Arcte coerula (Guenée) (Lepidoptera: Erebidae): Biology, Ecology, Distribution and Qualitative Pathway Analysis

Prepared for the Coordinating Group on Alien Pest Species (www.cgaps.org) by

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1.0 Introduction

Arcte coerula (Guenée), commonly referred to as ramie moth, is native to Southeast Asia and feeds on nettles (Urticaceae) (Au and Wright, 2022). Its primary hosts are *Boehmeria* spp., particularly: ramie, *Boehmeria nivea*; Japanese false nettle, *Boehmeria niponoivea*; and nettle tree, *Boehmeria australis* (Ide, 2006; Jackson and Mua, 2019; Zeng *et al*., 2016). It is an economic pest only where ramie is commercially grown as an important natural fiber crop for making cloth and high-quality clothes (Ide, 2006; Zeng *et al*., 2016). Thus, generally an unknown pest, *A. coerula* is nowhere on the priority pest detection list of the United States Department of Agriculture (USDA)-Animal and Plant Health Inspection Service (APHIS)-Plant Protection and Quarantine (PPQ).

Arcte coerula was first discovered in November 2018 on Maui, where it wreaked havoc to māmaki trees, *Pipturus albidus*. Since then, it has spread widely on Maui and the Island of Hawaii (Au and Matsunaga, 2021; Au and Wright, 2022). The introduction and establishment of *A. coerula* endangers the vulnerable endemic nettle plant species in the native forests of Hawaii and poses a significant threat to the endemic native insects by competing for the same host plant resources (Au and Wright, 2023; Au and Wright, 2024).

The arrival of *A. coerula* to Hawaii is extremely ambiguous because of the complete absence of commodity importation pathways. The scope of this work is to conduct literature research on biology, ecology, and distribution of *A. coerula* and evaluate the gathered data to identify the likely pathways that may have resulted in the introduction of this pest to Hawaii.

2.0 Taxonomy

Animalia, Arthropoda, Insecta, Lepidoptera, Noctuoidea, Erebidae, *Arcte coerula* (Guenée) (Byrne and Moyle, 2019; https://www.catalogueoflife.org/data/taxon/922SL)

Noctuoidea is one of the largest superfamilies of the order Lepidoptera and includes the taxonomically diverse family Noctuidae (Byrne and Moyle, 2019; Zahiri *et al*., 2012). Based on molecular phylogenetic analysis on several subfamilies of the family Noctuidae, subfamily Erebinae is elevated to the family level (Zahiri *et al*., 2012), which consequently moves the genus *Arcte* from Noctuidae to Erebidae.

Synonym: *Cocytodes coerula* Guenée, 1852

3.0 Host Plants

3.1 Larval Hosts

Larvae of *A. coerula* are destructive and feed voraciously under natural field conditions on foliage of shrubs and trees belonging to family Urticaceae (Au and Wright, 2022), including perennial bichu grass, *Urtica dioica*; China ramie, *Boehmeria niponnivea*; ramie, *B. nivea*, *B. platanifolia*[1], and *B. spicata*; and māmaki tree, *P. albidus* (Arif and Kumar, 1995; Au and Wright, 2022; Ide, 2006; Kagata and Ohgushi, 2012; Yamada, 1933; Zeng *et al*., 2016). Other natural host plants of *A. coerula* are the deciduous broad-leaf mulberry, *Broussonetia kazinoki* in family Moraceae; thorn-elm, *Hemiptelea davidii* (Lee *et al*., 2008; Nishi, 1979) in family Ulmaceae; and the Chinese wingnut tree, *Pterocarya stenoptera* (Ohga *et al*., 1995) in family Juglandaceae. Under laboratory conditions, suitable hosts of *A. coerula* include paper mulberry, *Broussonetia papyrifera*; trumpet tree, *Cecropia obtusifolia*; and ōpuhe[2], *Touchardia oahuensis* (Au and Wright, 2023, Au and Wright, 2024; Nishi, 1979). Based on no-choice feeding test, Au and Wright (2023) reported that larvae of *A. coerula* feed on leaves of ʻakolea, *Boehmeria grandis*; olonā, *Touchardia latifolia*; and *Phenax hirtus*[3]; however, not a single larva completes development to pupal stage. Au and Wright (2023) observed that larvae of *A. coerula* do not feed on leaves of *Pilea mollis*, *Trema orientalis*, and *Vitis rotundifolia* (Au and Wright, 2023, 2024). The list of verified larval hosts is summarized in Table 1[4].

Questionable larval host plants of *A. coerula* or plant taxa listed as hosts without any supporting infestation data include nettle tree, *Boehmeria australis* (Jackson and Mua, 2019); *Boehmeria* spp. (Au and Matsunaga, 2021; Au and Wright, 2022; Jackson and Mua, 2019); *Cypholophus* spp. (Au and Matsunaga, 2021; Au and Wright, 2022; Jackson and Mua, 2019); *Debregeasia salicifolia*[5] (Sanyal, 2015); *Debregeasia* spp. (Au and Matsunaga, 2021; Au and Wright, 2022; Jackson and Mua, 2019); Himalayan nettle, *Girardinia diversifolia* (Sanyal, 2015); *Girardinia* spp. (Au and Matsunaga, 2021; Au and Wright, 2022; Jackson and Mua, 2019); and *Pipturus* spp. (Au and Matsunaga, 2021; Au and Wright, 2022; Jackson and Mua, 2019) in family Urticaceae. Other reported larval host plants of *A. coerula* based on host listings are grapes, *Vitis* spp., family Vitaceae (Au and Matsunaga, 2021; Au and Wright, 2022; Robinson *et al*., 2023); poison peach, *Trema tomentosa*, family Cannabaceae (Au and Matsunaga, 2021; Au and Wright,

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[1] Synonym of *Boehmeria tricuspis* (Hance) Makino in USDA-ARS Germplasm Repository Information Network (GRIN, https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearch).

[2] *Urera glabra* is the botanical name of ōpuhe in Au and Wright (2023). *Touchardia oahuensis* is the valid name of *Urera glabra* in the Catalogue of Life (COL, https://www.catalogueoflife.org/data/taxon/8TKFN).

[3] *Boehmeria hirta* Sw. is a basionym of *Phenax hirtus* in Tropicos (https://www.tropicos.org/name/33400446).

