful to native birds if they ate them, or that they might adapt to the local environment and start attacking native beetles. Mistrust was expressed about whether such an insect could change over time and become a problem later on, as has occurred with weeds that have spread throughout the landscape.

Table 3. Pre-application consultation mailing list

Name	Iwi/ Group	Location
Tania Pene	Te Runanga a Iwi o Ngapuhi	Kaikohe
Bryce Smith	Ngapuhi HSNO Komiti	Kawakawa
Pita Tipene	Te Tai Tokerau Maori Forests Inc	Kaeo
Tame Te Rangi	Te Runanga o Ngati Whatua	Whangarei
Vanessa Eparaima	Raukawa Settlement Trust	Tokoroa
John Bishara	Tuwharetoa Maori Trust Board	Turangi
Kelly Martin	Tuwharetoa Settlement Trust	Taupo
Bronco Carson	Te Runanga o Nati Whare	Murupara
Karen Vercoe	Te Pumautanga o Te Arawa Trust	Rotorua
Wally Tangohau	Te Pumautanga o Te Arawa Trust	Rotorua
Karen Vercoe	Te Arawa Lakes Trust	Rotorua
Roku Mihinui	Te Arawa Lakes Trust	Rotorua
Hohepa Maxwell	Tapuika Iwi Autority Trust	Te Puke
Piki Thomas	Ngati Pikiao Iwi Trust	Rotorua
Ngarepo Eparaima	Tuhourangi Tribal Authority	Rotorua
Evelyn Forrest	Ngati Tahu Ngati Whaoa Runanga Trust	Reporoa
Te Hau Tutua	Tuhoe - Te Uru Taumatua	Taneatua
Rereata Rogers	Tuhoe - Te Uru Taumatua	Taneatua
Grant Huwyler	Ngati Wairiki-Ngāti Apa	Bulls
Jonathan Dick	Ngati Kahungunu Iwi Incorporated	Hastings

Max Temara	Hinepukohurangi Trust	Ruatahuna, Minginui
Paul Quinn	Ngati Awa Group Holdings	Whakatane
Edward Ellison	Ngai Tahu	Christchurch

5. Risks, costs and benefits

Provide information of the risks, costs and benefits of the new organism(s).

These are the positive and adverse effects referred to in the HSNO Act. It is easier to regard risks and costs as being adverse (or negative) effects and benefits as being positive. In considering risks, cost and benefits, it is important to look at both the likelihood of occurrence (probability) and the potential magnitude of the consequences, and to look at distribution effects (who bears the costs, benefits and risks).

Consider the adverse or positive effects in the context of this application on the environment (e.g. could the organism cause any significant displacement of any native species within its natural habitat, cause any significant deterioration of natural habitats or cause significant adverse effect to New Zealand's inherent genetic diversity, or is the organism likely to cause disease, be parasitic, or become a vector for animal or plant disease?), human health and safety, the relationship of Māori to the environment, the principles of the Treaty of Waitangi, society and the community, the market economy and New Zealand's international obligations.

You must fully complete this section referencing supporting material. You will need to provide a description of where the information in the application has been sourced from, e.g. from in-house research, independent research, technical literature, community or other consultation, and provide that information with this application.

5.1 RISKS

A. Potential risks on the environment, in particular on ecosystems and their constituent parts

In recent decades there has been considerable debate about the risks associated with classical biological control (Barratt et al., 2010). Therefore the research emphasis has been on selecting biological control agents that are most likely to be highly effective at reducing the population densities of the target pest or weed, while being unlikely to impact on non-target species. The primary risk from the proposed release of *E. daenerys* as a biological control agent of *P. charybdis* is its potential to have an adverse effect on non-target host beetles (Table 4). New Zealand has about 156 native species of leaf beetles (Coleoptera: Chrysomelidae) (Leschen & Reid, 2004), while another 30 species have been either accidentally introduced and become invasive pests, or deliberately introduced as beneficial weed biological control agents (MacFarlane et al., 2010). A comprehensive host specificity testing programme to quantify the direct risks posed by *E. daenerys* to non-target beetles in the New Zealand environment addresses this issue, identified as risks 1 and 2 in Table 4 (Withers et al. 2018, Appendix Five).

Other risks presented by introducing a new organism such as *E. daenerys* into the New Zealand environment are known as indirect effects. Indirect effects include potential impacts on other organisms via displacement of native species, competition, or other flow-on impacts within food webs. Any impacts that have the potential to create deterioration of natural habitats are considered. In-house expertise and external consultation were used to establish potential indirect effects arising from interactions between *E. daenerys* and other species across trophic levels. Ecosystem complexity invariably relegates the analysis of these complex types of food-web interactions to qualitative evaluations only (Barratt et al., 2010) and the indirect risks, listed as 3 - 5 in Table 4, fall into this category.

Table 4. Summary of sources of the main risks posed by the unique characteristics of *Eadya daenerys,* the proposed new organism for release. Points identified as a result of Scion in-house expert opinions and pre-application consultation with iwi (Table 2).

Source of the risk – characteristics of organism	***Possible reasons for event triggering the risk***	***Adverse Effect***	***Exposure Pathway***
1. Female parasitoids may attack larvae of native sub-alpine Chrysomelinae beetles and cause mortality (e.g., *Allocharis* sp., *Chalcolampra*, sp.) even if they cannot form a self-sustaining population	Female parasitoids may be blown on wind to sub-alpine habitats that lack *Eucalyptus* sp. and *P. charybdis*. Such parasitoids may attack native chrysomelid larvae even though they are less attractive than *P. charybdis*	Increased mortality of native beetles reducing their population size.	An adult wasp actively flies or is carried on wind currents out of its preferred habitat by a wind event
2. Female parasitoids may attack beneficial Chrysomelinae beetles (e.g., *Chrysolina abchasica, Gonioctena olivacea*) and cause mortality even if they cannot form a self-sustaining population	Weeds present beneath *Eucalyptus* spp. may have beneficial biocontrol agents feeding on them and become a target for oviposition even though they are less attractive than *P. charybdis*	Increased mortality of other biological control agents	An adult flying wasp

3. Indirect effects to other organisms caused by a reduction in *P. charybdis or Trachymela* populations	If *Eadya* successfully reduced *P. charybdis or Trachymela* populations, the reduction in beetles could have indirect effects on other organisms	Birds or other insects using *P. charybdis* or *Trachymela* beetles as food may have to switch to an alternative prey items	Indirect food web effects
4. New species of parasitoid is eaten by native birds and is unpalatable	Many birds catch flying insects on the wing and *Eadya daenerys* flies during November and December	Although most birds are generalists in terms of prey and many species such as piwakawaka are also present in Australia, they may be distasteful.	An adult flying wasp
5. Parasitoids take nectar from plants as food, in competition with other species	Parasitoids commonly drink drops of water and plant exudate	Reduced quantities of nectar available for other insects	An adult flying wasp

Process for selecting test species

In order to boost confidence that the most appropriate non-target species were chosen for laboratory host specificity testing, two test list selection methods were compared: 1) The traditional best-practice method of non-target species selection (Kuhlmann et al., 2006; Withers et al., 2015), and 2) the Priority Ranking Of Non-Target Invertebrates model (PRONTI), a tool designed to remove subjectivity from selection of invertebrate species for host-specificity testing (Withers et al., 2018). The two published papers that discuss the two test list selection methods in detail, the traditional method (Withers et al., 2015), and the PRONTI tool (Withers et al., 2018), are attached to this application in Appendix Four, and we summarise just the key findings here.

