

Draft Recovery Plan for 15 Species from the Island of Hawai‘i



Hawaiian picture-wing fly (*Drosophila digressa*). Photo by Dr. Karl Magnacca.



Cyrtandra nanawaleensis (ha‘iwale or kanawao ke‘oke‘o). Photo by Joshua VanDeMark.

Draft Recovery Plan for 15 Species from the Island of Hawai‘i

U.S. Fish and Wildlife Service
Portland, Oregon

Draft Approved:

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Literature citation of this document should read as follows:

U.S. Fish and Wildlife Service. 2022. Draft Recovery Plan for 15 Species from the Island of Hawai'i. Portland, Oregon. xiii + 84 pp.

An electronic copy of this draft recovery plan is available at:

<https://www.fws.gov/node/266264>

ACKNOWLEDGMENTS

We gratefully acknowledge the contributions of the following individuals and organizations in developing the Draft Recovery Plan for 15 Species from the Island of Hawai‘i. The primary authors of this draft recovery plan are Chelsie Javar-Salas, James Breeden, Eldridge Naboa, and Diane Sether (with the Service’s Pacific Islands Fish and Wildlife Office [PIFWO], Honolulu Hawai‘i). Fred Amidon (PIFWO) provided mapping assistance. PIFWO reviewers were Lauren Weisenberger, John Vetter, Megan Laut, Gregory Koob, and Mary Abrams.

We particularly thank the species experts and their staff who provided information used in the development of this draft recovery plan: Matthew Keir, State of Hawai‘i, Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife; Scott Santos, Biological Sciences Professor and Chair of the Department of Biological Sciences, Auburn University; Troy Sakihara, State of Hawai‘i, DLNR, Division of Aquatic Resources; Joshua VanDeMark, Plant Extinction Prevention Program; Karl Magnacca, O‘ahu Army Natural Resources Program; Kenneth Kaneshiro and Megan Lamson Leatherman, University of Hawai‘i at Mānoa; Sallie Beavers and Tyler Paikuli-Campbell, National Park Service; the Hawai‘i and Pacific Plants Recovery Coordinating Committee (HPPRCC).

RECOVERY PLANNING PROCESS

The Service uses a three-part framework for recovery planning (click [here](#) for details). This approach is intended to reduce the time needed for recovery planning, increase the relevancy of recovery plans over a longer timeframe, and increase the flexibility of recovery planning documents by making them easier to modify as new information or circumstances arise. Under this process, a recovery plan includes the statutorily-required elements under section 4(f) of the Endangered Species Act (Act) (objective and measurable recovery criteria, site-specific management actions, and estimates of time and costs), along with a concise introduction and our strategy for how we plan to achieve species recovery. The recovery plan is supported by two supplementary documents: a species status assessment or species biological report, which describes the best available scientific information related to the biological needs of the species and assessment of threats; and the recovery implementation strategy, which details the particular near-term activities needed to implement the recovery actions identified in the recovery plan. Under this approach, new information on species biology or details of recovery implementation may be incorporated by updating these supplementary documents without concurrent revision of the entire recovery plan, unless changes to statutorily-required elements are necessary.

Thus, this recovery plan document is one piece of a three-part framework.

1. The **Species Status Assessment (SSA)** or **Species Report (SR)** inform the recovery plan. Each SSA or SR describes the biology and life-history needs of the species (includes distinct population segments, subspecies, species groups), includes analysis of each species' historical and current conditions, and includes discussion of threats and conservation needs of each species. The SSA or SR's format is structured around the conservation biology principles of resiliency, redundancy, and representation (Shaffer and Stein 2000, pp. 307-310; Wolf et al. 2015, entire; Smith et al. 2018, entire). This document may be updated as needed based on new information.

There are 15 Species Report documents associated with this draft recovery plan (USFWS 2021a through USFWS 2021o, entire), summarizing the biology and threat status of each species addressed in the plan and including the geography and environmental context of their range on the island of Hawai'i, respectively. Species Reports include information from Habitat Status Assessments completed by the Service (Ball et al. 2020; Browning et al. 2020; Clark et al. 2020; Javar-Salas et al. 2020; Kim et al. 2020; Lowe et al. 2020; Nelson et al. 2020; Pe'a et al. 2020; Phillipson et al. 2020). Habitat Status Assessments are used to evaluate the current status, stressors, and future viability of the terrestrial habitats found in the Hawaiian Islands.

2. The **Recovery Plan** contains a concise overview of the recovery strategy for the species (indicating how its recovered state will achieve redundancy, resiliency, and representation), as well as the statutorily-required elements of recovery criteria, recovery actions, and estimates of the time and costs to achieve the plan's goals.
3. The **Recovery Implementation Strategy (RIS)** outlines how the recovery plan will be implemented. The RIS is a short-term, flexible operational document focused on how, when, and by whom the recovery actions from the recovery plan will be implemented.

This document may be updated as needed based on new information, allowing it to be adapted to changing circumstances with greater flexibility and efficiency. The RIS will be developed and maintained in cooperation with our conservation partners and will focus on the period of time and activities that work best for our partners to achieve recovery goals.

For this draft recovery plan, we are coordinating with conservation partners at the State of Hawai‘i, Department of Land and Natural Resources (Division of Forestry and Wildlife, Division of Aquatic Resources), Plant Extinction Prevention Program (PEPP), watershed partnerships, National Park Service, and public and private stakeholders, to identify the highest priority actions for recovery of these species to develop a RIS.

EXECUTIVE SUMMARY

Species Status

This draft recovery plan addresses 15 species or subspecies (13 plants [10 species, 3 subspecies; hereafter species] and 2 invertebrates) endemic to the island of Hawai‘i. These 15 species were listed as endangered on October 29, 2013 (USFWS 2013). Critical habitat was designated for *Bidens micrantha* ssp. *ctenophylla* in 2018 (USFWS 2018) and is currently being determined for the remaining 14 species.

Species included in this recovery plan

Taxon	Common Name	Plant Life History and Growth Form
Plants		
<i>Bidens hillebrandiana</i> ssp. <i>hillebrandiana</i>	ko‘oko‘olau	Short-lived perennial herb
<i>Bidens micrantha</i> ssp. <i>ctenophylla</i>	ko‘oko‘olau	Short-lived perennial herb
<i>Cyanea marksii</i>	hāhā	Short-lived perennial palm-like tree
<i>Cyanea tritomantha</i>	‘akū	Short-lived perennial palm-like tree
<i>Cyrtandra nanawaleensis</i>	ha‘iwale, kanawao ke‘oke‘o	Short-lived perennial shrub
<i>Cyrtandra wagneri</i>	ha‘iwale, kanawao ke‘oke‘o	Short-lived perennial shrub
<i>Melicope remyi</i> (listed as <i>Platydesma remyi</i>)	no common name	Long-lived perennial shrub or shrubby tree
<i>Phyllostegia floribunda</i>	no common name	Short-lived perennial subshrub
<i>Pittosporum hawaiiense</i>	hō‘awa	Long-lived perennial tree
<i>Pritchardia lanigera</i>	loulu	Long-lived perennial tree
<i>Schiedea diffusa</i> ssp. <i>macraei</i>	no common name	Short-lived perennial vine
<i>Schiedea hawaiiensis</i>	no common name	Short-lived perennial herb
<i>Stenogyne cranwelliae</i>	no common name	Short-lived perennial vine
Invertebrates		
<i>Drosophila digressa</i>	picture-wing fly	Not applicable
<i>Vetericaris chaceorum</i>	anchialine pool shrimp	Not applicable

Recovery Vision

A recovery vision builds on the description of viability for the species and defines what recovery looks like for the species. The recovery vision for the 15 species addressed in this draft recovery plan (hereafter, the 15 species) is redundant, self-sustaining populations representing the genetic and ecological diversity of the species distributed across their ranges in habitats where threats are managed. A recovery vision for each species group or species is presented in the main body of this document.