[4] Table 1 has complete annotation of the botanical name of each listed suitable host plant of *A. coerula*. The following are the complete botanical names of plants reviewed herein that are deemed either unsuitable larval hosts or non-hosts of *A. coerula*:

ʻakolea, *Boehmeria grandis* (Hook. & Arn.) A. Heller;
gunpowder tree, *Trema orientalis* (L.) Blume;
moon valley pilea, *Pilea mollis* Wedd.;
muscadine grape, *Vitis rotundifolia* Michx.;
olonā, *Touchardia latifolia* Gaudich.; and
Phenax hirtus (Sw.) Wedd.

[5] Synonym of *Debregeasia saeneb* (Forssk.) Hepper & J. R. I. Wood in USDA-ARS Germplasm Repository Information Network (GRIN, https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearch).

2022; Robinson *et al*., 2023); and citrus, *Citrus* sp., family Rutaceae (Ye, 2011). The list of questionable larval hosts is summarized in Table 2.

3.2 Adult Hosts

Adult ramie moths feed on ripe, overripe, and decaying fruits (Au and Matsunaga, 2021; Au and Wright, 2022). Adults may also feed on tree sap without causing any direct damage to the host plants (Au and Matsunaga, 2021; Au and Wright, 2022; Jackson and Mua, 2019; Schneider, 2001). Considered a non-economically important fruit piercing moth in Japan, adults were reported feeding on fleshy fruits of apple, *Malus domestica*; fig, *Ficus carica*; grape, *Vitis vinifera*; loquat, *Eriobotrya japonica*; peach, *Prunus persica*; pear, *Pyrus communis*; and persimmon, *Diospyros* sp. (Hattori, 1969). In Papua New Guinea, adults were observed feeding on banana, *Musa* sp., and pawpaw, *Carica papaya,* fruits (Schneider, 2001). The list of reported adult host fruits is summarized in Table 3.

4.0 Life History

Arcte coerula is multivoltine, producing two to seven generations annually (Au and Wright, 2022; Ide, 2006; Zeng *et al*., 2016). Low density populations can be found throughout the year, peaking in August through September in Korea (Dubatolov *et al*., 2023 citing Kononenko, 2010; Ide, 2006). Surveys conducted in Hawaii show *A. coerula* populations increasing from March to May, with the highest density observed in May (Au and Wright, 2024). The population density of *A. coerula* appears to be highly correlated with environmental conditions: positively correlated with temperature and negatively correlated with relative humidity or rainfall (Au and Wright, 2024).

4.1 Eggs

Eggs are clear-white, round, measure about 1.0 mm in diameter, and usually laid singly on the underside of leaves (Figure 1A) (Au and Matsunaga, 2021). However, it is not uncommon to find multiple eggs oviposited on a single leaf (Au and Wright, 2022). On *P. albidus* in Hawaii, females oviposit an average of five to ten eggs per plant, but they can also lay egg masses with as many as 220 eggs (Au and Wright, 2022). On *B. nivea* fields in Hunan, China, females lay egg masses with approximately 400 eggs on abaxial leaf surface (Zeng *et al*., 2016). Eggs laid on leaves of bichu grass (Arif and Kumar, 1995) and māmaki leaves (Au and Wright, 2022) hatch within a week.

4.2 Larvae

Early instar larvae are green and white. As they mature, larvae become more distinctive, with vibrant yellow and black markings and bright orange-red spots on their sides (Au and Wright, 2022). There are two larval color morphs in response to varying population density levels impacting the production of a juvenile hormone (JH) analogue (Ikemoto, 1984). The black bands along the larvae's body length are narrow under solitary conditions, creating yellow morph larvae (Figure 1B), and conspicuously wide under crowded conditions, creating black morph larvae (Figure 1C) (Ide, 2006 citing Ohtaishi, 1977; Ikemoto, 1984; Ikemoto, 1989). Larvae collected in Hawaii are predominantly black morph indicating a gregarious larval behavior (Au and Wright, 2022).

Newly emerged first instar larvae measure 0.70 mm (Yamada, 1933) to about 2 mm in length and grow rapidly mostly through five instars, reaching up to 100 mm in length before pupating (Au and Wright, 2022). Larvae reared on *B. nivea* leaves have six larval instars (Ide, 2006; Ikemoto 1984). Field collected larvae on *P. albidus* in Hawaii typically undergo five instars, with occasional larvae having six or seven molts (Au and Wright, 2022). The duration of the larval stage is variable, with an average of about a month from emergence to pupation for larvae reared on *U. dioica* (Arif and Kumar, 1995) and *P. albidus* (Au and Wright, 2022).

Larvae feed on both young and mature leaves of their host plants. The larval feeding damage ranges from small and large holes in the middle of the host leaves to completely stripped leaves with only major veins remaining (Figure 2).

4.3 Pupae

Under natural conditions, pupation occurs under the soil, fallen leaves on the ground or in the root zone of the host plants (Arif and Kumar, 1995; Au and Wright, 2022). Pupae have an average length of 28 mm (range: 25-39 mm) (Au and Wright, 2022) (Figure 1D). Pupal stage duration is highly variable, probably due to seasonal changes in ambient temperature. The pupal duration ranges from 10 to15 days in Japan (Yamada, 1933) and 13 to 25 days in Hawaii (Au and Wright, 2022).

4.4 Adults

Adults have a dark brown head; dark brown forewings with black markings, speckles of silvery-blue, and scalloped termen or wing edges; and hindwings with distinctive bright silvery-bluish markings (Figure 1E) (Au and Matsunaga, 2021). The body length ranges from 28-32 mm, with wingspans ranging from 65-90 mm (Au and Matsunaga, 2021; Au and Wright, 2022; Sanyal, 2015; Viette, 1950; Zeng and Gao, 2015). The adult male to female ratio is approximately 1:1 (Au and Wright, 2022).

Adults of *A. coerula* are nocturnal, strong fliers and attracted to ripe and overripe fruits (Au and Wright, 2022; Schneider, 2001). Adults have been reported to overwinter in South Korea (An and Choi, 2013; Shin, 2001) and Russia (Dubatolov *et al*., 2023, citing Kononenko, 2010). Aggregation in large numbers on the ceiling of a residential house was observed in Papua New Guinea during a period of drought (Schneider, 2001).

There is no available information on the moth's mating habits. Coppens (2019) notes it is difficult to study the mating habits of Erebinae moths as adults have relatively long lifespans, the propensity to fly long distances, and require specific temperature and lighting conditions to achieve successful mating.