The key point is that New Zealand does not have any endemic species of *Paropsis*. The exotic pests *Paropsisterna beata, Paropsisterna variicollis, Trachymela sloanei, Trachymela catenata* and *Dicranosterna semipunctata* are phylogenetically the most closely related species to *P. charybdis* (Reid, 2006). Collectively they all belong to the tribe Chrysomelini and are all invasive species of Australian origin. Host range data obtained in the field confirms only *P. charybdis* and three species of *Paropsisterna* are field hosts of *Eadya daenerys* (Peixoto et al., 2018). In addition to using *P. charybdis* as a control beetle in all host tests, both PRONTI and the traditional host testing list agreed on the usefulness of testing two or three of these exotic non-target pest species to delimit the host range and oviposition behaviour of *Eadya daenerys.*

Chrysomelinae

The closest endemic species to *Paropsis or Paropsisterna* in New Zealand are from the subfamily Chrysomelinae: *Allocharis*, *Aphilon*, *Caccomolpus, Chalcolampra* and *Cyrtonogetus* (Leschen & Reid, 2004). These genera represent 40 described species, with some taxa awaiting description. Most New

Zealand chrysomelines are small (1-5 mm) and have been collected by beating adults from ferns or from tussock swards at night in mountainous areas of the South Island. All described species are classified by the Department of Conservation (DOC) as “Naturally Uncommon” (Leschen et al., 2012). Seldom are larvae collected with adults. The larvae of many species, and hence their biology, host plants, and distribution, are largely unknown. Wardhaugh et al. (2018, Appendix Three) summarises in detail all currently available knowledge and distribution data. Both PRONTI and the traditional host testing list method recommended we test a number of the endemic species. We aimed to collect the largest two species of endemic beetle for host testing against *Eadya daenerys.*

Galerucinae

The Galerucinae are the phylogenetic sister group of the Chrysomelinae (Reid, 1995). New Zealand Galerucinae belong to either the subtribe Luperina (tribe Galerucini) or the tribe Alticini. Luperina are commonly referred to as rootworms. The Alticini have more variable larval biologies (Samuelson, 1973). The larvae of all endemic species are believed to feed cryptically on plants roots where they are unlikely to be exposed to *E. daenerys* (Wardhaugh et al. 2018, Appendix Three). The PRONTI model ranked five endemic galerucines in the top 18 of a potential host testing ranked list (Withers et al, 2018, Appendix Four) but in the traditional list no endemic species were listed due to the root-feeding larval biology. Therefore as a substitute for endemic Galerucinae species, the traditional list instead chose to test two exotic species originating from the northern hemisphere, both with leaf-feeding larvae: *Agasicles hygrophila* (alligator weed flea beetle) (Coleoptera: Alticini) and *Lochmaea suturalis* (heather beetle) (Coleoptera: Luperini), both of whose larvae remain exposed on the leaves for three instars before pupation (Withers et al., 2015).

Beneficial Chrysomelidae

The value of non-target species to people is an important aspect of all non-target test list selection methods. Both PRONTI and the traditional list considered all valued species of chrysomelid beetle (Withers et al., 2015; Withers et al., 2018). Following consultation with Landcare Research scientists, the traditional list included six beneficial species for testing, whereas PRONTI only ranked three beneficial species in the top 20. The traditional list included two species even less closely related to *P. charybdis* to increase the certainty that beneficial non-target beetles would not be at risk.

Process/methods used for laboratory host testing

No-choice physiological host range tests are considered to be the most definitive for determining whether a parasitoid poses a risk to non-targets. This is because no-choice tests force a parasitoid into contact with non-target larvae for an extended period of time, with no means of escape, and no alternative prey. Our no-choice testing procedure placed one female *E. daenerys* in a 500ml plastic cage, with a sprig of foliage on which 8 larvae of the non-target beetle were feeding, and all were left for 24 hours. The parasitoid was then removed and the larvae reared until: 1. *E. daenerys* parasitoids emerged from them; 2. they reached their pupal stage, which indicates no parasitism; or 3. they were dissected if they died prematurely as larvae.

Behavioural assays have the potential to provide even more important insights into the degree to which different non-target species stimulate the parasitoid to approach and oviposit (Withers & Barton Browne, 2004). The behaviour of individual *E. daenerys* was observed in experimental arenas that consisted of large, clean glass petri dishes measuring 140 mm diameter x 20 mm high, and under two test conditions: either sequential no-choice tests or two-choice tests. For the sequential no-choice tests, one female *E. daenerys* was observed for 10 minutes with either eight target or eight non-target host larvae settled onto a leaf or sprig of their host foliage, using an A-B or B-A sequence (representing whether the target larvae were presented to the parasitoid first (A) and the non-target larvae presented second (B), or vice versa). For the two-choice tests, one female parasitoid was observed for 25 minutes with two sprigs of foliage present in the arena at the same time: one sprig of *E. nitens* bearing eight larvae of the target larvae *P. charybdis*, plus one sprig of the non-target foliage bearing eight of the non-target larvae (A+B) appropriate to whichever species was being tested. Time recording began when the parasitoid contacted a host plant. All times spent on the plants were recorded, along with all interactions with larvae, such as attempted or successful sting-insertions (attacks), as well as attempting to sting but failing (misses) and probing other objects such as larval frass (Withers et al., Appendix Five). Target and non-target larvae were reared only when attack-insertions were observed during the behavioural observations. This potentially added more data to the rearing undertaken after the no-choice physiological host range tests.

Results

The following sections summarise the results of the host testing, firstly in relation to the risk to native beetles, then secondly in relation to risk to beneficial beetles, as identified in Table 4.

1. **Risk to non-target native beetles**

Three field trips (20 person-days search effort) were undertaken to Kahurangi National Park and the Takaka Hill Scenic Reserve (DOC Permit 54216-RES; see Wardhaugh et al. 2018, Appendix Three) searching for the species of most interest. These were the larger *Allocharis* species, such as *A. tarsalis* or *A. robusta*, (Hudson 1934), the larger *Caccomolpus* species (*C. amplus*), and *Chalcolampra speculifera (*even though this species is reported to be nocturnal, hiding during the day in refuges excavated into the stems of their host plants). These particular native Chrysomelinae are restricted to high-elevation sites in the South Island. The search effort in Kahurangi NP was spread across ~20 square kilometres. Live larvae and two adult beetles of one species were collected from *Veronica albicans* (Pétrie) Cockayne (host identified by M. Scott, Scion) (Wardhaugh et al 2018, Appendix Three). Identified subsequently as *Allocharis* nr. *tarsalis* Broun (by R. Leschen, Landcare Research) they were collected from seven sites between 1200 and 1400m above sea level. *Allocharis* nr *tarsalis* larvae feed externally on the leaves of the host plant during the day (similarly to the closely-related species *A. robusta*). The larvae are black in colour and once mature reach 10mm in length. They feed on the leaf by scraping away the surface layers, which results in dark scars. The adult beetles are nocturnal. The larvae were returned to the laboratory in Rotorua for host specificity testing against *E. daenerys.*

We did not locate a population of *Chalcolampra speculifera* despite detailed searches of *Olearia colensoi*, *Celismia* spp. and *Olearia* spp. specifically looking for leaf damage and stem refugia (swellings). We are confident that our search effort would have detected any additional day-active leaf-feeding beetles if they had been present on the host plants we searched (*Veronica spp.*, *Olearia spp., Celmisia* spp., *Dracophyllum* spp., *Brachyglottis* spp*., Coprosma* spp., *Olearia* spp., *Hoheria* spp.). This field research is described in more detail in Wardhaugh et al. 2018 (Appendix Three).