Recovery Strategy

Achieving recovery for the 15 species will require assessments of populations and their habitat, selection of sites for long-term conservation, threat management, development of regulatory protections (e.g., increased biosecurity regulations), species-specific research, and conservation translocation (hereafter, translocation [i.e., deliberate movement of organisms for conservation]) to maximize resiliency, redundancy, and representation. The recovery strategy for each species group or species is presented in the main body of this document.

Many of the plant species covered by this recovery plan persist at very low numbers and are in rapid decline. To target and track recovery efforts for critically rare plants, the Hawai'i and Pacific Plants Recovery Coordinating Committee (HPPRCC) developed two interim recovery stages with the goal of minimizing the likelihood of extinction and to stabilize populations (HPPRCC 2011). While defining these two interim recovery stages is not required under the ESA, they are vital for the recovery of these species. In addition to these interim stages, we have identified the required recovery criteria that, when met, indicate downlisting or delisting a species may be warranted. Recovery will be achieved through a series of conservation stages: (1) preventing extinction, (2) interim stabilization, (3) downlisting, and (4) delisting.

The conservation measures recommended by these stages include genetic storage, managing threats in the immediate vicinity of individual plants, and translocation with the goal of protecting and/or creating multiple resilient populations of each species across its known range. The recovery of each species will follow from these initial efforts and include continued assessments of the distribution and condition of the 13 plant species and their habitat, selection of sites for their long-term conservation, management of threats, and development of regulatory protections to assure their long-term protection. Several species will also need protection from species-specific threats including vandalism, collection, rodents, logging of *Acacia koa*, predation or herbivory by nonnative invertebrates (e.g., slugs, leafhoppers, beetles), introduction of disease, and limited numbers.

The invertebrate species covered by this recovery plan presumably persist at very low numbers. Preventing extinction and stabilizing populations are immediate needs. The recovery strategy for the anchialine pool shrimp and picture-wing fly includes identification of all extant populations throughout the historical and existing suitable range of each species to assess their distribution, respectively. For both species, establishing captive rearing programs to prevent extinction and provide future sources for conservation translocation is an immediate need. Research will inform adaptive management. Each species will need long-term protection of habitat and populations from species-specific threats including habitat degradation from a variety of sources, predation,

loss of host plants, competition, disease, water quality, lack of sufficient breeding or food resources, and human-associated threats such as collection of individuals.

Recovery and long-term protection of all 15 species will require collaboration with Federal, State, County, nonprofit, and private stakeholders to develop adaptive management and monitoring plans for each species' habitats, threats, and biosecurity. Some species may require conservation translocation to historical, restored, or created habitats suitable to achieve the resiliency necessary for a species to thrive. Recovery strategies for individual species and species groups are in the body of the recovery plan.

Interim Recovery Stages

Plant Species

Preventing Extinction

To meet the preventing extinction goal, a thorough and accurate population survey and population size estimate of the 13 listed plants must be completed throughout each species' historical range. Reproductive studies must be completed as needed to inform management actions for various species. Each species requires a minimum of 3 to 6 self-sustaining populations comprised of 25 to 50 mature individuals per population with evidence of natural reproduction (i.e., viable seeds, seedlings, saplings). Threats are assessed and managed in the immediate vicinity of the populations. Genetic storage of at least 50 individuals per population, or the total number of individuals if fewer than 50 remain, are secured in a well-managed *ex situ* collection (such as a nursery or seed bank) (Guerrant et al. 2004, entire).

Interim Stabilization

To meet the interim stabilization goal, all preventing extinction targets must be achieved as well as having 3 to 6 self-sustaining populations comprised of 100 to 300 mature individuals per population and threat management continues around each population. Monitoring is in place to assess individual plant survival, population trends, trends of major limiting factors, and the response of populations to threat management. In addition, all populations must be adequately represented in a well-managed *ex situ* collection (Guerrant et al. 2004, entire).

The following table summarize the downlisting and delisting criteria for the 13 plant species covered in this recovery plan. See the body of the recovery plan for a detailed explanation of each of the criteria.

Recovery Criteria

Plant Species

Downlisting and Delisting Criteria — 13 Plant Species

	Criterion 1	Criterion 2
Downlisting Criteria	At least 5 or 10 resilient populations, each with 200 or 500 individuals.	Habitat and threats are managed; monitoring and management plans are completed and implemented for all species.
Delisting Criteria	At least 10 or 20 resilient populations, each with 200 or 500 individuals.	Habitat and threats are managed; population status and threats monitored.

Animal Species

The following tables summarize the downlisting and delisting criteria for the 2 animal species covered in this recovery plan. See the body of the recovery plan for a detailed explanation of each of the criteria.

Downlisting and Delisting Criteria — *Vetericaris chaceorum*

	Criterion 1	Criterion 2	Criterion 3	Criterion 4
Downlisting Criteria	At least six distinct anchialine pool complexes occupied by stable populations.	Land protections are in place for each distinct anchialine pool complex in <i>Downlisting Criterion 1</i> .	Occupied anchialine pools in <i>Downlisting Criterion 1</i> have sufficient water quality to support the species and are protected from habitat degradation.	All major threats to habitat and individuals are managed; monitoring and management plans are completed and implemented.
Delisting Criteria	At least 11 distinct anchialine pool complexes occupied by stable populations.	Land protections are in place for each distinct anchialine pool complex in <i>Downlisting Criterion 1</i> .	Occupied anchialine pools in <i>Delisting Criterion 1</i> have sufficient water quality to support the species and are protected from habitat degradation.	All major threats to individuals and habitat are managed; monitoring of population status and threats is ongoing.

Downlisting and Delisting Criteria — *Drosophila digressa*

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
Downlisting Criteria	At least five populations with stable population indices are distributed throughout the species' historical range or in otherwise suitable habitat; all units of designated critical habitat are occupied by at least one population.	A captive rearing program is established that supports reestablishment in historical and suitable range.	Each picture-wing fly population site in <i>Downlisting Criterion 1</i> has viable populations of appropriate host plant species.	Threats to suitable habitat supporting populations in <i>Downlisting Criterion 1</i> , are managed and habitats are afforded land protections to maximize the long-term persistence of the species.	All major threats to individual picture-wing flies in <i>Downlisting Criterion 1</i> are managed; monitoring and management plans are completed and implemented; measures are in place to prevent introduction of new threats to host plants.
Delisting Criteria	10 years of systematic surveys have documented significant increases in population indices and the species is represented by at least 10 populations distributed throughout its historical range or in otherwise suitable habitat; all units of designated critical habitat are occupied by one or more populations.	Each population site in <i>Delisting Criterion 1</i> has viable populations of appropriate host plant species.	All major threats to suitable habitats supporting populations in <i>Delisting Criterion 1</i> , habitats are managed and habitats are afforded land protections to maximize the long-term persistence of the species.	All major threats to individuals and populations in <i>Delisting Criterion 1</i> are managed; monitoring of threats and population status is ongoing; measures are in place to prevent introduction of new threats.	N/A

Recovery Actions and their Costs

Recovery actions and cost estimates for all 15 species are shown in the table below. Cost estimates are preliminary. Project-level details of recovery action implementation will be developed with partners in a separate recovery implementation strategy (RIS) document, which will supplement this draft recovery plan. Implementation is subject to availability of funds and is at the discretion of partners.

Estimated Costs of Recovery Actions for all 15 Species (in Fiscal Year 2022 dollars)

Recovery Actions	Recovery Action #	Estimated Cost
Determine the current distribution and status of the species and their habitats.	1.0	\$15,330,000
Protect populations and manage threats to habitat.	2.0	\$499,343,600
Manage species-specific threats.	3.0	\$159,456,400
Expand the distribution of existing wild populations and establish new populations.	4.0	\$231,669,500
Conduct additional research essential to recovering the 15 species and restoring their habitats.	5.0	\$105,890,000
Implement regulations and policy to support species recovery.	6.0	\$13,150,000
		TOTAL: \$1,024,839,500

Date of Recovery

If all actions are fully funded and implemented as outlined, including cooperative efforts by all partners needed to achieve recovery, we estimate the earliest that the delisting criteria could be met would be between 2077 and 2117 for the plant species, 2072 for the picture-wing fly, and 2082 for the anchialine pool shrimp.