5.0 Distribution

The documented range of *A. coerula* includes Asia and Oceania. It is present in **North Asia**—Russia (Dubatolov *et al*., 2023; Ivin *et al*., 2014); **East Asia**—China (Sviridov, 2018), Hong Kong (Ades and Kendrick, 2004), Japan (Ohga *et al*., 1995; Kimura and Ikeda, 2023), South Korea (Kononenko and Han, 2007), and Taiwan (Lin, 1993); **Southeast Asia**—Brunei (Holloway, n.d.), Philippines (Domine and dela Cruz, 2020), Thailand (Hreblay, 2022), and

Vietnam (Nhi *et al*., 2019); **South Asia**—India (Arif and Kumar, 1995); and **Oceania**—Australia (Jackson and Mua, 2019), Fiji (Clayton, 2023 citing personal communications with G. S. Robinson in 1996; Jackson and Mua, 2019), New Caledonia (Holloway, 1979; Viette, 1950), Norfolk Island (Jackson and Mua, 2019), Papua New Guinea (Basset *et al*., 1996), Samoa (Edwards, 2012), Vanuatu (Muniappan *et al*., 2002), and United States: Hawaii (Au and Matsunaga, 2021; Au and Wright, 2022, 2023, 2024). Refer to Tables 4 and 5 and Figures 3 and 4 for specific geographic locations.

Arcte coerula has been reported to occur, without any available infestation or field collection data in: **South Asia**—Sri Lanka (formerly Ceylon) (Au and Wright, 2022; Hampson, 1892) and Nepal (Sanyal, 2015); and **Southeast Asia**— Myanmar (formerly Burma) (Hampson, 1892), Indonesia: Java (Hampson, 1892), and Malaysia: West Malaysia (Robinson *et al*., 2023) (Figure 4).

6.0 Plant Hardiness Zones (PHZ)

The global geographic areas where *A. coerula* could potentially survive are determined using the Global Plant Hardiness Zones (PHZ) tool in the application *Spatial Analytic Framework for Advanced Risk Information Systems* (SAFARIS, https://safaris.cipm.info/safarispestmodel/StartupServlet?phz). The PHZs in SAFARIS are adapted from the USDA Plant Hardiness Zone Map (https://planthardiness.ars.usda.gov). The PHZs are assigned on a scale from 1 to 14 in incremental 10°F thermal bands ranging from -60°F to 80°F (Takeuchi *et al*., 2018). The specific locations of the reported geographic distributions of *A. coerula* were matched to specific PHZ in SAFARIS. It is estimated that *A. coerula* has a high likelihood of establishing natural populations in areas corresponding to Plant Hardiness Zones 6-14 (Table 5).

7.0. Assessing the Risk of *Arcte coerula* in Hawaii and the Continental United States

7.1 Geographic Areas of the Continental United States Endangered by *Arcte coerula*

The risk elements assessed here, using information presented in previous sections, are climatic suitability, availability of potential suitable hosts, and the risk posed to commercial and naturally occurring wild hosts.

Climatic suitability	The reported distribution of *A. coerula* includes Russia; China, Hongkong, Japan, South Korea, and Taiwan in East Asia; Brunei, Myanmar, Indonesia, Philippines, Thailand, and Vietnam in Southeast Asia; India, Nepal, and Sri Lanka in South Asia; and Australia, Papua New Guinea, New Caledonia, Norfolk Island, Fiji, Samoa, Vanuatu, and Hawaii in Oceania. Based on native and invasive habitats of *A. coerula* and the ability of adults to overwinter, it is estimated that this pest could survive within Plant Hardiness Zones 6-14 (Table 5). Thus, *A. coerula* could establish populations in the continental U.S., except for Wyoming, North Dakota,

	South Dakota, Minnesota, Wisconsin, Vermont, Maine and most of Alaska, Montana, Nebraska, Iowa, New York and New Hampshire.
Potential hosts	In the continental U.S., many potential larval hosts of *A. coerula* occur in Plant Hardiness Zones 6-14. This pest has confirmed larval hosts belonging to the families Juglandaceae, Moraceae, Ulmaceae, and Urticaceae. Other reported host plants belong to the families Cannabaceae, Rutaceae, and Vitaceae.
Commercial hosts at risk	Potential larval hosts of *A. coerula* at risk of defoliation include *Citrus* spp. and *Vitis* spp. Adults of *A. coerula* feed on exudate and soft tissue of damaged, ripe and overly ripe fruits and do not directly damage firm host fruits. Commercial unripe and harvest mature fruits are not at risk of infestation by *A. coerula.*
Naturally occurring wild hosts at risk	Shrubs and trees in the family Urticaceae appear to be the primary and preferred hosts of *A. coerula*. The reported host plants of *A. coerula,* especially *Urtica* spp. and *Boehmeria* spp., are widely distributed in the continental U.S.

7.2 Likelihood of Establishment in Vulnerable Areas of Hawaii

The biological parameters assessed for the likelihood of establishment in environmentally vulnerable areas of Hawaii are likelihood of finding suitable hosts, likelihood of survival, and dispersal potential.

Element	Explanation
Likelihood of finding suitable host plants	*Arcte coerula* has a high likelihood of finding suitable hosts in fallowed lands, cultivated farms, and in vulnerable native forests of Hawaii. The potential larval hosts of *A. coerula*, including *Boehmeria* spp., *Urtica* spp., and *Pipterus* spp., grow and are available from near sea level up to the tree line of the rainy windward slopes of Mauna Kea and Mauna Loa on Hawaii and Haleakala on Maui. In primary native forests of Hawaii, *A. coerula* feeds and causes defoliation of endemic species *P. albidus* (Au and Wright, 2022). The Hawaii Department of Land and Natural Resources (HDLNR) lists the endemic nettle plants *Boehmeria grandis, Hesperocnide sandwicensis,* the endangered *Neraudia melastomaefolia,* and the non-native nettles *Laportea interrupta* and *Touchardia latifolia* as vulnerable to *A. coerula* infestations (Au and Wright, 2023; Au and Wright, 2024; HDLNR-Forestry, 2024; HDLNR-HISC, 2024; HDLNR-MKFRP, 2024).