The laboratory host specificity testing showed that *A. nr tarsalis* is an incomplete physiological host for *E. daenerys*, which cannot form a population on this species:

- *A*. nr *tarsalis* had a high rearing survival of 90%, which surpassed that of the exotic species.
- No-choice assays resulted in internal parasitism by *E. daenerys* in 7.5% of *A.* nr *tarsalis.*
- Parasitised larvae did not complete development to the pupal stage. After being held for an additional 20 days they were killed and dissected.
- Internally infested individuals contained *E. daenerys* first instar head capsules, encapsulated first instar larvae, or some larger larvae. No *E. daenerys* larvae emerged or completed development in *A*. nr *tarsalis.*

Behavioural observations confirmed that *A*. nr *tarsalis* larvae were of low attraction to *E. daenerys* for oviposition. The number of *E. daenerys* attack-insertions on larvae, number of attack-fails, and the attack-insertion rate per time on the plant were all greater for the target *P. charybdis* than for the native *A*. nr *tarsalis*. This was observed in both two-choice assays and no-choice assays (apart from one behavioural measure that was not significantly different; see Withers et al. 2018, Appendix Five).

No *Eucalyptus* species that could be hosts of *P. charybdis* are recorded on botanical databases for Kahurangi National Park (Scion National Forest Herbarium, iNaturalist https://www.inaturalist.org, Australasian Virtual Herbarium, http://avh.chah.org.au) (Fig. 2B). Therefore, in addition to the geographical distribution of *A. nr tarsalis* in the subalpine zone (1,200–1,400 metres), we believe it is extremely unlikely that *A. nr tarsalis* will ever overlap with *E. daenerys*. The closest eucalypts are in the Motueka River valley east of Kahurangi National Park, approximately 5 km away, and 1100 m lower in elevation. We surmise that the only potential for *E. daenerys* to geographically overlap with *A. nr tarsalis* would be if individual parasitoids were to be blown with an easterly updraft up into the sub-alpine zone where *Veronica albicans* grows. On arrival, no populations of preferred hosts (*P. charybdis*) are present and *E. daenerys* could not then form a self-sustaining population in areas solely inhabited by *A.* nr *tarsalis* as it is not a physiological host of *E. daenerys*. As *E. daenerys* cannot establish a population and develop a preference for this non-target, the only potential negative impacts on *A.* nr *tarsalis* are mortality from any individual *E. daenerys* that locate and attack larvae during the month of December (the only time of year when phenological overlap will occur). Such parasitism would prevent those individuals from pupating. This scenario is likely to be a rare event, especially due to the low propensity of females to attack *A.* nr *tarsalis*.

The climatic suitability of *E. daenerys* to New Zealand is a further potential constraint on establishment and potential geographic overlap with non-target species. We implemented the Match Climates Regional model (in Climex™ v.3.3) to assess this risk. The method is explained in detail in Phillips et al. (2018). We applied the model to New Zealand to quantify the suitability of the sub-alpine climate matches to the known distribution of *E. daenerys* in Tasmania (see details in Pugh et al., Appendix Two). The resultant map shows that the majority of the Southern Alps are a very poor match (<0.4 Climate Match Index; values >0.7 are considered suitable) compared to the known distribution of *E. daenerys* in Tasmania*.* This poor match, indicated by the green colour in Figure 4 from Pugh et al. 2018 (Appendix Two), overlaps most geographical distributions where native Chrysomelinae have been collected, e.g., Ben Lomond, Mt Earnslaw, Mt Dick, and Arthur's Pass (see Tables 2 and 3 in Wardhaugh et al. 2018, Appendix Three). In its native distribution of Tasmania, *E. daenerys* has not been recorded in any alpine sites higher than Moina at 600m a.s.l. (Peixoto et al., 2018). To evaluate whether the same poor match was predicted for the geographic distribution of *A. nr tarsalis* we overlaid the larval collection localities (Appendices B and E in Wardhaugh et al. 2018, Appendix Three) (Figure 2A). This CLIMEX-MCR analysis does not rule out the possibility of *E. daenerys* reaching the habitat of *A. nr tarsalis* (CMI of 0.7-0.8). Although Figure 2 suggests some potential for geographical overlap, the MCR model used a climate surface spatial resolution in Tasmania of 50 by 50 km (Pugh et al. 2018, Appendix Two). Therefore Figure 2 may not accurately reflect the climate extremes that occur within a grid cell that covers both high elevation and lowland habitat. Kahurangi National Park is still devoid of any *P. charybdis* host trees (Figure 2B); therefore in the absence of paropsine host beetles, we conclude that there is a low risk that *E. daenerys* could persist there, even though Figure 2 indicates a CMI >0.7 for the *A*. nr *tarsalis* collection localities (Pugh et al. 2018, Appendix Two).

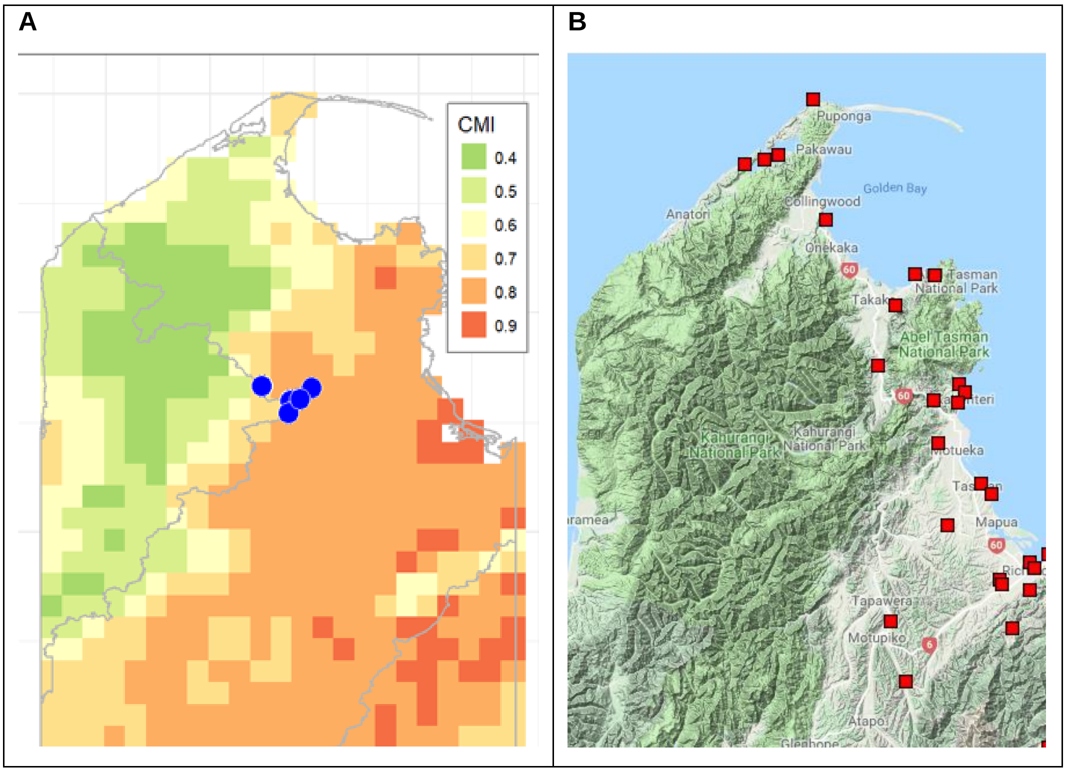


Figure 2: A. Known localities of *A. nr tarsalis* in Kahurangi National Park (blue dots) overlaid with predicted future *E. daenerys* distribution in the north-west Nelson region based on matched climate information (CLIMEX-MCR) from Tasmania. B. Recorded localities of *Eucalyptus* trees (red dots) in the same region (National Forestry Herbarium, Scion. 2018. NZFRI online dataset: nzfri.scionresearch.com, accessed on 22/08/2018).

