Draft Assessment Report – sterile codling moth

1. Provide information on the taxonomy of the species

Family: Tortricidae

Genus: *Cydia*

Species: *Cydia pomonella* (Linnaeus, 1758)

Taxonomic reference: Linnaeus, C. (1758). *Systema Naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis*. Editio decima, reformata [10th revised edition], vol. 1: 824 pp. Laurentius Salvius: Holmiae.

Synonyms: *Phalaena pomonella* Linnaeus, 1758, *Carpocapsa pomonella* (Linnaeus, 1758), *Carpocapsa pomonana* (Treitschke, 1830), *Enarmonia pomonella* (Linnaeus, 1858), *Laspeyresia pomonella* (Linnaeus, 1858).

Common Names: codling moth

2. Provide information on the status of the species under CITES

Cydia pomonella is not listed on CITES Appendix I or II.

3. Provide information about the ecology of the species

Adult codling moths have a wingspan of about 15–20 mm and are around 8–10 mm long at rest. They are grey marked with lighter grey wavy lines across the wings, and a distinctive copper patch at the tip of the wings (Figs. 1-2). Adults live for 8-11 days (Jones & Wiman, 2008). Male and female moths can be easily distinguished by genitalia.

Adult codling moths feed little, if at all. There are no known published accounts of adult codling moth feeding on ripe fruit in nature (Wenninger & Landolt, 2011).

Adult codling moths can be confused with several other species in the tribe Grapholitini, including *Grapholita molesta* (Busck), *G. funebrana* (Treitschke), *G. prunivora* (Ragonot)). Codling moth is most similar to dark specimens of *Cydia splendana* (Hübner) (Wearing et al., 2001). *C. pomonella* can be distinguished from the *Grapholita* species by its larger size and from all similar species by the presence of the distinct patch of slender, elongate sex scales that arises in a moderately deep fold of the cubital vein of the hindwing of the male (Wearing et al., 2001).

Mature larvae are 15-19 mm in length, cream coloured body with a yellow-brown head capsule (Fig. 3)

Fig. 1. Male

Fig. 2. Female

Walker, K. (2006) Codling moth *(Cydia pomonella)* Updated on 11/25/2011 10:34:41 AM Available online: PaDIL - http://www.padil.gov.au.

Fig. 3 Late instar larva

LepIntercept - An identification resource for intercepted Lepidoptera larvae by Todd M. Gilligan and Steven C. Passoa Identification Technology Program (ITP), Fort Collins, CO. Last updated February 2014.

Codling moth is believed to originate from Europe, Western and central Asia (Barnes, 1991). Codling moth is not a migratory species. Its spread around the world has mostly been through the movement of infested apple fruit.

Codling moth habitat is dependent on the presence of host fruit on which the larval stage feeds. These hosts are apple, pear, walnut, quince and occasionally stone fruit. Survival and development is largely determined by temperature and humidity. Optimal conditions are 32°C and 75% humidity. Larval development ceases below 0°C, however larvae are able to survive for long periods of time at low temperature and resume normal activity when temperature is returned to an optimal level.

Codling moth overwinters as a diapausing (hibernating) fifth instar larva in cocoons in and on the bark of host trees, in soil or on debris (Wearing et al. (2001). As day-length and temperature increase in Spring, larvae pupate and later emerge as adult moths.

A number of parasitoids, mostly hymenopterous, attack codling moth (CMISS, 1988).

Egg parasitoids include: *Ascogaster quadridentata* Wesmael (Hymenoptera: Braconidae); *Trichogramma minutum* Riley, *Trichomma enecator* Rossi *Trichogramma platneri* Nargarkatti, *Trichogramma evanescens* Westwood, *Trichogramma embryophagum* Hartig and *Trichogramma cacoeciae* Marcha (Hymenoptera: Trichorammatidae).

Larval and pupal parasitoids include: *Microdus conspicuous* Wesmael and *Microdus rufipes* Nees von Esenbeck (Hymenoptera: Braconidae); *Hyssopus pallidus* (Askew) (Hymenoptera: Eulophidae); *Cryptus sexmaculatus* Gravenhorst, *Ephialtes extensor* Taschenberg, *Ephialtes caudatus* Ratzeburg, *Liotryphon caudatus* (Ratzeburg), *Mastrus ridens* (Horstmann), *Pimpla aquilonia* Cresson, *Pimpla turionellae* (Linnaeus) and *Pristomerus vulnerator* Panz (Hymenoptera: Ichenumonidae); *D.cavus* (Hymenoptera: Chalcididae); and *Elodia tragica* (Meigen) (Diptera: Tachinidae).