Element	Explanation
Likelihood of survival	Based on the recorded distribution of *A. coerula*, it can survive and reproduce whole year-round from sea level all the way up to the tree line, which is generally at about 3,000 m elevation of Mauna Kea, Mauna Loa and Haleakala. This pest has a high likelihood of surviving and reproducing year-round where suitable host plants are available.
Dispersal potential	Adults of *A. coerula* have a high dispersal potential. They are strong fliers and can disperse over long distances (Au and Wright, 2022; Arif and Kumar, 1995; Schneider, 2001). The high dispersal capability of adults and their ability to oviposit and feed on a variety of host plants assure successful spread and survival of introduced populations of *A. coerula.*

8.0 Pathway of Introduction to Hawaii

The recorded host fruits of *A. coerula* include apples and pears, which are among USDA-approved commodity imports from Australia, China, Japan and Korea. These fruit commodities are allowed entry to the U.S. upon meeting the quarantine mitigation requirements of the USDA (ACIR, 2024) and are not likely to be the pathway of introduction of *A. coerula* to Hawaii. Adults feed on exudate and exposed soft tissue of ripe and overly ripe fruits (Au and Matsunaga, 2021; Au and Wright, 2022) and not on intact commercial-grade fruits.

The likelihood of *A. coerula* arriving as eggs or larvae on leaves of its host is negligible. *Boehmeria* spp., the primary hosts of *A. coerula,* are processed as fiber crops. The leaves of *B. kazinoki* and *U. dioica* maybe eaten raw or cooked, but they are not common delicacies. The likelihood of anyone bringing nettle leaves to Hawaii as contraband is negligible.

Arcte coerula may have a high likelihood of arriving in Hawaii as adult hitchhikers in cargos for personal effects or in checked-in or carry-on luggage unintentionally containing ripe or rotting host fruits, e.g., bananas, papayas, etc. The propensity of adults to aggregate on rotting host fruits (Hattori, 1969) and even on physical structures like house walls (Schneider, 2001) supports this hypothesis.

A single or few gravid *A. coerula* females arriving in Hawaii as hitchhikers could start a successful founding population. Thus, it is recommended to request USDA-APHIS-PPQ for access to the ports-of-entry interception databases on Noctuidae and Erebidae (PestID, 2024) and assess the likelihood of adults of *A. coerula* arriving in Hawaii as hitchhikers in cargo containers and personal luggage. In addition, the current inspection requirements and procedures of USDA-APHIS-PPQ and the United States Department of Homeland Security (USDHS)-Customs and Border Protection (CBP) at the ports-of-entry should be re-evaluated for any loopholes that may have been allowing arrival of hitchhiking pests in Hawaii.

9.0 Summary

Arcte coerula (Guenée), commonly referred to as ramie moth, is native to Southeast Asia and prefers feeding on host plants in family Urticaceae, particularly *Boehmeria* spp. It was first discovered on Maui in November 2018 defoliating native *P. albidus* trees and has since been spreading on Maui and Hawaii. An unknown pest, *A. coerula* is economically significant only where *B. nivea* is commercially grown as a natural fiber crop. This document evaluates the risk of *A. coerula* to the agriculture and natural resources of Hawaii and the continental U.S. and identifies the likely pathways that may have resulted in its arrival to Hawaii.

Native and invasive populations of *A. coerula* occur in tropical, subtropical, and high-elevation temperate zones of East, South, and Southeast Asia and Oceania. Based on its current distribution, it is estimated that *A. coerula* could survive in Plant Hardiness Zones 6-14 and could establish populations in the continental U.S., except for Wyoming, North Dakota, South Dakota, Minnesota, Wisconsin, Vermont, Maine and most of Alaska, Montana, Nebraska, Iowa, New York and New Hampshire. The potential larval hosts of *A. coerula* at risk of defoliation in continental U.S. include *Citrus* spp. and *Vitis* spp. Adults of *A. coerula* do not directly damage host fruits and feed on exudate and soft tissue of damaged, ripe and overly ripe fruits. Thus, the commercial export fruit commodities produced in the continental U.S. are not at risk of infestation by *A. coerula*.

In Hawaii, the potential larval hosts of *A. coerula*, including *Boehmeria* spp., *Urtica* spp., and *Pipterus* spp., grow near sea level, and possibly, up to the tree line of Mauna Loa, Mauna Kea, and Haleakala. Where suitable host plants are available, *A. coerula* has a high likelihood of surviving and reproducing whole year-round. In primary native forests of Hawaii, infestations of *A. coerula* could cause severe defoliation of native and non-native nettle species. Consequently, *A. coerula* could lead to the extinction of vulnerable and endangered native nettles and the native insects that feed on them.

The introduction of *A. coerula* to Hawaii is extremely ambiguous because of the complete absence of commodity importation pathways. The likelihood of *A. coerula* arriving as eggs or larvae on leaves of its hosts is negligible. *Boehmeria* spp., the primary hosts of *A. coerula,* are processed as fiber crops. The leaves of *B. kazinoki* and *U. dioica* while edible raw or cooked are not common delicacies. The likelihood of anyone bringing contraband neetle leaves for food consumption is negligible.

Arcte coerula may have arrived in Hawaii as adult hitchhikers on ripe or overly ripe host fruits. They may have hitchhiked in cargo containers for personal effects or in checked-in or carry-on luggage unintentionally containing ripe or rotting host fruits, e.g., bananas, papayas, etc. A single gravid *A. coerula* female arriving in Hawaii as a hitchhiker could start a successful founding population. Thus, it is recommended to request USDA-APHIS-PPQ for access to the port-of-entry interception databases on Noctuidae and Erebidae (PestID, 2024) and assess the likelihood of adults of *A. coerula* arriving in Hawaii as hitchhikers. In addition, the current inspection requirements and procedures at the ports of entry of USDA-APHIS-PPQ and the USDHS-CBP should be reviewed and re-evaluated to prevent the arrival of hitchhiking pests in Hawaii.

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11.0 Tables and Figures

Table 1. Suitable Larval Host Plants of *Arcte coerula* (Guenée).
The suitable host category is conferred to a plant taxon with validated record of infestation under natural field and/or experimental laboratory conditions.