ACRONYMS AND ABBREVIATIONS

Act	Endangered Species Act
CRB	coconut rhinoceros beetle
DLNR	State of Hawai‘i Department of Land and Natural Resources
DOFAW	State of Hawai‘i Division of Forestry and Wildlife
ft	feet
HDOH	Hawai‘i State Department of Health
HPPRCC	Hawai‘i and Pacific Plants Recovery Coordinating Committee
in	inch
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
km	kilometer
m	meter
mm	millimeter
NAR	Natural Area Reserve
NMFS	National Marine Fisheries Service
ppt	Parts per thousand
PEPP	Plant Extinction Prevention Program
PIFWO	Pacific Islands Fish and Wildlife Office
RIS	Recovery Implementation Strategy
ROD	Rapid ‘Ōhi‘a Death
RPI	Recovery Planning and Implementation
Service	U.S. Fish and Wildlife Service
SR	Species Report
SSA	Species Status Assessment
ssp	subspecies
USFWS	U.S. Fish and Wildlife Service

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I. INTRODUCTION

The Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*) (Act) protects species of wildlife and plants that are listed as endangered or threatened. Recovery is defined as “the process by which listed species and their ecosystems are restored and their future is safeguarded to the point that protections under the Act are no longer needed,” according to National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (Service) Interim Recovery Planning Guidelines, Version 1.4 (NMFS and USFWS 2018).

Recovery plans are guidance documents developed to provide recommendations to reduce or alleviate threats to the species (includes distinct population segments, subspecies, species groups) and ensure self-sustaining populations in the wild. Section 4(f)(1) of the Act requires that recovery plans include: (1) a description of site-specific management actions necessary to conserve the species; (2) objective, measurable criteria that, when met, will allow the species to be removed from the Federal Lists of Endangered and Threatened Wildlife and Plants (Lists); and (3) estimates of the time and cost required to achieve the plan’s goals and intermediate steps.

This draft recovery plan addresses 15 species or subspecies (13 plants [10 species, 3 subspecies; hereafter species], 1 anchialine pool shrimp, and 1 picture-wing fly) that occur on the island of Hawai‘i (Figure 1). All 15 species were listed as endangered on October 29, 2013 (Table 1; USFWS 2013). The Recovery Outline for Hawai‘i Island was published on October 31, 2019, and addressed these same 15 species (USFWS 2019).

Critical habitat was designated on August 21, 2018 (USFWS 2018), for one plant species, *Bidens micrantha* ssp. *ctenophylla* (Table 1). Critical habitat is currently being determined for the anchialine pool shrimp, the picture-wing fly, and the other 12 plant species.

A. BACKGROUND

1. Species Information

The species addressed in this draft recovery plan occur on the island of Hawai‘i (Figure 1). Detailed species descriptions, life history, status, historical and current range, and distribution are contained in the proposed listing rule (USFWS 2012), final listing determination (USFWS 2013), and 15 Species Reports (USFWS 2021a through USFWS 2021o). The 15 listed species are known from 8 habitats: coastal, dry shrublands and grasslands, dry forest, mesic forest, mesic shrublands and grasslands, wet forest, wet shrublands and grasslands, and wetlands (Tables 2 and 3; Ball et al. 2020; Browning et al. 2020; Clark et al. 2020; Javar-Salas et al. 2020; Kim et al. 2020; Lowe et al. 2020; Nelson et al. 2020; Pe‘a et al. 2020; Phillipson et al. 2020). These species and their habitats occur on public and private lands (USFWS 2013). See the Appendix for the list of species with their associated Species Report and Habitat Status Assessment(s).

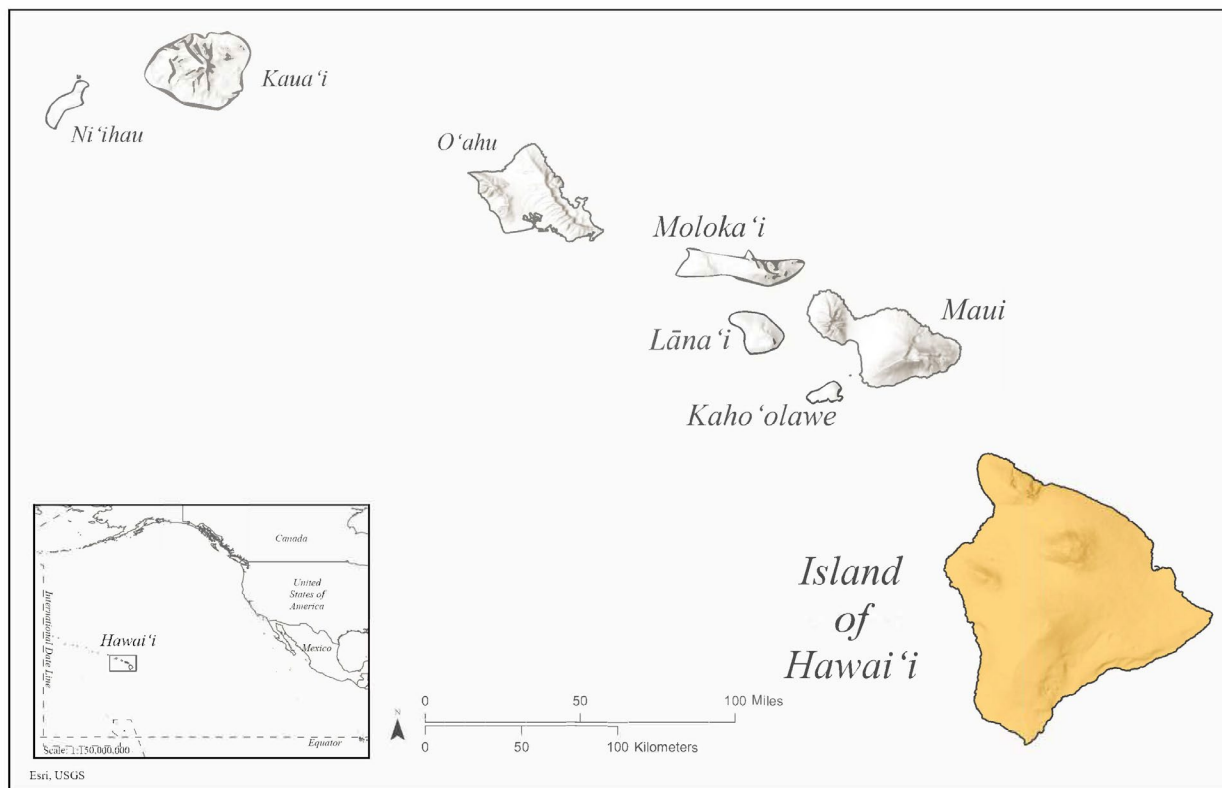


Figure 1. The main Hawaiian archipelago with the island of Hawai'i shown in yellow. Map compiled from Esri (2021) and Hawai'i Statewide Geographic Information System Program (2021) datasets.

The 13 plant species addressed in this recovery plan consist of perennial trees, palm-like trees, shrubs, subshrubs, vines, and herbs. Many of these plant species are maintained *ex situ* (off site, e.g., in a botanical garden or rare plant facility) in controlled propagation, as germplasm, or in micropropagation storage such as seedbanks, or both (Table 1). Ten of the plant species have short life spans defined here as greater than 1 year but less than 10 years, and the remaining 3 species (*Melicope remyi*, *Pittosporum hawaiiense*, and *Pritchardia lanigera*) have life spans greater than 10 years. Collectively, the 13 plant species occupy 7 terrestrial habitats: coastal habitat, dry shrublands and grasslands, dry forest, mesic forest, mesic shrublands and grasslands, wet forest, and wet shrublands and grasslands.