Insect predators that prey on eggs and larvae of codling moth are predominantly generalists within the Neuroptera, Thysanura, Heteroptera, Dermaptera, Thysanoptera and Coleoptera. Various ant species have also been reported feeding on codling moth larvae (CMISS, 2019). Birds and spiders also prey on codling moth, mostly at the larval stage. There are no predators known to rely exclusively on codling moth as a food source.

Codling moth does not cause harm to humans or other species.

4. Provide information on the reproductive biology of the species

Female moths typically oviposit 50-100 eggs, attaching them singly to fruits, leaves or twigs. Eggs take 5-12 days to hatch. Emerging larvae enter fruit where they feed and develop through five instars, before pupating. Larval development is completed in 3-5 weeks. In areas where more than one generation occurs, pupation takes approximately two weeks. In Tasmania one and sometimes two generations occur, while 2-4 generations are seen on mainland Australia.

Codling moth overwinters as a diapausing (hibernating) fifth instar larva in cocoons in and on the bark of host trees, or in soil or debris (Wearing et al. (2001). As day-length and temperature increase in Spring, larvae pupate and later emerge as adult moths.

The sex ratio of adults is approximately 1:1. Adults are capable of mating 12 h after emergence (Gehring and Madsen, 1963). Females have their full complement of eggs at eclosion, which are matured and laid individually. Females start ovipositing the day after mating (Gehring and Madsen, 1963).

Compatibility testing has shown no evidence of incompatibility between codling moth populations from different geographical origins (Dyck, 2010). The species is not known to hybridise.

5. Provide information on whether this species has established feral populations

Codling moth has spread from its native range in Europe to Asia, Africa, North and South America, Australia and islands in the Pacific. It is now established in the temperate regions of all major continents, across almost 80 countries (CABI, 2019).

6. Environmental risk assessments of the species

Codling moth is restricted to a small number of non-native plant hosts (apple, pear, walnut, quince, stone fruit) and poses no direct risk to the environment.

Codling moth has been assessed in several import risk assessments conducted by the Department of Agriculture, including apples from China and New Zealand and stone fruit from the New Zealand and the USA (DA 2019). The species was considered to be a pest of quarantine concern for Western Australia and therefore required phytosanitary measures to be applied. In these assessments potential environmental risks were only considered to be associated with control measures, such as insecticides or biological control agents, being applied to manage the pest.

Sterile codling moths from the OKSIR facility in Canada have been approved for import and release in New Zealand since 2014. Sterile moths have been imported and released weekly during the apple season for over five years and no environmental impact has been observed (J Walker, *pers comm*, Jul 2019). Sterile codling moths have also been imported from OKSIR by USA, France and South Africa.

7. Assess the likelihood that the species could establish a breeding population in Australia

Codling moth has been established in Australia since at least the late 1850s (Department of Agriculture, 2019), and likely from multiple introductions.

8. Provide a comprehensive assessment of the potential impact of the species should it become established in Australia

Codling moth has been established in Australia since at least the late 1850s (Department of Agriculture, 2019) and the impact on agricultural systems and export market access is well established. The release of imported sterile codling moth in New Zealand apple production areas has resulted in a substantial reduction in the population of codling moth in these areas. Consequently, there has been a significant reduction in the use of insecticides to control this pest (J Walker, *pers comm*, Jul 2019).

9. What conditions or restrictions could be applied to the import of the species to reduce any potential negative environmental impacts?

Imports of the species could be restricted to sterilised individuals. Sterile insects have now been included in the *International Standard for Phytosanitary Measures 3 – Guidelines for the export, shipment import and release of biological control agents and other beneficial organisms*. Sterile organisms are considered to be beneficial organisms in ISPM 3 and were specifically included to help facilitate the transnational shipment of such organisms. Any import of sterile codling moths will be conducted in accordance with ISPM 3, relevant IAEA guidelines and subject to approval by the Department of Agriculture to ensure any risks are mitigated and that assurance systems are in place.

A commercial production facility for sterile codling moth in Canada has already been identified. Imported moths are derived from clean, factory culture with a strict quality control system in place, to ensure the population is free of parasitoids and pathogens. Codling moth are sterilised with gamma radiation (150 Gy) prior to release from the factory. This import pathway

has been used for the release of sterile codling moths in New Zealand since 2014 (J. Walker, *pers comm*, July 2019).

10. Summary of proposed activity

The purpose of importing sterile codling moth into Australia is for use in a Hort Innovation funded project to assess the feasibility of using sterile moths to control wild moth populations in commercial apple orchards. Released sterile moths mate with wild moths, resulting in sterile progeny.