Family	Botanical Name	Common Name	Country, Infestation Category[1] and References
Juglandaceae	*Pterocarya stenoptera* C. DC.	Chinese wingnut	Japan (Ohga *et al*., 1995 [N])
Moraceae	*Broussonetia kazinoki* Siebold	Kozo, Mulberry	Japan (Nishi, 1979 [N, L]; Yamada, 1933 [U])
	Broussonetia papyrifera (L.) Vent	Paper, Mulberry	Japan (Nishi, 1979 [L])
Ulmaceae	*Hemiptelea davidii* (Hance) Planch.	Thorn-elm	South Korea (Lee *et al*., 2008 [N])
Urticaceae	*Boehmeria nipononivea* Koidz.	China ramie	Japan (Ide, 2006 [N])
	Boehmeria nivea (L.) Gaudich.	Ramie	China (Zeng *et al*., 2016 [N, L]) Japan (Yamada, 1933 [N])
	Boehmeria spicata (Thunb.) Thunb.	Ramie	Japan (Yamada, 1933 [N])
	Boehmeria tricuspis (Hance) Makino[2]		Japan (Kagata and Ohgushi, 2012 [N])
	Cecropia obtusifolia Bertol.	Trumpet-tree	USA: Hawaii (Au and Wright, 2023; Au and Wright, 2024 [L])
	Touchardia oahuensis T. Wells & A. K. Munroe[3,4]	Ōpuhe	USA: Hawaii (Au and Wright, 2023; Au and Wright, 2024 [L])
	Urtica dioica Linn.[5]	Bichhu grass	India (Arif and Kumar, 1995 [N])
	Pipturus albidus (Hook. & Arnott.) A. Gray	Māmaki	USA: Hawaii (Au and Wright, 2022 [N])

[1] N = Natural field infestation; L = Infestation under experimental laboratory conditions; U = Infestation not specified whether observed in the field or laboratory.
[2] Botanical name listed as *Boehmeria platanifolia* (Maxim.) Franch. & Sav. ex F. B. Forbes & Hemsl. in Kagata and Ohgushi (2012).
[3] Botanical name listed as *Urera glabra* in Au and Wright (2023).
[4] *Urera glabra* catalogued as synonym of *Touchardia oahuensis* in the Catalogue of Life.
[5] Botanical name erroneously listed as *Urtica divica* in Arif and Kumar (1995).

Table 2. Questionable Larval Host Plants of *Arcte coerula* (Guenée).
The questionable host category is conferred to a plant taxon without any reported infestations under natural field or laboratory conditions and the host association is based on a mere listing as a host without any verifiable infestation data.

Family	Botanical Name	Common Name	References
Cannabaceae	*Trema tomentosa* (Roxb.) H. Hara	Poison peach	Au and Matsunaga, 2021; Au and Wright, 2022; Robinson *et al*., 2023
Rutaceae	*Citrus* sp.	Citrus	Ye, 2011
Urticaceae	*Boehmeria* spp.	Ramie	Au and Matsunaga, 2021; Au and Wright, 2022; Jackson and Mua, 2019
	Boehmeria australis Endl.	Nettle tree	Jackson and Mua, 2019
	Boehmeria japonica (L. f.) Miquel[1]		Nishi, 1979
	Cypholophus spp.		Au and Matsunaga, 2021; Au and Wright, 2022; Jackson and Mua, 2019
	Debregeasia saeneb (Forssk.) Hepper & J. R. I. Wood[2]		Sanyal, 2015
	Debregeasia spp.		Au and Matsunaga, 2021; Au and Wright, 2022; Jackson and Mua, 2019
	Girardinia diversifolia (Link) Friis	Himalayan nettle	Sanyal, 2015
	Girardinia spp.		Au and Matsunaga, 2021; Au and Wright, 2022; Jackson and Mua, 2019
	Urtica thunbergiana Siebold & Zucc.		Nishi, 1979
	Pipturus spp.		Au and Matsunaga, 2021; Au and Wright, 2022; Jackson and Mua, 2019
Vitaceae	*Vitis* spp.	Grape	Au and Matsunaga, 2021; Au and Wright, 2022; Robinson *et al*., 2023

[1] Botanical name listed as *Boehmeria grandifolia* (Thunb.) Wedd. in Nishi (1979).
[2] Botanical name listed as *Debregeasia salicifolia* (D. Don) Rendle. in Sanyal (2015).

Table 3. Suitable Adult Host Fruits of *Arcte coerula* (Guenée).

Family	Botanical Name	Common Name	Country and References
Caricaceae	*Carica papaya* L.	Pawpaw	Papua New Guinea (Schneider, 2001)
Ebenaceae	*Diospyros* sp.	Persimmon	Japan (Hattori, 1969)
Moraceae	*Ficus carica* L.	Fig	Japan (Hattori, 1969)
Musaceae	*Musa* sp.	Banana	Papua New Guinea (Schneider, 2001)
Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl.	Loquat	Japan (Hattori, 1969)
	Malus domestica (Suckow) Borkh.	Apple	Japan (Hattori, 1969)
	Prunus persica (L.) Batsch	Peach	Japan (Hattori, 1969)
	Pyrus communis L.	Pear	Japan (Hattori, 1969)
Vitaceae	*Vitis vinifera* L.	Grape	Japan (Hattori, 1969)

Table 4. Geographic Distribution of *Arcte coerula* (Guenée) Based on Egg and Larval Infestation Records and Presence of Adults.

Country	Eggs and Larvae	Adults	Reports Without Defined Specific Life Stage
Australia: Queensland			Jackson and Mua, 2019
Brunei		Holloway, n.d.	
China	Zeng *et al*., 2016	Kadoorie Farm and Botanic Garden, 2004; Sviridov, 2018	
Fiji		Clayton, 2023 citing pers. comm. with G. S. Robinson in 1996	Jackson and Mua, 2019
Hong Kong			Ades and Kendrick, 2004
India	Arif and Kumar, 1995; Smetacek and Smetacek, 2011	Gohil *et al*., 2022; Kirti and Singh, 2013; Kirti *et al*., 2013; Sanyal, 2015; Sivasankaran *et al*., 2017	
Japan	Ide, 2006; Kagata and Ohgushi, 2012; Nishi, 1979; Ohga *et al*., 1995; Yamada, 1933	Asano, 2012; Chettri, 2022; Kanai and Moriyama, 2014; Kimura and Ikeda, 2023; Nomura and Kamitani, 2013; Sato and Tsurimaki, 2021	Jinbo *et al*., 2019; Katayama and Ota, 2022
New Caledonia		Holloway, 1979	Viette, 1950
Norfolk Island			Jackson and Mua, 2019
Papua New Guinea		Basset *et al*., 1996; Schneider, 2001	
Philippines		Domine and dela Cruz, 2020	
Russia		Dubatolov *et al*., 2023; Ivin *et al*., 2014	Ivin *et al*., 2014
Samoa		Edwards, 2012	
South Korea	Lee *et al*., 2008	An, 2013; An *et al*., 2016; Csorba *et al*., 2004; Jung and Oh, 2012; Kononenko and Han, 2007; Lim *et al*., 2009; Min *et al*., 2009	An and Choi, 2013; Choi and Park, 2019; Kim *et al*., 2006
Taiwan		Lin, 1993	
Thailand			Hreblay, 2022
United States: Hawaii	Au and Wright, 2022	Au and Wright, 2022	Au and Wright, 2024
Vanuatu		Muniappan *et al*., 2002	
Vietnam		Nhi *et al*., 2019	

Table 5. Plant Hardiness Zones (PHZ) of Documented Geographic Areas where *Arcte coerula* (Guenée) Occurs.