There has been a recent taxonomic change for one plant species that does not affect its range or endangered status. *Platydesma remyi* was first described by Sherff (1939, pp. 557–558) as *Claoxylon remyi* and was later placed in the genus *Platydesma* by Degener et al. (1960, entire). This taxonomy was accepted by Stone in Wagner et al. (1999, p. 1210). In 2017, Appelhans et al. placed *Platydesma* within the genus *Melicope*, as supported by molecular phylogenetic studies. The new scientific name for this species is *Melicope remyi* in the most recent taxonomic treatment in the checklist of Hawaiian flora (Smithsonian Institution 2020, entire). We will refer to this species as *Melicope remyi* through the remainder of this recovery plan.

The anchialine pool shrimp (*Vetericaris chaceorum*) addressed in this recovery plan is a member of the family Procarididae and the only known species in the genus *Vetericaris*. The species is endemic to anchialine pools, which are coastal land-locked bodies of water that have underground hydrological connections to the ocean and show tidal fluctuations in water level. These pools are mixohaline (brackish), with salinities typically ranging from 2 parts per thousand (ppt) to concentrations just below that of sea water (32 ppt), although some pools are recorded as having salinities as high as 41 ppt (Maciolek 1983, pp 607–612; Brock et al. 1987, p. 200; Browning et al. 2020 p. 4). The shrimp inhabit an extensive network of water-filled interstitial spaces (cracks and crevices) leading to and from the actual pool, a trait that has precluded researchers from ascertaining accurate population size estimates without draining the entire pool (Holthuis 1973, p. 36; Maciolek 1983, pp. 613–616; Iwai et al. 2009, entire). Anchialine pools occur singly or in groups and are located in lava fields, tubes, and cracks; under rock overhangs and open wells (Maciolek and Brock 1974, p. 2; Browning et al. 2020, p. 4). Water flow in anchialine pools is influenced by tidal fluctuations and occurs primarily underground with no consistent surface connection to the ocean (Maciolek and Brock 1974, p. 5; Browning et al. 2020, p. 4). Some pools contain surface water only during high-tide events (Maciolek and Brock 1974, p. 5). The water chemistry in anchialine pools is variable with salinities ranging from 0 to 41 parts per thousand and surface temperatures ranging from 62.6 to 96.8 degrees Fahrenheit (17 to 36 degrees Celsius) (Yamamoto et al. 2015, pp. 5, 7).

This anchialine pool shrimp is known only from two separate anchialine pool complexes on the island of Hawai‘i where it coexists with other anchialine pool shrimp (Table 1; Kensley and Williams 1986, pp. 417–418; Brock 2004, entire; Sakihara 2012, p. 89). *Vetericaris chaceorum* is a blind predator of small invertebrates and captures prey in a basket formed by its pereopods (walking limbs) as it swims (Kinzie 2010 in litt., entire). Gut content analysis by Kensley and Williams (1986, p. 426) documented a large quantity of orange-colored oil and numerous crustacean fragments, some of which proved to be from another endangered anchialine pool shrimp, *Procaris hawaiana*. While feeding habits have not been observed in the field, in the lab *V. chaceorum* actively catch and consume ‘ōpae‘ula (*Halocaridina rubra*) (Sakihara 2012 in litt., entire; Yamamoto et al. 2015, p. 40).

Vetericaris chaceorum was first discovered at Lua o Palahemo in 1986; since then, the species has been documented in five anchialine pools consisting of two populations. Of these, one occurs at Lua o Palahemo, three occur inside the Manukā Natural Area Reserve (NAR) and another occurs outside the Manukā NAR (USFWS 2021o). Lua o Palahemo is approximately 9.3 miles (mi) (15 kilometers [km]) from the anchialine pools at Manukā and there is no known subterranean connection between the two areas (Fransen et al. 2013, p. 630), thus we consider them two distinct populations. The last detection of the anchialine pool shrimp at Lua o Palahemo and at Manukā occurred in 1991 and 2016, respectively (Shizuma et al. 2016, p. 33). For the purposes of this recovery plan, because there is no evidence that the species has been extirpated from Lua o Palahemo, it is considered extant despite a lack of surveys (USFWS 2021o, p. 7). It is considered extant at Manukā because conditions have not changed since the 2016 surveys (USFWS 2021o, pp. 8, 18).

The picture-wing fly addressed in this recovery plan is *Drosophila digressa*, in the family Drosophilidae. It is endemic to the island of Hawai‘i and historically known from five locations,

ranging in elevation from approximately 2,000 to 4,500 feet (ft) (610 to 1,370 meters [m]) in mesic forest and montane wet forest habitats (Hardy and Kaneshiro 1968, p. 182; Montgomery 1975, p. 95; Magnacca 2006 in litt., entire; Magnacca 2012 in litt., entire; Kaneshiro 2013 in litt., pp. 1–2; USFWS 2013, p. 64643). The picture-wing fly was not observed at the species' historical Kīpuka puauulu site during intensive surveys in 1997 and 1998, and that population may now be extirpated as this forest area is currently too open and dry to support this picture-wing fly species (Magnacca 2006 in litt., entire; Magnacca 2012 in litt., entire). The species was observed only once at the Kīpuka 9 site despite several surveys prior and after 1986. The closest population of its breeding host, *Charpentiera* spp., is several miles away at 'Ōla'a, and it is likely that this record is of a vagrant individual (Magnacca 2012 in litt., entire). The Hualālai site, where *D. digressa* was observed once in 1971 and 1972, has not been intensively searched since the mid-1970s, but the area has become significantly degraded and it is unlikely the conditions support the picture-wing fly species (Magnacca 2006 in litt., p. 2). Based on the most recent surveys conducted in 2009 and 2010, the species persists at two locations. One population occurs in the Olopuia Kīpuka fenced exclosure in the mesic montane habitat of the Manukā NAR, and the other population occurs in montane wet habitat of 'Ōla'a Forest within Hawai'i Volcanoes National Park. The number of individuals at each of these locations is unknown (Table 1). Given the limited number of surveys outside of the species known range, it is possible that small populations exist in areas not recently surveyed (Table 1) (Magnacca 2019 in litt., entire).

Adult picture-wing flies are generalist microbivores (microbe eating) and feed on decomposing plant material. Females oviposit (lay their eggs) only in stems and bark of decaying *Charpentiera* spp. (pāpala), *Ceodes brunoniana* (pāpala kēpau [previously known as *Pisonia brunoniana*]), and *Rockia sandwicensis* (pāpala kēpau [previously known as *Pisonia sandwicensis*]) (Magnacca 2012 in litt., entire; Rossetto and Caraballo-Ortiz 2020, entire). *Rockia sandwicensis* and *C. brunoniana* are found only at the sites where this picture-wing fly is already known ('Ōla'a Forest and Manukā NAR), or where the forest is currently too open and dry to support this species of picture-wing fly (e.g., Kīpuka puauulu, Pu'uwa'awa'a cinder cone). The third plant species, *Pisonia umbellifera*, can be found at lower elevations on the windward side of the island, such as gulches on the east slopes of Kohala and Mauna Kea below 1,500 ft (457 m), but the picture-wing fly has never been recorded from these areas or elevation (Magnacca 2012 in litt., entire).

Breeding generally occurs year-round, but egg laying and larval development increases following the rainy season, which increases the availability of decaying plant material that picture-wing fly larvae feed on. The larvae complete their development in the decaying tissue before dropping to the soil to pupate. Pupae develop into adults in approximately 1 month. Adults become sexually mature about 1 month later and live for 1 to 2 months (Spieth 1974 pp. 385, 389; Science Panel 2005 pp 3–5). This picture-wing fly species is not currently in a captive rearing program.

Table 1. Species, number of wild populations and individuals, *ex situ* or captive rearing status, recovery priority number, and dates of final listing rule and critical habitat designation or status.