2. Risks to non-target beneficial beetles

Six beneficial weed biocontrol agents were host tested against *E. daenerys* (Withers et al. 2018, Appendix Five). The potential risk posed by *E. daenerys* to these six species is discussed in detail in Appendix Five (Withers et al. 2018). The most important results are summarised here.

Non-target beetle survival to pupation averaged 68%. The best rearing survival in the biocontrol agents was for the broom leaf beetle *G. olivacea* (85%) and tradescantia leaf beetle *N. ogloblini* (85%). The worst rearing success to pupation (40%) was achieved with the tutsan leaf beetle *C. abchasica,* a problem inherent to the species. Landcare Research, from whom we obtained the colony, have experienced similar issues with this species (H. Gourlay, pers. comm). Evidence of attempted parasitism (incomplete physiological host status) was quantified by dissecting dead non-target larvae.

- None of the beneficial weed biocontrol agents tested were complete physiological hosts for *E. daenerys*.

- No-choice assays resulted in internal parasitism by *E. daenerys* only in the chrysomelines, *C. abchasica* (1.8%) and the broom leaf beetle *G. olivacea* (5.2%)
- Internally infested individuals showed the presence of *E. daenerys* first instar head capsules, encapsulated first instar larvae, and some larger larvae.
- No *E. daenerys* larvae emerged or completed development in any beneficial weed biocontrol agents.

In behavioural observations the number of larval attack-insertions, and the number of attack-fails and insect-attacks were consistently higher towards target *P. charybdis* larvae than towards any of the weed biocontrol agents. This was observed in both no-choice and two-choice assays. The *E. daenerys* attack rate per time on the plant (a behavioural measure of activity) against *P. charybdis* larvae was significantly higher than the attack rate on any beneficial biocontrol agent larvae in both the no-choice and two-choice tests. The only behaviour *E. daenerys* exhibited that was more frequent in the presence of non-target species compared with *P. char*ybdis was "disregard" or ignoring of non-target larvae encountered. There was one exception to this, where *E. daenerys* parasitoids participated in object attacks on *C. abchasica* in 12 of the 15 replicates of no-choice tests between these species (Fig. 3 in Withers et al. 2018, Appendix Five). During the bioassay *C. abchasica* larvae produced large round black frass pellets of a similar size to a paropsine larva. This frass may have been a visually stimulating cue for *E. daenerys* females, inducing attacking behaviours. Some object attacks were also directed towards the cut end of a tutsan twig.

Internal parasitism of the broom and tutsan leaf beetle larvae following exposure to *Eadya daenerys*, will result in minimal or no impact on field populations of these two species. This is because attraction to these larvae in behavioural assays was less than that shown towards target larvae (Fig. 2 in Withers et al. 2018, Appendix Five). It is likely that both broom and tutsan will be present in the same geographical areas of New Zealand as individual eucalypt trees or eucalypt plantations. If *E. daenerys* establishes it is likely that its geographical distribution will overlap with these non-target beetle species, and inter-specific interactions could occur if *E. daenerys* ever lands on these weeds to rest and groom. However, in our observations female *E. daenerys* were more likely to actively search for paropsine larvae to attack when they were in the presence of eucalypt foliage (T. Withers, pers. observations). Furthermore, in analysing the likelihood of attack in relation to ecological analogues (Paynter et al., 2010), none of the weed biocontrol agents are ecological analogues of the *Eucalyptus* leaf feeding beetles, and this suggests that none of them will be attacked by any host-specific parasitoids of *Paropsis or Paropsisterna spp.* (Withers et al. 2018, Appendix Five).

Risks to non-target pest chrysomeline beetles

Two exotic pest beetles that are closely related to *P. charbydis* were also included in host testing to quantify the behavioural and physiological host range of *E. daenerys*. These were the small tortoise beetle *Trachymela sloanei* and the blackwood tortoise beetle *Dicranosterna semipunctata* (Withers et al., 2015, Appendix Four). *Trachymela sloanei* established in New Zealand in 1976 and is a defoliating pest of *Eucalyptus* trees from mainland Australia. Larvae of *T. sloanei* feed nocturnally on young leaves, hence encounters with *E. daenerys* are likely to be rare, as current evidence shows that *E. daenerys* are diurnal (T. Withers, pers. observations). Laboratory behavioural attraction assays showed that *E. daenerys* was attracted to *T. sloanei* larvae, something not observed with other non-target species tested. In no-choice tests 62.5% of *E. daenerys* actively attacked *T. sloanei* larvae at least once, compared to 100% attack rates against *P. charybdis*. This was not a significant difference in attraction. These tests confirmed that *T. sloanei* was a physiological host in 13% of the larvae exposed to *E. daenerys.* Three of the five emergent parasitoid larvae from *T. sloanei* spun tiny unviable cocoons (less than 5 mg), one did not spin at all, and a fourth spun a 12 mg cocoon that was viable and produced a very small adult wasp (head capsule width 1.04 mm) confirming *T. sloanei* as a physiological host. This can be compared to *E. daenerys* development through the target *P. charybdis,* where viable spun cocoons weighed a mean of 84.8 mg (range 46-137 mg, n=30) and the resultant adult head capsule width had a mean value of 1.48 mm wide (Withers et al. 2018, Appendix Five). Probing of *T. sloanei* frass was observed in 38% of interactions. *T. sloanei* larvae may emit cues that stimulate *E. daenerys* attack, by producing similar chemical cues generated by feeding on *Eucalyptus* foliage. However, *T. sloanei* larvae are normally nocturnal and the act of transferring them to leaves during our experiments caused them to run very rapidly around the petri dish. This behaviour inadvertently exposed them to the parasitoid. We cannot accurately predict *E. daenerys* field parasitism rates in *T. sloanei* larvae, but they may be low, given the nocturnal-diurnal differences between the two species. *Trachymela sloanei* larvae have not been recorded as a host of *E. daenerys* in Australia. *T. sloanei* is small, with a mean pupal weight of 38.4 mg, which is near to the predicted minimal host size for *E. daenerys* of 35 mg (Withers et al. 2018, Appendix Five); hence it is likely to be a sub-optimal host.

Dicranosterna semipunctata is an exotic defoliating pest of *Acacia melanoxylon* (blackwood) that established in New Zealand in 1996 from Australia. Physiological host range assays resulted in a 1.6% internal parasitism rate; however, all were non-viable, with no adults emerging. *Dicranosterna semipunctata* despite being large enough is therefore considered an incomplete physiological host. Both no-choice and choice behavioural assays revealed few *E. daenerys* attacks, with most *E. daenerys* ignoring any *D. semipunctata* larvae encountered on blackwood foliage (Fig 3, Withers et al. 2018, Appendix Five). In choice tests 71% of *E. daenerys* disregarded *D. semipunctata* larvae in favour of *P. charybdis* larvae. Blackwood is often grown in similar locations to eucalypts in New Zealand. However, the combination of different host plants and the low attack rates in the behavioural assays suggest that *D. semipunctata* larvae are not emitting chemical cues that stimulate *E. daenerys* to attack, they are unlikely to be attacked in the field and are not physiological hosts (Withers et al. 2018, Appendix Five).

3. Risks due to indirect effects reducing prey items.

We established the possibility that indirect food-web effects related to *E. daenerys* could occur following reductions of the populations of the pest *P. charybdis* (likely) and the pest *T. sloanei* (unlikely). Reduction in populations of these two pests could reduce the normal prey items available to predators of these two species.