PHZ	Continent/ Region	Country	Specific Geographic Location[1,2] and References
6	Asia	Japan	Kudoji Temple in Hirosaki city (U) (Katayama and Ota, 2022)
6	Asia	Korea (South)	Mt. Munsusan (U) (Choi and Park, 2019)
6–7	Asia	India	Pahalgam in Jammu and Kashmir (A) (Kirti *et al*., 2013)
6–7	Asia	Russia	The Far Eastern Marine State Natural Biosphere Reserve in southern Primorski Krai (U) (Rikord Island, Srednyaya Bay, Furugelma Island, and Bolshoy Pelis Island) (Ivin *et al*., 2014)
7	Asia	India	Srinagar in Jammu and Kashmir (A) (Kirti *et al*., 2013)
7	Asia	Japan	Fukushima (L) (Nishi, 1979)
7	Asia	Korea (South)	Daejeon (U) (Kim *et al*., 2006), Mt. Jirisan National Park (A) (An, 2013; An *et al*., 2016)
7–8	Asia	Japan	Kashihara City (A) (Kimura and Ikeda, 2023)
8	Asia	India	Gulmarg in Jammu and Kashmir (A) (Kirti *et al*., 2013)
8	Asia	Korea (South)	Mt. Ibamsan (A) (Lim *et al*., 2009), Mt. Seungdal-san in Muan (A) (An and Choi, 2013)
8	Asia	Russia	Kunashir Island (A) (Dubatolov *et al*., 2023)
9	Asia	China	Changsha, Hunan (E, L) (Zeng *et al*., 2016)
9	Asia	India	Lumla in Arunachal Pradesh (A) (Kirti and Singh, 2013), Kumaon Hills in Uttarakhand (L) (Arif and Kumar, 1995)
9	Asia	Japan	Kyoto University in Kyoto city (L) (Kagata and Ohgushi, 2012), Kyushu University Ito Campus in Fukuoka city (A) (Nomura and Kamitani, 2013), Tatsuda-yama hill in Kumamoto city (L) (Ide, 2006), Tenjin Kurumi Road in Fukuoka city (L) (Ohga *et al*., 1995), Minato (U) (Jinbo *et al*., 2019), Nagoya (A) (Asano, 2012), Tsuchiura City (A) (Sato and Tsurimaki, 2021)
9	Asia	Korea (South)	Dolsan-do in Dadohae Marine National Park (A) (Min *et al*., 2009)
10	Asia	China	Huaiji County, Guangdong (A) (Kadoorie Farm and Botanic Garden, 2004)
10	Asia	India	Bhimtal in Uttarakhand (L) (Smetacek and Smetacek, 2011), Takdah in West Bengal (A) (Chettri, 2022)
10	Asia	Korea (South)	Jeju Island (A) (Csorba *et al*., 2004), Mt. Hallasan National Park (A) (Jung and Oh, 2012)
10	Asia	Taiwan	National Taiwan University Montane Horticultural Experimental Station (A) (Lin, 1993)
10	Asia	Thailand	Doi Phukha in North Changwat Nan (U) (Hreblay, 2022)
11	Asia	Hong Kong	(U) (Ades and Kendrick, 2004)

[1] Observed life stage: A, adult; E, egg; L, larva; U, unspecified.
[2] The specific geographic distributions of *A. coerula* are cited by country. Hong Kong (Special Administrative Region) and Norfolk Islands (External Territory) are listed separately from China and Australia, respectively, because of their historical and administrative status.

Table 5. Continued...

PHZ	Continent/ Region	Country	Specific Geographic Location[1,2] and References
11	Asia	Vietnam	Trang An Landscape Complex in Ninh Binh (A) (Nhi *et al*., 2019)
11	Oceania	Papua New Guinea	Bulolo University College (A, 700 m) (Schneider, 2001), Mount Kaindi (A) (Basset *et al*., 1996)
11	Oceania	United States	Hawaii Island, Hawaii: Kaʻū District (L) (Au and Wright, 2022), Volcano (U), Pāhala (U), Captain Cook (U) (Au and Wright, 2024)
11-12	Asia	India	Various locations near Ooty in Tamil Nadu (A) (Sivasankaran *et al*., 2017)
12	Asia	Brunei	Bukit Retak (A) (Holloway, n.d.)
12	Asia	India	Bhavnagar in Gujarat State (A) (Gohil *et al*., 2022)
12	Asia	Philippines	Andanan Watershed Forest Reserve (A) (Domine and dela Cruz, 2020)
12	Oceania	United States	Hawaii Island, Hawaii: Puna District (L) (Au and Wright, 2022), Kalapana (U), Kea'au (U), Mountain View (U), Pāhoa (A) (Au and Wright, 2024)
12-13	Oceania	New Caledonia	New Caledonia (A) (Holloway, 1979), South Province (U) (Viette, 1950)
12-14	Oceania	Fiji	Country (A) (Clayton, 2023 citing pers. comm. with G. S. Robinson in 1996)
13	Oceania	New Caledonia	Loyalty Islands (U) (Viette, 1950)
13	Oceania	United States	Hawaii Island, Hawaii: Hilo and Hāmākua Districts, Hawaii Island (L) (Au and Wright, 2022), Hilo (U), Honokaʻa (U), Pāpaʻikou (U) (Au and Wright, 2024); Maui Island, Hawaii: Olowalu (L), Olinda (L) (Au and Wright, 2022), Honolua (U), ʻĪao Valley (U), Kēōkea (U), Waikapū (U) (Au and Wright, 2024)
13-14	Oceania	Vanuatu	New Hebrides (U) (Viette, 1950)
14	Oceania	Samoa	Savai'i Island (A) (Edwards, 2012)
14	Oceania	Vanuatu	Klem's Hill in Efate (A) (Muniappan *et al*., 2002)
N/A	Asia	Japan	Suwanosejima Air Base, northern Ryukyu Islands (A) (Kanai and Moriyama, 2014)[3].
N/A	Asia	India	Gangotri Landscape in Uttarakhand (A) (Sanyal, 2015)[4]

[3] Although the SAFARIS Global Plant Hardiness Zones (PHZ) is comprehensive, there is no information on Suwanosejima Air Base in Ryukyu Islands.