Taxon	Number of Populations	Number of Individuals	<i>Ex situ</i> Conservation	Recovery Priority Number¹	Listing	Critical Habitat
PLANTS						
<i>Bidens hillebrandiana</i> ssp. <i>hillebrandiana</i>	1	40	Propagation	6	USFWS 2013	Being determined ³
<i>Bidens micrantha</i> ssp. <i>ctenophylla</i>	4	500	Seed storage, propagation	3	USFWS 2013	USFWS 2018
<i>Cyanea marksii</i>	4	67	Seed storage, propagation	5	USFWS 2013	Being determined ³
<i>Cyanea tritomantha</i>	18	>400	Seed storage, propagation	5	USFWS 2013	Being determined ³
<i>Cyrtandra nanawaleensis</i>	6	<37	Leaf cuttings, propagation	5	USFWS 2013	Being determined ³
<i>Cyrtandra wagneri</i>	3	5	Seed storage, propagation	5	USFWS 2013	Being determined ³
<i>Melicope remyi</i>	2	25	Propagation	5	USFWS 2013	Being determined ³
<i>Phyllostegia floribunda</i>	3	9	Seed storage, propagation	5	USFWS 2013	Being determined ³
<i>Pittosporum hawaiiense</i>	24	317	Propagation	2	USFWS 2013	Being determined ³
<i>Pritchardia lanigera</i>	9	150–200	Seed storage, propagation	2	USFWS 2013	Being determined ³
<i>Schiedea diffusa</i> ssp. <i>macraei</i>	1	1	Seed storage, propagation	6	USFWS 2013	Being determined ³

Taxon	Number of Populations	Number of Individuals	<i>Ex situ</i> Conservation	Recovery Priority Number ¹	Listing	Critical Habitat
	PLANTS Cont'd.					
<i>Schiedea hawaiiensis</i>	1	12	Seed storage, propagation	5	USFWS 2013	Being determined ³
<i>Stenogyne cranwelliae</i>	2	7	Propagation	5	USFWS 2013	Being determined ³
	INVERTEBRATES					
<i>Drosophila digressa</i>	≥2	Unknown	None	5	USFWS 2013	Being determined ³
<i>Vetericaris chaceorum</i>	2	Unknown	None	5 ²	USFWS 2013	Being determined ³

¹Recovery Priority Number is based on degree of threat, recovery potential, taxonomic distinctiveness, and presence of an actual or imminent conflict between the species and development activities (click [here](#) for details).

²Recovery Priority Number revised since finalization of the Recovery Outline for Hawai'i Island.

³Critical habitat for 14 of the species is being determined and is expected to be made available for public comment in 2022.

2. Threats

A description of the threats to the 15 species is provided below and summarized in Table 2 (plants) and Table 3 (anchialine pool shrimp and picture-wing fly). Threats are organized by species groups and by the five listing threat factors (A through E). Although some threats are shared among species groups, impacts to individual species and the actions needed to eliminate or manage the threats may differ, as highlighted below. Due to space limitations, some potential threats are not listed in Table 2, but are discussed below. These include the nonnative two-spotted leaf hopper, coconut rhinoceros beetle, nonnative ants, and vandalism and trash dumping.

Plants

Factor A (Present or threatened destruction, modification or curtailment of its habitat or range)

The 13 plant species addressed in this draft recovery plan (hereafter 13 plant species) face varying degrees of habitat loss and degradation (Table 2) from ungulates, human development, invasive species, fire, drought, and stochastic events.

Depending on the native plant species and its habitat, nonnative ungulates including mouflon sheep (*Ovis gmelini musimon*), pigs (*Sus scrofa*), feral cattle (*Bos taurus*), goats (*Capra hircus*), and sheep (*O. aries*) threaten the 13 plant species by degrading native vegetation in occupied or suitable habitats (Table 2). Ungulates degrade habitats by: (1) creating trails that damage native vegetative cover; (2) destabilizing substrate causing erosion, landslides, rockfalls, and vegetation loss; (3) injuring roots, seedlings, or plants through trampling, and/or rooting; (4) creating gullies that contribute to flooding or destabilization of the substrate; and (5) promoting invasion of nonnative species through the transport of seeds, vegetative plant parts, or creation of openings (Cuddihy and Stone 1990, pp. 63–64; Duenas et al. 2018, entire; Wehr et al. 2018, entire).

Destruction and degradation of habitat by development is a threat specific to *Bidens micrantha* ssp. *ctenophylla* (Table 2). This species is currently found in an area of less than 10 square mi (26 square km) on the leeward slopes of Hualālai, an increasingly urbanized region of north Kona, where there is very little undisturbed native habitat (Pratt and Abbott 1996, p. 25). Development and urbanization results in habitat loss and fragmentation, which leads to edge effects and decreases in pollinator interactions (Harrison and Bruna 1999, pp. 227–228).

Depending on the native plant species and its habitat, various invasive plant species threaten the 13 plant species by degrading native vegetation in occupied or suitable habitats (Table 2, USFWS 2013, entire). Invasive plant species compete with native plant species for water, space, nutrients, and light. Nonnative plant species modify the availability of light and nutrient cycling, alter soil-water regimes and the fire regime affecting native plant communities, and ultimately, convert native-dominated plant communities to nonnative plant communities (Smith 1985, pp. 180–181; Cuddihy and Stone 1990, p. 74; D’Antonio and Vitousek 1992, p. 73; Vitousek et al. 1997, p. 6).

Fire is a serious and ongoing threat to three plant species addressed in this plan (Table 2). Fire damages and destroys native plant species, including dormant seeds, seedlings, and juvenile and adult plants. Because native plants of Hawai‘i were subjected to fire during their evolution only

in areas of volcanic activity and from occasional lightning strikes, they are not adapted to recurring fire regimes and do not quickly recover following a fire (Smith and Tunison 1991, pp. 395–397). Many invasive plants, particularly fire-tolerant grasses, outcompete native plants and inhibit their regeneration (D’Antonio and Vitousek 1992, pp. 70, 73–74; Tunison et al. 2002, p. 122). The number and size of wildfires are increasing in the main Hawaiian Islands and successive fires burn deeper into native habitat, further reducing available habitat. Fire alters microclimatic conditions, creating conditions favorable to nonnative plants. Human alteration of landscapes and the introduction of nonnative plants, especially grasses, has led to greater frequency, intensity, and duration of fires (Brown and Smith 2000, p. 172). Grass-fueled fire often kills most native trees and shrubs (D’Antonio and Vitousek 1992, pp. 70, 73–74).

Drought may directly affect at least five plant species addressed in this plan and their habitats (Table 2). Drought has the potential to occur at any time and causes the direct loss of individuals due to dehydration and death. In addition, it causes the loss or degradation of habitat due to the mortality of individual native plants, increases the frequency and extent of forest and brush fires, and modifies water availability and vegetation composition (Javar-Salas et al. 2020; Lowe et al. 2020; Ball et al. 2020; Pe‘a et al. 2020; Clark et al. 2020; Nelson et al. 2020). Drought frequency and extent may be exacerbated by climate change, as noted below under *Factor E (Other natural or manmade factors affecting the species continued existence)*.

All 13 plant species are vulnerable to stochastic events (e.g., hurricanes, earthquakes, lava flows, and tsunamis) that can result in mortality of individuals or destroy and alter their habitat; habitat alteration may modify the amount of light and create disturbed areas conducive to invasion by nonnative pest species (Table 2; USFWS 2013, entire). Disturbed areas and gaps in the canopy facilitate the establishment of nonnative plants, which can outcompete native species. Depending on location, some species are also vulnerable to erosion, landslides, rockfalls, treefalls, and flooding which cause either direct loss of the species or alter their habitat (Table 2). For plant species that persist in low numbers, stochastic events can be particularly devastating.