The only predators recorded attacking *P. charybdis* larvae are the predatory native bugs *Cermatulus nasalis* (Hemiptera: Pentatomidae) (brown soldier bug) and *Oechalia schellembergii* (Schellenberg's soldier bug) (Edwards & Suckling, 1980). Both species were shown by Edwards and Suckling (1980) to be able to complete development when supplied with *P. charybdis* larvae alone. The average prey consumption rate of *P. charybdis* larvae was one per day (Edwards & Suckling, 1980). They concluded the predatory bugs will have minimal impact upon *P. charybdis* populations in the field. As generalist predators they feed on a wide range of soft-bodied insect prey; hence are unlikely to be affected by a reduction in *P. charybdis*. The likelihood of flow-on effects then impacting upon other insects that are prey items for these two bugs is very low.

There are anecdotal reports of birds such as pheasants consuming *P. charybdis* beetles. Pheasants are widespread in rural areas and were introduced to New Zealand as a sport shooting bird. They are generalists and it is unknown how often they would consume eucalyptus-feeding beetles. It is likely they would switch prey items in response to any reduction in *P. charybdis* and *T. sloanei* resulting from the introduction of *E. daenerys*.

4 and 5. Other food-web impacts

Any species introduced to a new environment has the potential to affect other parts of the ecosystem, including air, water, fauna and flora, in ways that are not direct or obvious. Indirect negative effects such as damage to birds that may catch and ingest adult *E. daenerys* wasps as a novel food item are possible. We consider the risks to be low, as many birds use a wide range of insects as prey with no known negative effects. Birds such as grey warblers, fantail and morepork are also native to Australia or have Gondwanan close relatives, and these species have evolved with paropsine beetles and their parasitoid fauna feeding on eucalypts and acacias. There is no evidence in the literature of these insects being toxic to such birds, so we think it is unlikely they will be toxic to insectivorous birds in New Zealand.

There is also the possibility that *E. daenerys,* like any parasitoid, will use leaf exudates and floral resources such as nectar for food from time to time. The potential for this to cause competition with other species such as honey bees or native pollinators is uncertain. There is a potential for negative effects should *E. daenerys* compete with native species for floral resources. We know *E. daenerys* parasitoids only live as adults for approximately 40 days (Pugh et al. 2018, Appendix Two). Floral resources tend to be abundant during the months of November and December in most environments in which both *P. charybdis* and *E. daenerys* will be present. When *E. daenerys* finds itself in the same flower as a larger species of insect, such as a native fly or honey bee, we expect the larger or more aggressive insect will be the one to use that flower. Therefore there is a low risk that *E. daenerys* will create a new negative effect by competing with other native species within flowers.

Summary Table 5 of magnitude of risks

Source of the risk	***Adverse Effect***	***Likelihood of adverse effect occurring***	***Magnitude of effect (if it occurs)***	***Evaluated level of risk***
1. Female parasitoids may attack larvae of the native sub-alpine Chrysomelinae beetles and cause mortality (e.g., *Allocharis, Chalcolampra,* sp.) even if they cannot form a self-sustaining population	Reduces populations of valued native beetles, leading to extinctions and loss of native biodiversity	Unlikely	May attack some valued native species with magnitude ranging from **minimal** to **major**. Magnitude would depend on: a) the likelihood of the parasitoid being blown into sub-alpine areas where no eucalypts are present b) the likelihood of the parasitoid locating and attacking the alternative host larvae feeding externally during the day on leaves at the same time of year c) the other unknown population or parasitism pressures being felt by those same native species and populations Because we could only locate one species for host testing our estimated level of risk spans the range from minimal to major.	Insignificant to Medium
2. Female parasitoids may attack beneficial Chrysomelinae beetles and cause mortality (e.g., *Chrysolina abchasica, Gonioctena olivacea)* even if they cannot form a self-sustaining population	Reduces populations of valued beetles leading to a reduction in effective weed biological control	Probably low for those most closely related: tutsan leaf beetle and broom leaf beetle.	May attack some valued weed biocontrol species with magnitude ranging from **minimal** to **minor** Magnitude may depend on: • Species of beetle, only the chrysomelinae likely to be attacked • Geographical and phenological overlap of adjacent niches containing adult *E. daenerys* • Whether the parasitoid is deprived enough to attack a species that does not present an attractive cue.	Insignificant to Low

			• Other parasitism already occurring on those species	
3. Indirect effects to other organisms caused by a reduction in *P. charybdis or Trachymela* populations	Reduced food for predatory bugs may lead to some other insects being impacted	Highly unlikely	Predatory bugs are generalists and are unlikely to respond to a reduced availability of *P. charybdis or Trachymela. .*Effects on other prey species are likely to be insignificant.	Insignificant
4. New species of parasitoids become prey of native birds and are unpalatable	Unpalatable or toxic to birds	Highly unlikely	Magnitude could range from nil to minimal but only if *E. daenerys* was more toxic than other insects in the environment. Insectivorous birds such as fantails and pheasants are likely to be adapted to eating a broad range of prey containing a range of different plant-derived secondary compounds.	Insignificant
5. Parasitoids take nectar from plants as food, competing with other species	Reduced floral sources for other insects	Highly unlikely	These insects are so small the volume of nectar removed from a flower or sap from a cut leaf would have an insignificant impact on other insects.	Insignificant

B. Potential adverse effects on public health (including occupational exposure)

It is very unlikely that *E. daenerys* would pose a risk to human health. They are unlikely to be inhaled by people as they are approximately 6 mm long. When males form mating swarms for short times together it has been observed to be in the sun, high in the *Eucalyptus* canopy, presumably near to where un-mated females are "calling" from the foliage (T. Withers, pers. observations). Scion staff purposefully attempted to induce parasitoids to try to oviposit into human skin by smearing fresh *P. charybdis* frass on their finger tips and presenting this to the parasitoid. The parasitoid's stinger was too weak to pierce human skin (E. Peters and T. Withers, pers. observations). *Eadya daenerys* do not inject venom, nor do they form colonies. A Scion staff brainstorming exercise failed to identify any other risks presented by *E. daenerys* that could result in negative impacts on humans and therefore upon public health.

C. Potential adverse effects on the relationship of Māori and their culture and traditions with their ancestral lands, water, sites, waahi tapu, valued flora and fauna and other taonga

Face-to-face discussions reveal that many Māori have strong views against biological control (refer to section 4). There is a general dislike of invasive species, which have in the past disrupted the affinity Māori have with the natural environment. Sometimes this dislike is generalised to biological control, and there is sometimes disagreement over introducing what is seen as yet another invasive species into New Zealand, even for the purported benefit of managing the first pest. However, sometimes the dislike for existing invasive species means that Māori support biological control for its potential to bring harmony back into the ecosystem that has been affected by the pest.

Consultation with Māori about the biological control projects underway at Scion resulted in feelings of distrust being aired, particularly about the potential for escape of biocontrol agents from containment facilities during safety testing, and about whether these proposed biological control agents might become pests themselves (Table 2). Many opportunities have been taken to inform and educate local representatives about the likelihood of these risks.

There is a risk that an introduced parasitoid that ends up attacking New Zealand native beetles would have adverse effects on the relationship of Māori with valued flora and fauna and other taonga. We have undertaken a thorough investigation into the likelihood of non-target impacts on native beetles occurring (see Table 5 above), and conclude the risk to be insignificant to moderate. During pre-application consultation, no other potential adverse effects on Māori culture and traditions were identified in relation to this proposed biological control project.