Codling moth is the most significant pest of commercial apple production in Australia. Pest suppression requires multiple insecticide applications, in some cases every 10-14 days from petal fall to near harvest. Codling moth also attacks pear, quince, walnut and occasionally stone fruit.

Adoption of SIT to control codling moth in Australia could potentially deliver a number of beneficial economic, social and environmental outcomes:

- Reduced on-farm loss from lower levels of damaged fruit
- Reduced application of insecticides
- Delayed onset of insecticide resistance
- Reduced impact from future suspension of insecticides by the APVMA
- Increased economic sustainability
- Increased market opportunities, particularly to markets with nil tolerance to codling moth and to markets with demand for nil-residue fruit
- Increased opportunities for certified organic production
- Enhancement of agro-tourism activities that benefit from a clean environment and the perception of a clean environment
- Reduced impact or perceived impact of pest suppression operations on peri-urban residents living near orchard areas
- Protection of on-farm biodiversity with reduced insecticide usage
- Promote further uptake of SIT in other industries

The use of codling moth SIT in Canada since 1992 has resulted in most growers in the release areas no longer needing to spray insecticides to control the moth. Similar success has also been achieved in New Zealand, which has successfully imported and released sterile codling moths from OKSIR in Canada since 2014 (J Walker, *pers comm*, July 2019). South Africa has also run a codling moth SIT program since 2002, using moths reared in Western Cape, South Africa (Addison, 2005).

The sterile moths would be obtained from the Okanagan-Kootenay Sterile Insect Release Program (OKSIR) in British Columbia, Canada. The source is a factory culture, with each release sterilised with gamma radiation (150 Gy). Approximately 2500 moths per hectare of apple orchard would be imported weekly between November and February each year.

11. Guidelines on how species should be kept

Sterile moths will be transported as adults in petri dishes in cooled boxes according to International Air Transport Association (IATA) regulations. The moths will be transported directly to apple orchard trial sites in Tasmania and South Australia and released. All

packaging material associated with importing moths into Tasmania will be designated as prescribed matter under the Plant Quarantine Act 1997, requiring disposal by deep burial by a service provider acting under an approved arrangement, or, if deep buried by a provider without an approved arrangement, the deep burial observed by an authorised officer.

12. State/Territory controls

Codling moth is absent from Western Australia and is listed on the Western Australian Organism List (WAOL) as a prohibited pest. Import Requirement 61 for codling moth host produce entering Western Australia requires all produce to be treated with a methyl bromide.

Release sites under this project are limited to Tasmania and South Australia. No codling moth will be imported to Western Australia.

References

Addison M.F. 2005. Suppression of codling moth *Cydia pomonella* L. (Lepidoptera: Tortricidae) populations in South African apple and pear orchards using sterile insect release. Acta Horticulturae **671**: 555-557.

CABI. 2019. Invasive Species Compendium. Wallingford, UK: CAB International. www.cabi.org/isc.

Codling moth information support system (CMISS) 1988 Agricultural Research Service, International Plant Protection Center, Oregon State university, USA.

Department of Agriculture. 2019. Plant Risk Analyses. Available online at www.agriculture.gov.au/biosecurity/risk-analysis/plant (Accessed November 2019).

Dyck, V.A. 2010. Rearing codling moth for the sterile insect technique. In *FAO Plant Production and Protection Paper*; Food and Agriculture Organization of the United Nations (FAO): Rome, Italy, p. 197.

Gehring, R.D., Madsen, H.F., 1963. Some aspects of the mating and oviposition behavior of the codling moth, Carpocapsa pomonella. Journal of Economic Entomology **56**: 140-143.

Jones V.P. and Wiman N.G. 2008. Longevity of the adult codling moth, Cydia pomonella, and the obliquebanded leafroller, Choristoneura rosaceana, in Washington apple orchards. Journal of Insect Science **8**: 14. doi:10.1673/031.008.1401

Meraner A., Brandstätter A., Thaler R., Aray B., Unterlechner M., Niederstätter H., Parson W., Zelger R., Dalla Via J., Dallinger R. 2008. Molecular phylogeny and population structure of the codling moth (Cydia pomonella) in Central Europe: I. Ancient clade splitting revealed by mitochondrial haplotype markers. Molecular Phylogenetics and Evolution **48**: 825–837

Wearing, C.H., Hansen, J.D., Whyte, C., Miller, C. E., and Brown, J. 2001. "The potential for spread of codling moth (Lepidoptera: Tortricidae) via commercial sweet cherry fruit: a critical review and risk assessment" USDA Systematic Entomology Laboratory. 7. https://digitalcommons.unl.edu/systentomologyusda/7

Wenninger, E.J. & Landolt, P.J. 2011. Apple and sugar feeding in adult codling moths, Cydia pomonella: effects on longevity, fecundity, and egg fertility. Journal of Insect Science **11**: 161.