Factor B (Overutilization for Commercial, Recreational, Scientific or Educational Purposes)

Pritchardia species are one of the most widely cultivated ornamental palm genera in the world (Maunder et al. 2001, cited in Chapin et al. 2004, p. 278). Of the 13 plant species addressed in this plan, *Pritchardia lanigera* is particularly vulnerable to overutilization. Several websites advertise the sale of Hawaiian *Pritchardia* plants and seeds, including *P. lanigera*. Based on the number of *Pritchardia* plants and seeds collected from the wild in Hawai‘i and the demand for them, overcollection of *P. lanigera* is a serious and ongoing threat (Table 2; Chapin et al. 2004, p. 278).

Factor C (Disease and Predation)

Several plant diseases have the potential to negatively affect the 13 plant species either directly or indirectly by disrupting the native forest canopy structure. The plant disease Rapid ‘Ōhi‘a Death (ROD) is an ongoing threat to *Metrosideros polymorpha* (‘ōhi‘a), an important canopy tree in many Hawaiian forests. Rapid ‘Ōhi‘a Death is caused by two fungal pathogens, *Ceratocystis lukuohia* and *C. huliohia*, and can kill individual trees as well as groups of trees

(Barnes et al. 2018, entire). Both pathogens are found on the island of Hawai‘i and the disease is widespread (Friday et al. 2022, entire). While ‘ōhi‘a is not a listed species, it is a major structural element of native forests and thus ROD has the potential to create canopy gaps, modify light and microclimate conditions in the understory, and promote establishment of nonnative plants within the habitats of all 13 species. Other disease threats include myrtle rust (*Austropuccinia psidii*), which also affects ‘ōhi‘a and other plants in the Myrtaceae family, and powdery mildew (*Neoerysiphe galeopsidis*), which affects species in the genus *Phyllostegia* and thus could directly affect populations of *P. floribunda* (Table 2; USFWS 2021i).

Introduced ungulates threaten the 13 plant species by eating seedlings, shoots, or young plants before they can become established and tolerate herbivory. In addition, ungulates trample and crush individual listed plants.

Three species of nonnative rats, including the Polynesian rat (*Rattus exulans*), the roof rat (*R. rattus*), and the Norway rat (*R. norvegicus*) are present in the Hawaiian Islands and threaten at least 11 of the plant species addressed in this plan. Rodents in general, and particularly rats, can damage or kill individual plants by eating their seeds, flowers, stems, leaves, roots, and other plant parts (Table 2; Atkinson and Atkinson 2000, p. 23), which can significantly affect regeneration. Rats have been responsible for the decline, extirpation, and extinction of plant species throughout Hawai‘i (Cuddihy and Stone 1990, pp. 68–70).

Intentionally introduced game birds, such as ring-necked pheasant (*Phasianus colchicus*), California quail (*Callipepla californica*), Erckel’s francolin (*Pternistis erckelii*), black francolin (*Francolinus francolinus*), gray francolin (*F. pondicerianus*), and the Chukar partridge (*Alectoris chukar*), threaten *Schiedea hawaiiensis* at Pōhakuloa Training Area (Table 2; CSU 2015, pp. 55–56) by feeding on individual plants and by spreading nonnative plants by dispersing seeds via their droppings, including grasses, which contributes to fuel loads and increases the threat of fire (D’Antonio and Vitousek 1992, p. 73; Vitousek et al. 1997, p. 6). While these species may also disperse native seeds, as previously noted, invasive plants often outcompete native Hawaiian species for resources (Cole et al. 1995, p. 311; Cuddihy and Stone 1990, p. 74).

Nonnative slug species in Hawai‘i are generalist herbivores found in mesic shrublands, mesic forests, and wet forest ecosystems that threaten populations of at least seven plant species addressed in this plan and their habitats by feeding on seedlings and low-statured herbaceous plants, destroying plant parts and killing plants (Table 2; Joe 2006, p. 10; HBMP 2010, unpublished data; USFWS 2016b, p. 67803; Clark et al. 2020, p. 9; Lowe et al. 2020, p. 14). Slugs have a two-fold effect on the ecosystems of Hawai‘i. Not only do they reduce recruitment of rare species by consuming seedlings, but they may also facilitate the success of some invasive plant species (Joe and Daehler 2008, pp. 252–253).

The nonnative two-spotted leaf hopper (*Sophonia rufofascia*) has been reported to be a potential threat to *Pritchardia* species in the Hawaiian Islands and thus may be a potential threat to *P. lanigera* (Table 2; Chapin et al. 2004, p. 279). This insect damages leaves and typically causes chlorosis (yellowing due to disrupted chlorophyll production) to browning resulting in the eventual death of the foliage (Jones et al. 2000, pp. 171–180). This damage can result in death of the plant, owing to the combined action of its feeding and oviposition (i.e., egg laying). In

addition to the mechanical damage, the insect may introduce pathogens that can also lead to loss of vigor and death (Alyokhin et al. 2004, p. 1).

Nonnative *Coccotrypes* beetles bore into and feed on native palm tree fruits, including *Pritchardia* species (Table 2; Swezey 1927, entire; Science Panel 2005, entire; Magnacca 2005 in litt., p. 1). *Coccotrypes* beetles prefer trees with large seeds like those of *Pritchardia*. They bore into the fruit causing it to drop before reaching maturity, thereby reducing natural regeneration (Magnacca 2005 in litt., p. 1; Science Panel 2005, entire). The effect of *Coccotrypes* beetles on Hawaiian *Pritchardia* species is expected to increase if these beetles are not controlled, potentially resulting in significant impacts to populations of *P. lanigera* (Magnacca 2005 in litt., p. 1).

Another nonnative beetle that is a potential threat to *Pritchardia lanigera* is the coconut rhinoceros beetle (CRB, *Oryctes rhinoceros*). The CRB, a large scarab beetle about 2 in (5 cm) long, is considered one of the most damaging insects to coconut and African oil palm trees in southern and southeast Asia, as well as to the western Pacific islands, and could devastate populations of native and nonnative palm trees in Hawai‘i (OISC 2021, entire). Beetles bore into the crowns of palms where they feed on sap. Eggs are laid inside rotting palm logs, mulch, or compost, and larvae develop to adults within 4 months, continuing the cycle. In 2013, the CRB was discovered on O‘ahu and spread across the island within a few months (Hawai‘i Department of Agriculture 2022, entire). While currently not present on the island of Hawai‘i, if the CRB reaches the island, the effect on the remaining *P. lanigera* palms could be devastating.

Nonnative ant species can interfere with the pollination of some plant species that are suspected to be pollinated by insects and ants and are therefore considered a potential threat to the 13 plant species. Ants, particularly yellow crazy ants (*Anoplolepis gracilipes*), deprive pollinators such as yellow-faced bees (*Hylaeus* spp.) of food by consuming large quantities of nectar without pollinating the plant (Lach 2008, entire). In addition, native bees are less likely to land on flowers occupied by ants (Krushelnicky et al. 2005, p. 9; Magnacca 2015 in litt., entire).

Factor D (Inadequacy of existing regulatory mechanisms)

Existing State and Federal regulatory mechanisms are inadequate at preventing introduction of nonnative species into Hawai‘i or managing the spread of nonnative species between islands and watersheds (Table 2; Howarth and Medeiros 1989, entire; Staples and Cowie 2001, pp. 9–10). Many invasive plants established in Hawai‘i have ranges that are expanding into various ecosystems. Resources available to reduce the spread of these species and counter their negative ecological effects are limited (State of Hawai‘i 2017, p. 44). Management of established nonnative invasive plants is largely focused on a few invasive species that cause significant economic or environmental damage to public and private lands, and comprehensive control of an array of invasive plants remains limited in scope (State of Hawai‘i 2017, pp. 12, 42). The introduction of new invasive plant species to the State of Hawai‘i is a significant risk to the 13 plant species.