D. Other potential adverse effects (such as New Zealand's international obligations, social or economic adverse effects, ethical issues)

No other potential adverse effects have been identified.

5.2 POTENTIAL BENEFITS

Table 6 Summary of benefits to New Zealand of introducing *Eadya daenerys*

Source and description of the benefit	***Likelihood of benefit effect occurring***	***Magnitude of effect (if it occurs)***
Economic benefits: Increased yield of susceptible Symphyomyrtus *Eucalyptus* species (Appendix One).	Dependent on successful biological control of 1st generation of *P. charybdis* by *E. daenerys*. Co-dependent on the probability of establishment:	Magnitude **moderate** on average: Magnitude of the benefit achieved will depend on percent parasitism of *P. charybdis* in relation to the degree of damage in different regions

	-CLIMEX modelling suggests all major eucalypt growing areas in NZ are suitable for establishment. -if approved, *E. daenerys* will be mass-reared and released in spray-free areas set-aside within plantations in all growing regions. -historical 63% establishment success rate of biocontrol agents previously released against forestry pests (Cameron et al., 1993) suggest establishment can be achieved. Estimate benefits **highly likely**	-27% parasitism achieved on *Pst. agricola* in Tasmania when competing with other parasitoids. In NZ no competition exists so control *could* be even higher. -economic modelling has shown this level of control has a growth benefit of 4.1 m^3 ha^{-1} per year that is valued at \$417 ha^{-1} per year. - potential to prevent \$5.8-\$7.2 million in losses to eucalypt forestry in NZ.
Reduced pesticide costs (Appendix One)	**Highly likely** that successful biocontrol will reduce pesticide costs. **Unlikely** that successful biocontrol will totally eliminate need for pesticides. -chemical applications may still occur under outbreak conditions, however outbreaks are less likely with parasitoid present. -changes to plantation manager behaviour in response to pest damage will be required.	Magnitude range of cost savings will range from **minor** to **moderate**. -\$1.0–\$2.6 million/year is total current pesticide costs. -potential to reduce pesticide cost to \$300,000 per year (saving \$1 to 2 million p.a.) if only 2000 hectares require one treatment.
Environmental benefits: Sustainability is the quality of minimising harm to the environment in order to maintain a human/ ecosystem equilibrium and supporting ecological balance. Utilising biological control to manage pest populations is sustainability at work.	**Highly likely** that successful biocontrol of *P. charybdis* will enhance sustainability of eucalypt forestry by reducing pesticide use.	Magnitude of enhanced sustainability will depend on the extent of pesticide reduction, range from **minor** to **moderate**.
Maintaining environmental certification (FSC and PEFC) of eucalypt plantations in NZ	**Highly likely** FSC certification will be retained with New Zealand plantation managers able to show	Magnitude will depend on pesticide reduction and certification

- FSC enables wood products to enter unique markets -PEFC permits consumer choice of products that are produced in accordance with sustainable practices	funding for, and promotion of, biological control. Derogation to use alpha cypermethrin for outbreaks likely to be retained while actively encouraging biological control.	requirements over time, range from **minor** to **moderate**.
Reduced pesticide inputs -Human health and ecosystem health (air, land, water) will be enhanced. -Non-target organisms protected (e.g. pollination services, aquatic organisms, soil invertebrates, decomposers) -conservation of biodiversity.	**Highly likely** (see reduced pesticide costs above) ecosystem health and biodiversity will be enhanced in eucalypt plantations should the need for pesticide use be reduced by *E. daenerys.*	Benefits will range from **minor** to **moderate** depending on the biodiversity within the eucalypt plantations and non-target organisms previously impacted by broad spectrum sprays.
Enhanced ecosystem services by promoting sustainably grown eucalypt plantations and woodlots in NZ (Appendix One). -carbon sequestration -habitats for taonga species -shelter for people and animals -shading for people and animals	**Likely** that all these ecosystem services will be promoted by enhanced biological control and reduced pesticide inputs, however they will interact in complex and difficult to measure ways.	Benefits of each ecosystem service enhancement will be on average **minor** (see Appendix One).
Increased biodiversity and sustainability within New Zealand plantations will promote human values and recreation (Appendix One)	Possible that human values and recreation will be enhanced, but this will depend upon access to eucalypt plantations and has not been quantified.	Nil to **minor** (as difficult to quantify, see Appendix One).

Economic benefits

Increased yield

The pulp and paper industry in New Zealand grows *E. nitens* for its fast growth rate and superior short fibre quality. This, and other Symphyomyrtus species grown on longer rotations for solid wood, are under constant threat of damage after they reach four years of age (Radics et al. 2018, Appendix One). Hardwood chips are either exported from the port of Southland or used at Kinleith Mill in the central North Island as a key ingredient in a pulp mix to manufacture packaging boards, including Kraft

Liner Board, Kraft Top Line and Semi Chemical Fluting (e.g. Oji Fibre Solutions Ltd). Pulp producers supplement *E. nitens* plantations with other hardwood species, such as the slower-growing *Eucalyptus fastigata* and *E. regnans,* which are more resistant to eucalyptus tortoise beetle attack. An in-depth analysis of the economics of pest management in New Zealand's *Eucalyptus* plantation estate (R. Radics et al, Appendix One) found that \$402-\$503 million worth of *Eucalyptus* plantations are at risk of being damaged by *P. charybdis*.

A major long-term study on the impact of leaf beetle defoliation on *E. nitens* growth helped us to quantify the potential economic impact of *P. charybdis* (Elek & Baker, 2017). Young trees that suffered defoliation late in the season for two consecutive years were at least 17% smaller in diameter compared to undefoliated trees over one 15-year rotation. This means they would need to be grown for three to four more years to reach the same stand volume as undefoliated trees at harvest. Plantation pest management needs to protect eucalypts from *P. charybdis* defoliation of 50% or more of the current season's adult foliage, and in particular, prevent defoliation from occurring in concurrent years (Elek & Baker, 2017). We incorporated these results into a growth and yield model to establish the impact of various yield losses on the value of New Zealand's plantation eucalypt estate (Radics et al. 2018, Appendix One).

The lost yield at harvest from *P. charybdis* damage in short rotation plantations was valued at \$1,600 ha^{-1} for low-severity, \$4,800 ha^{-1} for medium-severity, and \$9,700 ha^{-1} for high-severity damage. Based on the above costs of *P. charybdis* to the short rotation pulp and paper industry (which grows 15,300 ha. of species vulnerable to the pest), the potential yield loss in the absence of improved biological control of susceptible plantations in New Zealand is estimated at \$10 million/year.

Once *E. daenerys* is released, significant benefits will begin to accrue. Modelling indicates that effective biological control from *E. daenerys* would reduce tree damage from heavy defoliation to "light early season defoliation" with no on-going costs once the agent is established. Establishing *E. daenerys* as a biological control agent for *P. charybdis* will provide an average NPV of \$1,245 ha^{-1} over a sawlog 40-year rotation period for a *Eucalyptus* spp. stand. Effective biological control will prevent an average yield loss of 4.1 m^3 ha^{-1} per year in susceptible *Eucalyptus* stands, which is equivalent to \$417 ha^{-1} per year in value. Assuming 60-75% of New Zealand eucalypt plantations are susceptible to *P. charybdis*, effective biological control with *E. daenerys* could prevent \$5.8-\$7.2 million in losses per year (Radics et al. 2018, Appendix One).