Attachment 1

Reply to questions raised.

- *Are there multiple sources of the SIT moths or only OKSIR?*

  No. OKSIR would be the only provider of the SIT moths. Sterile codling moths are not currently produced in Australia.

- *How certain can you be that the moths imported are all male? If females are accidently imported what is the confidence that they also be sterile?*

  Both males and females will be shipped and released. Female codling moth are much more sensitive to sterilising doses than males, such that the applied dose provides full sterility of females and partial sterility of males.

- *Do the females that mate with sterile males lay eggs that produce offspring (sterile?) or are the eggs unfertilised?*

  The OKSIR codling moths are treated with a dose of radiation that has been shown in several studies (Bloem et al., 2005; Blomefield et al., 2010) to sterilize the moths so that no viable offspring will be produced when the irradiated moths mate with wild fertile moths. Therefore, it is not possible for the sterile OKSIR moths released in a SIT program to establish separate and independent breeding colonies, or to contribute any genetic material to a wild breeding population.

  Some sterile progeny may be produced depending on the sterilising dose. Inherited sterility is usually preferred as moths sterilised at a lower dose will have higher fitness and competitiveness. Horner et al. (2016) consider that 150 Gy is the optimum sterilising dose for fitness and sterility.

- *Is this a trial or an ongoing program?*

  This is a feasibility study, so technically it is a trial. If the outcomes of this feasibility study are positive, then it would be up to industry/Hort Innovation as to whether they would support further releases as part of an ongoing area-wide management system.

- *If this is a trial, please provide additional details: eg size of the trial areas, how long the trial will take, how many moths in total will need to be imported and how often? Roughly total numbers of moths/month etc.*

  The trial areas are yet to be finalised, but they would be in the order of 100-150 ha over several apple growing regions in Tasmania and South Australia. Moths would be imported weekly from Canada by air between November 2021 and February 2022. The approximate number of moths released would be 2500 moths/ha per week.

- *Are there currently controls over importing codling moths in any states/territories particularly Tas and SA?*

  Codling moth is a prohibited organism for Western Australia.

There are no controls on importing codling moth into South Australia.

Tasmania allows entry of animals for biological control without restriction if release permits have been issued by DAWE.

- *Could moths import any pests/parasites that could be spread to native species?*

  No. The OKSIR insectary is maintained under strict sanitary protocols and constantly inspected for product quality assurance (Dyck, 2010). In addition, the procedure for collecting the moths from the emergence room requires the moths to fly to a specific UV light source during the scotophase. This procedure not only ensures that moths shipped from the OKSIR insectary are able to fly, it also is a behavioral barrier that would prevent the collection of most insects/mites that can infest poorly maintained facilities. After the moths have been collected, they are inspected again as they are loaded into the containers for irradiation and transport. A final safeguard to eliminate any possible viable insect/mite contaminants would be the irradiation procedure which would certainly sterilize the contaminant, because most insects/mites are much more susceptible to radiation treatment than moth species (IDIDAS, https://nucleus.iaea.org/sites/naipc/ididas/SitePages/International%20Database%20on%20Insect%20Disinfestation%20and%20Sterilization%20(IDIDAS).aspx)

- *Do the moths have any impact on any Australian native species?*

  The Australian plant Pest Database does not hold any records of codling moth from Australian native plant species. No impact to Australian native plant species have been recorded.

- *Is there the potential for trade in the species?*

  No.

- *What is it the moths current quarantine status?*

  Codling moth is currently widespread across all Australian pome fruit producing regions, with the exception of Western Australia and Northern Territory, where it is not known to occur. Codling moth is a prohibited organism for Western Australia.

- *What is the relative fitness of SIT (sterile insect technique) moths compared to the existing wild type moths. Do the SIT outcompete the existing moths or just outnumber them?*

  Fitness depends on the sterilising dose. Higher dose rates reduce fitness. Sterilised moths are expected to have lower fitness and reduced longevity compared to wild moths. Horner et al. (2016) consider that 150 Gy is the optimum sterilising dose for fitness and sterility.

- *J Walker, pers com – please provide some context – who, where, why. Has there been anything published from the NZ use of sterile codling moth?*

  J. Walker refers to Dr Jim Walker, Principal Scientist (Entomology), Plant and Food Research, New Zealand. Dr Walker is a coauthor of Horner et al. (2016), “Use of the sterile insect technique in New Zealand: Benefits and constraints”.