Factor E (Other natural or manmade factors affecting the species continued existence)

Alteration of genetic composition due to hybridization is considered a threat to four plant species (Table 2; USFWS 2013, p. 64684). Hybridization can lead to the loss of genotypically distinct species and varieties and could ultimately result in the formation of new species or alternatively, lead to loss of a species' unique genetic characteristics through "introgression" of genes from another species (Orians 2000, p. 1949; Ellstrand 1992, pp. 77, 81; Levin et al. 1996, pp. 10–16; Rhymer and Simberloff 1996, p. 85). Hybridization is especially problematic for rare species in proximity to a closely related abundant species (Rhymer and Simberloff 1996, p. 83).

At least five plant species are threatened by lack of regeneration (Table 2; USFWS 2013, p. 64,684). The causes for this lack of reproduction (i.e., production of flowers, fruits, seeds) and recruitment are not well understood, though inbreeding depression, fruit abortion, or seed predation may play a role. Lack of recruitment due to herbivory by rodents and slugs has been noted for other plant species addressed in this plan as discussed above under *Factor C (Disease and Predation)*.

Vandalism and trash dumping are potential threats to *Bidens micrantha* ssp. *ctenophylla* at the Kaloko Makai Development area because these activities damage or destroy individuals (Table 2; USFWS 2013, p. 64645).

Acacia koa (koa) logging and habitat disturbance associated with logging on land adjacent to the Kīpāhoehoe NAR may be a threat to *Phyllostegia floribunda*; there is no fencing or other demarcation of land ownership in the area (Table 2; DLNR 2002, p. 9).

Limited numbers likely exacerbate threats to more than half of the plant species (Table 2). As a result, these species may experience the following: (1) reduced reproductive vigor due to ineffective pollination or inbreeding depression; (2) reduced levels of genetic variability, leading to a diminished capacity to adapt and respond to environmental changes, thereby lessening the probability of long-term persistence; and (3) increased likelihood that a single catastrophic event may result in the extirpation of remaining populations and the extinction of the species (Barrett and Kohn 1991, pp. 3, 7; Newman and Pilson 1997, pp. 354–355).

Small, isolated populations are inherently more vulnerable to extinction than are widespread species, because of the increased risk of genetic bottlenecks, random demographic fluctuations, climate change effects, and localized catastrophes such as hurricanes, landslides, rockfalls, drought, and disease outbreaks (Pimm et al. 1988, p. 757; Mangel and Tier 1994, p. 607).

All 13 plant species are susceptible, to varying degrees, to changes in environmental conditions resulting from climate change (Table 2). Changes include increasing storm frequency and intensity, increasing temperatures, and decreasing precipitation, which can result in changes to species' microclimates (IPCC 2014, pp. 6–11). Such changes may lead to the loss of listed individuals or the degradation or loss of the habitat that supports the listed species.

Table 2. Summary of habitats used by the 13 plant species addressed in this recovery plan and their threats¹ organized by the five listing factors².

Species	Habitat ³	Factor A					Factor B	Factor C				Factor D	Factor E ⁴	
		Agriculture and Urban Development	Ungulates	Nonnative Plants	Fire	Stochastic Events	Overutilization	Disease	Predation or Herbivory by Ungulates	Predation or Herbivory by Other Nonnative Vertebrates	Predation or Herbivory by Nonnative Invertebrates	Inadequate Existing Regulatory Mechanisms	Other Species-specific Threats	Climate Change
<i>Bidens hillebrandiana</i> ssp. <i>hillebrandiana</i>	CO	--	P, G	✓	--	Dr, E, H, HS, L, Rf,	--	Pt	✓	R	--	✓	LN	✓
<i>Bidens micrantha</i> ssp. <i>ctenophylla</i>	DSG, DF	✓	P, G	✓	✓	DR, H	--	Pt	✓	R	--	✓	Hy, LN	✓
<i>Cyanea marksii</i>	WF	--	P, G, C, M	✓	--	Dr, H, F, L, Rf	--	Pt	✓	R	Sl	✓	LN	✓
<i>Cyanea tritomantha</i>	WF, WSG	--	P, C	✓	--	F, H, L Rf, Tf	--	Pt	✓	R	Sl	✓	LN, NR	✓
<i>Cyrtandra nanawaleensis</i>	MF, MSG, WF	--	P	✓	--	H, V	--	Pt	✓	R	Sl	✓	Hy, LN	✓
<i>Cyrtandra wagneri</i>	WF	--	P, C	✓	--	E, F, H	--	Pt	✓	R	Sl	✓	Hy, LN	✓

Species	Habitat ³	Factor A					Factor B	Factor C				Factor D	Factor E ⁴	
		Agriculture and Urban Development	Ungulates	Nonnative Plants	Fire	Stochastic Events	Overutilization	Disease	Predation or Herbivory by Ungulates	Predation or Herbivory by Other Nonnative Vertebrates	Predation or Herbivory by Nonnative Invertebrates	Inadequate Existing Regulatory Mechanisms	Other Species-specific Threats	Climate Change
<i>Melicope remyi</i>	WF	--	P	✓	--	H	--	Pt	✓	--	--	✓	LN, NR	✓
<i>Phyllostegia floribunda</i>	MF, MSG, WF, WSG	--	P, C	✓	✓	Dr, H	--	Pt, PM	✓	--	Sl	✓	LN, K	✓
<i>Pittosporum hawaiiense</i>	DF, MF, WF	--	C, M, P	✓	--	H	--	Pt	✓	R	--	✓	NR, Hy	✓
<i>Pritchardia lanigera</i>	MSG, WF, WSG	--	C, G, M, P	✓	--	H	✓	Pt	✓	R	Lh, B	✓	NR	✓
<i>Schiedea diffusa</i> ssp. <i>macraei</i>	WF	--	P, C	✓	--	H	--	Pt	✓	R	Sl	✓	LN, NR	✓
<i>Schiedea hawaiiensis</i>	DF	--	P, G, M, S	✓	✓	Dr, H	--	Pt	✓	R, GB	--	✓	LN	✓

Species	Habitat ³	Factor A					Factor B	Factor C				Factor D	Factor E ⁴	
		Agriculture and Urban Development	Ungulates	Nonnative Plants	Fire	Stochastic Events	Overutilization	Disease	Predation or Herbivory by Ungulates	Predation or Herbivory by Other Nonnative Vertebrates	Predation or Herbivory by Nonnative Invertebrates	Inadequate Existing Regulatory Mechanisms	Other Species-specific Threats	Climate Change
<i>Stenogyne cranwelliae</i>	WF	--	P	✓	--	H	--	Pt	✓	R	Sl	✓	LN	✓

¹Threats: B = beetles; C = cattle; Dr = drought; E = erosion; F = flooding; G = goats; GB = Nonnative game birds; H = hurricanes; HS = high surf; Hy = hybridization; K = koa logging; L = landslide; Lh = leafhoppers; LN = limited numbers; M = mouflon; NN = nonnative; NR = no regeneration; P = pigs; PM = powdery mildew; Pt = potential threat to species; R = rats; Rf = rockfall; S = sheep Sl = slugs;; Tf = treefall; V = volcanic eruption; ✓ = Known threat to species, not itemized for brevity.

²Factor A = Present or threatened destruction, modification, or curtailment of the species habitat or range; Factor B = Overutilization for commercial, recreational, scientific, or educational purposes; Factor C = Disease or predation; Factor D = Inadequacy of existing regulatory mechanisms; and Factor E = Other natural or manmade factors affecting the species continued existence.

³Habitats: CO = coastal; DSG = dry shrubland and grassland; DF = dry forest; MF = mesic forest; MSG = mesic shrubland and grassland; WF = wet forest; WSG = wet shrubland and grassland; WT = wetland.

⁴Additional potential threats to some plant species are found in the *Threats Section* above and include nonnative two-spotted leafhopper, coconut rhinoceros beetle, nonnative ants, and vandalism and trash dumping.

Anchialine Pool Shrimp

Factor A (Present or threatened destruction, modification or curtailment of its habitat or range)

Anthropogenic activities are a threat to *Vetericaris chaceorum* and its habitat (Table 3). More than 90 percent of anchialine habitats across the State of Hawai‘i have been lost or degraded by anthropogenic activities like coastal development and the spread of invasive species (Brock 2004, p. i). Of the 300 pools on the island of Hawai‘i surveyed in 2002 (Acly 2003), 43 percent appeared to not support shrimp populations of any species (Wiegner et al. 2006, p. 30).