Reduced pesticide costs

Effective biological control of *P. charybdis* will reduce the current costs associated with aerial spraying of insecticides (\$160 ha^{-1} per year for larger plantations, currently undertaken once or twice yearly). It is uneconomical for small plantations or woodlots (<10ha) to undertake aerial spraying at the current cost of \$340 ha^{-1} per year. Current management by chemical control (Rolando et al., 2016) costs an estimated $1.0–$2.6 million/year and the Net Present Value of the pest control of all susceptible *Eucalyptus* species is $30-$38 million in New Zealand over a 40-year rotation. Our calculations revealed that in many situations establishing *E. daenerys* as a biological control agent would be more cost-effective than chemical control. For instance, should an outbreak occur and damage is potentially severe it may still be important for plantations to be able to be protected by chemical control, but it is not economically justifiable as an annual application when damage is light to moderate. Also, aerial application of pesticides will always be an uneconomic method for woodlots less than 10 hectares in size, such as those owned by farm foresters (Radics 2018, Appendix One).

Environmental benefits of *E. daenerys* reducing *Paropsis charybdis* populations

Sustainable population suppression

Eadya daenerys females prefer to oviposit in young larvae of their hosts *Paropsis charybdis, Pst. agricola*, *Pst. bimaculata*, and *Pst. nobilitata*. Tasmania has a very high climatic match to the largest eucalyptus plantation areas of New Zealand. Research on climate matching between Tasmania and New Zealand suggests *E. daenerys* will not be climate-limited from establishing in all the major eucalypt growing areas in New Zealand (Pugh et al Appendix Two). We expect *E. daenerys* will show the same phenology in New Zealand as it does in Tasmania. The adults are active between November and the beginning of January in Tasmania. Therefore, when established, we expect *E. daenerys* will be a good phenological overlap with the vulnerable first generation of *P. charybdis* that currently almost completely escapes other biological control agents. Egg parasitism of *P. charybdis* during Nov-Dec in New Zealand is consistently only 4–10%, meaning over 90% of eggs hatch and go on to become spring-feeding larvae. *E. daenerys* can target and exert control over this generation. The second generation is already well controlled by egg parasitoids, so together the agents will complement each other (Pugh et al. 2018, Appendix Two).

Quantifying the exact impact *E. daenerys* will have on *P. charybdis* populations in New Zealand is difficult. In Tasmania, overall parasitism of *Pst. agricola* was monitored in the field over six years and on average *E. daenerys* was reared from 27.3% of larvae. In sentinel trials laboratory-raised *P. charybdis* larvae were left exposed in field sites for just 72 hours. In this short time *E. daenerys* parasitized 0 to 6.25% of larvae (Peixoto et al., 2018). However, the ecosystems in New Zealand and Australia plantations are far from identical, and in Tasmania, *E. daenerys* is directly competing for host larvae with numerous tachinid parasitoids such as *Balde striatum* Rice and *Paropsivora australis* (Macquart) (Rice, 2005). Tachinidae that attack paropsine larvae generally cause much higher parasitism than *E. daenerys* (up to 29% in *P. charybdis*) (Peixoto et al., 2018). (Tachinidae were not considered as biological control agents for New Zealand as they tend to have a wide host range). In New Zealand, free from this competition with tachinids, it is likely *E. daenerys* effectiveness will only be limited by host density. *Eadya daenerys* has a high fecundity (estimated by instantaneous egg load), with a mean of 975 eggs and a longevity of up to 44 days. Each female will therefore have a number of weeks at peak adult fitness in which to deposit as many of her eggs as possible into *P.*

charybdis larvae. In the laboratory, 90% *P. charybdis* larvae commonly survive to adulthood, but after being stung by *E. daenerys* the survival rate to pupation of *P. charybdis* reduces to 9% (Withers et al. 2018, Appendix Five). This 90% reduction in survival demonstrates the potentially high effectiveness of *E. daenerys* in reducing *P. charybdis* populations. Although *E. daenerys* has a relatively low intrinsic rate of increase because it undergoes only one generation annually, we estimate the benefits of introducing *E. daenerys* will be seen within a few years of its establishment in the field.

Maintaining environmental certification

Eucalyptus nitens plantation managers spray insecticides against *P. charybdis* to avoid economic losses caused by lost growth. Currently FSC certification plays an extremely important role in New Zealand's forest product export markets (Rolando et al., 2016). Currently FSC enables wood products to enter unique markets, or gain a price advantage over non-FSC products. *P. charybdis* can be sprayed with alpha cypermethrin only as an emergency pest management measure (called a derogation) (Rolando et al., 2016), without losing certification. If this derogation should lapse and not be renewed it risks loss of the entire market for FSC wood chip exports. Currently all SWEL forest products are FSC wood chips – 12,000 ha with woodchips valued at $27 /m^3 (G. Manley 2018, Appendix Six). Effective biological control and sustainable management of *P. charybdis* with reduced need for pesticide inputs will ensure the future of FSC certification for these *Eucalyptus* plantations (Radics et al. 2018, Appendix One).

Reduced pesticide inputs to the environment

The pesticide alpha-cypermethrin is a broad-spectrum synthetic pyrethroid, which has many potential harmful non-target effects. Alpha-cypermethrin is highly toxic to aquatic invertebrates, fish, and bees (World Health Organization, 1992). There will be significant benefits to the environment from a reduction in its use to target *P. charybdis*, although these benefits are difficult to quantify. The benefits of improved waterway quality as a result of reduced pesticide use in plantation forests will include ecosystem, environmental and human health, and freshwater-related recreational activities (e.g. fishing, swimming, and boating).

Enhanced ecosystem services

Planted *Eucalyptus* forests in New Zealand provide important environmental benefits. These include carbon sequestration, habitats for taonga species, shelter, shading and reductions in nitrate leaching. Such benefits are not considered in market transactions but their values can be approximated using environmental economic valuation techniques. The quantifiable environmental value of existing *Eucalyptus* plantings is estimated to be about $11 million per year but this should be considered indicative only, as the value of these ecosystem services can vary substantially across space and time, and with tree ages and forest management practices (Radics et al. 2018, Appendix One).

In conclusion, the benefits for New Zealand of introducing *E. daenerys* to enable sustainable biological control of the pest *P. charybdis* are numerous, and any reduction in broad spectrum pesticide use in forests will be positive. We strongly believe the benefits as listed in this section clearly outweigh the risks (section four) and urge the Authority to approve this application to release *E. daenerys*.

6. Pathway determination and rapid assessment

Under sections 38I and 35 of the HSNO Act your application may be eligible for a rapid assessment. The pathway for your application will be determined after its formal receipt, based on the data provided in this application form. If you would like your application to be considered for rapid assessment (as per the criteria below), we require you to complete one of the below sections. **Fill in the section that is relevant to your application only.**

6A. New organism that is or is contained within a veterinary or human medicine (section 38I)

6.1. Controls for organism

Describe the controls you propose to mitigate potential risks (if any). Discuss what controls may be imposed under the ACVM Act (for veterinary medicines) or the Medicines Act (for human medicines)

6.2. Discuss if it is highly improbable (after taking into account controls if any):

- The doses and routes of administration of the medicine would have significant adverse effects on the health of the public or any valued species; and
- The organism could form an undesirable self-sustaining population and have significant adverse effects on the health and safety of the public, any valued species, natural habitats or the environment

Do not include effects of the medicine or new organism on the person or animal being treated with the medicine

6B. New organism (excluding genetically modified organisms) (section 35)

6.3. Discuss if your organism is an unwanted organism as defined in the Biosecurity Act 1993

It is not unwanted.

6.4. Discuss if it is highly improbable, after taking into account the proposed controls, that the organism after release:

- Could form self-sustaining populations anywhere in New Zealand (taking into account the ease of eradication)

- Could displace or reduce a valued species
- Could cause deterioration of natural habitats,
- Will be disease-causing or be a parasite, or be a vector or reservoir for human, animal, or plant disease
- Will have adverse effects on human health and safety or the environment

We hope the organism will form self-sustaining populations, as above.