[4] The SAFARIS Global Plant Hardiness Zones (PHZ) determination for the Gangotri Landscape in Uttarakhand is problematic because it encompasses an expansive region of the Himalayas and Sanyal (2015) did not specify the specific location in Gangotri where *A. coerula* adult was observed.

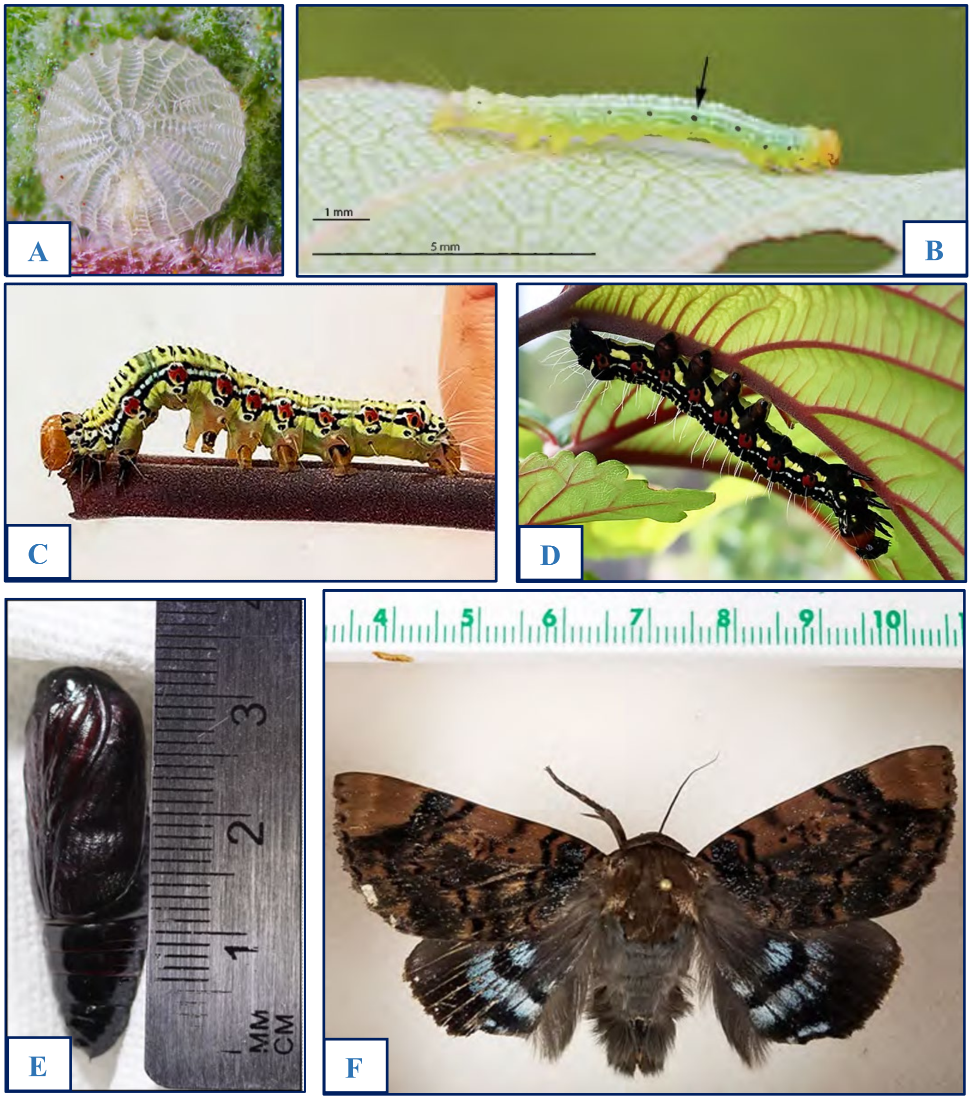

Figure 1. Life History Stages of *Arcte coerula* (Guenée).
A) Egg; B) First instar larva; C) Late instar yellow morph larva; D) Late instar black morph larva; E) Pupa; and F) Adult. Photos from Au and Matsunaga (2021) and Au and Wright (2022). Photo credits: Michelle Au (egg, pupa, and first instar), Anna Palomino (fully developed yellow and black morphs larvae), and the Hawaii Department of Agriculture (adult).

Figure 2. Larval Feeding Damage of *Arcte coerula* (Guenée).
A) Early instar feeding damage of māmaki, *Pipturus albidus* (Hook & Arnott.) A. Gray; B) Late instar feeding damage of the center of a māmaki leaf; C) Larvae (in red circles) extensively feeding and stripping leaves of māmaki. Photos from Au and Matsunaga (2021). Photo credits: Michelle Au (photos A and B) and Keahi Bustamante (photo C).