7. 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.

8. Checklist

This checklist is to be completed by the applicant

Application		**Comments/justifications**
All sections of the application form completed or you have requested an information waiver under section 59 of the HSNO Act	☒ Yes ☐ No (If No, please discuss with an Advisor to enable your application to be further processed)	
Confidential data as part of a separate, identified appendix	☐ Yes ☒ No	
Supplementary optional information attached:		
• Copies of additional references	☒ Yes ☐ No	
• Relevant correspondence	☒ Yes ☐ No	
Administration		
Are you an approved EPA customer?	☒ Yes ☐ No If Yes are you an: Applicant: ☒ Agent: ☐	
If you are not an approved customer, payment of fee will be by: • Direct credit made to the EPA bank account (preferred method of payment) Date of direct credit: 6 June 2018 • Cheque for application fee enclosed	☒ Yes ☐ No ☐ Payment to follow ☐ Yes ☒ No ☐ Payment to follow	
Electronic, signed copy of application e-mailed to the EPA	☒ Yes	

Signature of applicant or person authorised to sign on behalf of applicant

☒ I am making this application, or am authorised to sign on behalf of the applicant or applicant organisation.

☐ I have completed this application to the best of my ability and, as far as I am aware, the information I have provided in this application form is correct.

12 - 9 - 18

Signature	**Date**

Request for information waiver under section 59 of the HSNO Act

☐ I request for the Authority to waive any legislative information requirements (i.e. concerning the information that has been supplied in my application) that my application does not meet (tick if applicable).

Please list below which section(s) of this form are relevant to the information waiver request:

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

LIST OF APPENDICES:

Appendix One.

Radics RI, Withers TM, Meason DF, Stovold T, and Yao RT. 2018. Economic impact of eucalyptus tortoise beetle (*Paropsis charybdis*) in New Zealand. Scion report 61256.

Appendix Two.

Pugh AR, Withers TM, Peters E, Allen GR. 2018. The compatibility of the egg parasitoid guild of *Paropsis charybdis* (Col.: Chrysomelidae) in New Zealand with the predicted phenology of *Eadya daenerys* (Hymenoptera: Braconidae) a proposed new larval biocontrol agent. Scion report 61186.

Appendix Three.

Wardhaugh C, Pugh AR, Scott M, and Withers TM, 2018. Investigation into New Zealand endemic leaf beetles (Chrysomelinae and Galerucinae) and attempts to locate species in Kahurangi National Park for host testing against *Eadya daenerys*, a potential biocontrol agent. Scion report 60686.

Appendix Four.

Methods for drawing up a host testing list: Withers TM, Allen GR & Reid CAM (2015) Selecting potential non-target species for host range testing of *Eadya paropsidis*. New Zealand Plant Protection 68: 179-186 and Withers TM, Todd JH, Gresham BA & Barratt BIP (2018) Comparing traditional methods of test species selection with the PRONTI tool for host range testing of *Eadya daenerys* (Braconidae). New Zealand Plant Protection 71: 221-231.

Appendix Five.

Withers TM, Todoroki CL, Allen GR, and Pugh A. July 2018. Host specificity testing predicts *Eadya daenerys* (Hym.: Braconidae), a potential biological control agent for the invasive pest *Paropsis charybdis* will be host specific to Paropsini (Col.: Chrysomelidae: Chrysomelinae). Unpublished manuscript.

Appendix Six.

Manley, G. Southwood Export Limited. Letter in support of the application.

GLOSSARY of TECHNICAL TERMS

Broad-spectrum pesticides – These are pesticides that are designed to kill or manage a wide variety of organisms, unlike a selective pesticide, which may target only one type of insect pest.

Classical biocontrol – Natural enemies from the country of origin of the pest are identified and one or more are imported and released to control the pest. It is expected that the biological control agent will establish permanently from the relatively small founder populations released, and they will reproduce and spread.

Derogation – A dispensation that applies in the case of FSC to the emergency use of an otherwise banned substance in a certified forest.

Endemic – These species occur naturally only in New Zealand

Endoparasitoid – A type of parasitic organism that lives and develops on the inside of its host for a significant portion of its life cycle

Exotic – Non-indigenous species living in New Zealand. They may have arrived accidentally or have been deliberately introduced to the country

Forest Stewardship Council (FSC) Certification – The Forest Stewardship Council (FSC) is an international organisation that promotes responsible management of the world's forests. It does this by setting environmental and social standards, and issuing certification on any products arising that it recognises as eco-friendly. https://ic.fsc.org/en

Hyperparasitoid – A parasite whose host, often an insect, is also a parasite, often specifically a parasitoid

Kraft Liner board (KLB) – A strong packaging cardboard made at Kinleith Mill from 100% virgin fibre, of which 12% is eucalypt fibre

Kraft Top Liner (KTL) – A strong and printable packaging cardboard made at Kinleith Mill from virgin fibre on the topsheet which comprises 5-10% eucalypt fibre. The remainder is recycled cardboard fibre

Larva – the distinct juvenile form of an animal that is generally very different from the adult form, including different unique structures and organs

NPV – Net Present Value. NPV is the present value (PV) of all cash flows (with inflows being positive cash flows and outflows being negative), which means that the NPV represents the monetary value, now, of a project's future cash flows.

OJI Fibre Solutions NZ Ltd – A company specialised in producing market pulp, paper and fibre-based packaging. Its Kinleith and Tasman mills are Forest Stewardship Council® (FSC®) chain of custody and FSC® Mix Credit supplier certified. The eucalyptus chips are produced in a mix with recycled and softwood fibres into specialist containerboard products called Kraft Liner board, Kraft Top Liner and Semi Chemical Fluting. http://www.ojifs.com/

Ovarioles – These are the tubes of which the ovaries of most insects are composed. Typically an insect will have two ovaries composed of many ovarioles.

Parasitoid – A parasitoid is an organism that lives in close association with its host and at the host's expense, and which sooner or later kills it.

PEFC – Programme for the Endorsement of Forest Certification.

Physiological host range – the number of species that can support the successful development of a species, and if that species is a parasitoid, can support that parasitoid from the egg stage through to the emergence of adults

Pupation – The process of entering and completing the pupal stage, which is the transformation stage some insects undergo between immature and adult forms.

Semi Chemical Fluting (SCF) – A corrugated packaging board manufactured at Kinleith Mill comprising 30% eucalypt fibre. It is used between the top and base sheet of a box.

Symphyomyrtus – The largest sub-genus of the plant genus *Eucalyptus*, which is a diverse genus of flowering trees and shrubs in the myrtle family, Myrtaceae. It was first described by botanist L'Hér in 1789 and most are native to Australia.

Synthetic pyrethroids – A group of synthetic analogues of the naturally occurring pyrethrin (derived from *Chrysanthemum cinerariifolium*). Synthetic forms are not as rapidly biodegraded and accumulate in the environment, yet they constitute the majority of commercial household and many agricultural insecticides.

SWEL – Southwood Export Limited. Southwood Export Limited (SWEL) was established in 1981 to process indigenous logs into woodchips for export to pulp and paper mills in Japan. Since then SWEL and client companies Kodansha Treefarms Ltd and Southland Plantation Forest Co process plantation grown timber, principally of eucalyptus. All forests managed by SWEL are located in Southland or South Otago, are PEFC and and have a total current net stocked area of approximately 12,600ha, all FSC® Chain of Custody certified https://www.swel.co.nz/

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