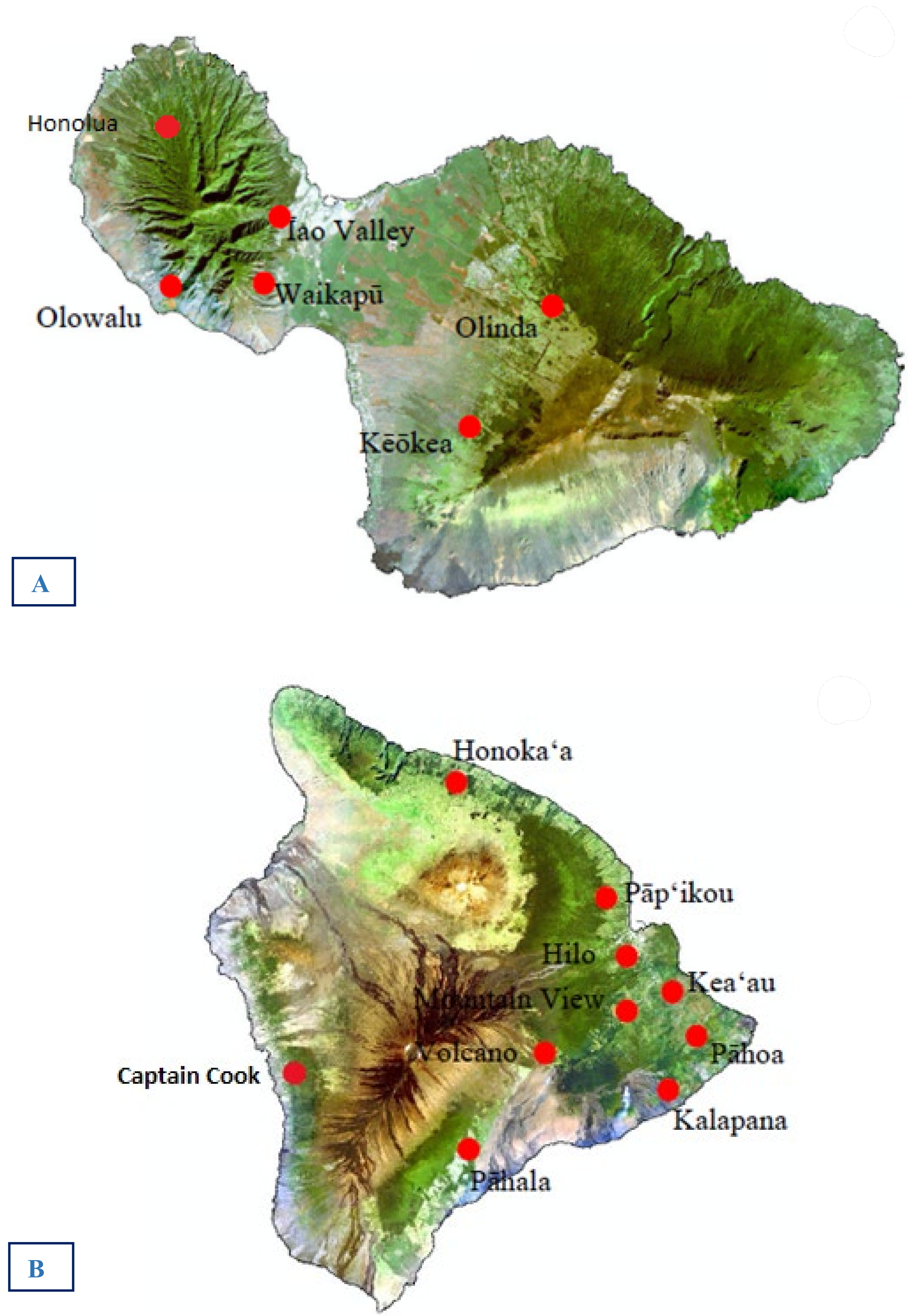

Figure 3. Distribution of *Arcte coerula* (Guenée) on the Islands of Maui (A) and Hawaii (B). Adapted from maps in Au and Wright (2023, 2024).

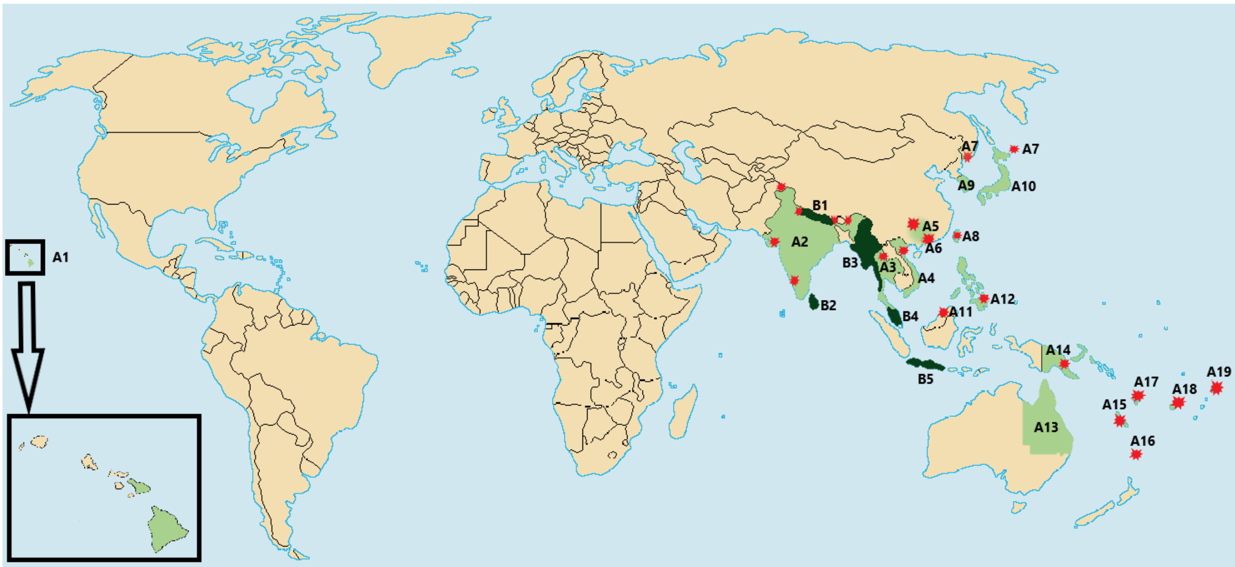

Figure 4. Verified (Light Green) and Unconfirmed (Dark Green) Global Distribution of *Arcte coerula* (Guenée).
Red marks highlight smaller islands, countries and specific locations within countries. Refer to Table 5 for the details of distribution records.

Group A. Verified country distribution records (light green): (A1) United States (Hawaii), (A2) India, (A3) Thailand, (A4) Vietnam, (A5) China, (A6) Hong Kong, (A7) southeastern Russia (including Srednyaya Bay, Bolshoy Pelis Island, Rikord Island Furugelma Island, and Kunashir Island), (A8) Taiwan, (A9) South Korea, (A10) Japan, (A11) Brunei, (A12) Philippines, (A13) Australia (Queensland), (A14) Papua New Guinea, (A15) New Caledonia, (A16) Norfolk Island, (A17) Vanuatu, (A18) Fiji, and (A19) Samoa.

Group B. Unconfirmed country distribution records (dark green): (B1) Nepal, (B2) Sri Lanka, (B3) Burma, (B4) West Malaysia, and (B5) Java (Indonesia).