Coastal development negatively affects *Vetericaris chaceorum* through direct destruction of their habitat, increases in nutrients, and reduction in water quality (Table 3). On the island of Hawai‘i, development between Kawaihae and Kailua-Kona, with a high density of anchialine pools, has resulted in the filling of many pools with rock and other debris (Mitchell et al. 2005, pp. 40, 44, 465; DLNR 2015, p. 7–410). In pools that have been infilled, anchialine pool shrimp may still be able to survive below the water table in cracks and crevices, but the species is likely to occur at a lower population density than in intact pools (Brock and Kam 1997, p. 12). Although regulations limit coastal development, habitat degradation and/or destruction remains a threat due to polluted runoff from rainfall and flooding, and from storm surge overflow events (Brock and Kam 1997, p. 12; see below). Reduced water salinity from runoff negatively affects anchialine pool shrimp, as they are thought to be intolerant of salinities below 10 parts per thousand (ppt) (Maciolek 1983 pp. 611–612).

Habitat degradation and/or destruction by ungulates is a threat to the anchialine pool shrimp (Table 3; Richardson 2012 in litt., pp. 1–2). Feral goats and cattle trample and forage on both native and nonnative plants around and near anchialine pools, which causes erosion and increases sediment entering the pool. Further, cattle carcasses have been observed in the pool at Lua o Palahemo, thus reducing water quality (Kinzie 2010 in litt., entire).

Aside from the direct destruction of anchialine pools via flooding and ungulates, indirect, persistent impacts can occur from nutrient loading and other activities and/or perturbations that reduce water quality (Table 3). Fertilizers, pesticides, and polluted runoff from resort, urban, and commercial development may leach into the groundwater and introduce these effluents into anchialine pools. This can cause direct harm to the anchialine pool shrimp or alter the chemical properties of the anchialine pool, thereby affecting productivity of all species that depend on anchialine pools. In addition to pesticides and nutrients, freshwater runoff from landscaping is also potentially harmful, because the anchialine shrimp is thought to be intolerant of low salinity (Maciolek 1983, pp. 611–612; Lau 2012 in litt., entire).

Water extraction (e.g., withdrawal of subsurface fresh water human use) from underground fresh water sources increases salinity levels of anchialine pools and negatively affects the anchialine pool shrimp that rely on the delicate balance of mixohaline (brackish water) habitats. Alteration of pool salinity may effect reproductive success as well as survival (Conry 2012 in litt., entire; USFWS 2016, p. 67834).

Anchialine pools can be degraded by changes to nearby native plant communities. Many native plants have been replaced by invasive plants, including *Prosopis pallida* (kiawe), mainly as the result of years of pressure from historical cattle grazing (D'Antonio and Vitousek 1992, p. 65; Wagner et al. 1999, pp. 45, 55, 58–62; Dudley et al. 2014, p. 4). While the impact of invasive plants is not as direct as invasive fish and invertebrates, some plants such as kiawe may threaten the health of anchialine pools through the introduction of leaf litter. Kiawe has been identified as a potential cause of nutrient loading (Table 3; Brock et al. 1987, p. 205; Street et al. 2008, p. 370). As a nitrogen-fixing plant, kiawe can add large quantities of nitrogen to the soils, which alters nutrient availability and productivity in anchialine pools through direct additions of nitrogen-rich litter (Dudley et al. 2014, p. 5). Furthermore, leaf litter that is deposited and trapped in the anchialine pool can lead to filling and accelerate the natural senescence of the anchialine pool habitat (Brock 2004, p. 34).

Both stochastic disturbance and catastrophic events such as hurricanes, earthquakes, and tsunamis can degrade or destroy habitat and result in the direct loss of *Vetericaris chaceorum* (Table 3). The coastal area where anchialine pools are found can be directly exposed to storm surge and flooding associated with severe storm events. Indirect effects may include flooding of anchialine pools with fresh water resulting in altered salinity. Altered salinity may effect reproductive success as well as survival of anchialine pool shrimp and/or their prey (Maciolek 1983, pp 607–612; Brock et al. 1987, p. 200; Conry 2012 in litt., entire; USFWS 2016, p. 67834). Anchialine pools can be degraded or destroyed by the transport and deposition of sand and coral rubble by storm surge (Brock 2004, p. 12). In addition, storm surge can result in the introduction of predators such as fish into anchialine pools. Because so few pools are occupied by the anchialine pool shrimp, introduction of fish into a single pool may have catastrophic population-level effects. Natural events such as earthquakes or lava flows can directly alter or destroy habitat. Since the anchialine pool shrimp depends on the hypogeal environment for connectivity, any alteration to this environment could have devastating consequences for reproductive success and the maintenance of genetic diversity. Small populations are demographically vulnerable to extinction caused by random fluctuations in population size and sex ratio. Thus, both catastrophic events and stochastic disturbance may lead to species extinction (Lande 1988, p. 1455).

Factor B (Overutilization for commercial, recreational, scientific, or educational purposes)

Collection for the pet trade threatens *Vetericaris chaceorum* (Table 3). In the past several years, one species of anchialine shrimp, *Halocaridina rubra*, has been increasingly prized by aquarists and companies in the pet trade industry worldwide because of its ability to live in hermetically (airtight) sealed containers and its utility as live feed for seahorses (Weese and Santos 2009, entire; Yamamoto et al. 2015, p. 83). Although *H. rubra* is not listed as threatened or endangered, there is an increasing chance that *V. chaceorum* may either intentionally or accidentally be harvested as the popularity of pet trade in *H. rubra* grows (*V. chaceorum* does occur in pools with *H. rubra* where it most likely preys on it). Because *V. chaceorum* are so rare, one person with a hand-net could do irreparable damage to a population (Yamamoto et al. 2015, entire). Existing legal restrictions are insufficient to deter or prevent collection. Additionally, because *V. chaceorum* appears to be blind (Lau and Williams 1986, p. 426; Lau 2012 in litt., entire), a marked reduction in the density of its prey (*H. rubra*) could impact foraging success (Kinzie 2010 in litt., entire).

Factor C (Disease and Predation)

In general, predation caused by the accidental or intentional introduction and spread of nonnative fish (e.g., bait and aquarium fish) is considered the greatest threat to anchialine pools in Hawai‘i (Table 3; Brock 2004, p. 16). More than 95 percent of anchialine pools along the Kona coast on the island of Hawai‘i have been contaminated by invasive fish over the past 20 to 30 years (Yamamoto and Tagawa 2000, p. 37; Havird et al. 2013, pp. 189–190). Nonnative fish species include members of the Poeciliidae and Cichlidae families (e.g., mosquito fish [*Gambusia affinis*], shortfin or Atlantic molly [*Poecilia mexicana*], guppy [*Poecilia reticulata*], and the tilapia [*Tilapia mossambica*]). These nonnative species can complete their entire life cycle in the pools and therefore are more of a threat than are native fish (see below). In addition to preying on *Vetericaris chaceorum*, nonnative fish are especially problematic for the anchialine pool habitat where their waste products block water flow, resulting in destruction of pool habitat (Wada 2018 in litt., entire).

Based on observations of other species of anchialine pool shrimp, invasive fish can potentially impact *Vetericaris chaceorum* through competition, predation, and the introduction and the potential transmission of parasites and disease (Table 3; Maciolek 1984, pp. 131–161; Chai 1993, p. 59). The presence of invasive fish has been directly linked to the decline in anchialine pool shrimp (*Halocaridina rubra* and *Metabetaeus lohena*) at Kaloko-Honokōhau on the west coast of the island of Hawai‘i (Brock and Kam 1997, p. 56). In areas where they are the dominant fauna, invasive fish prey on and displace anchialine pool shrimp from suitable habitat (Brock 1985, pp. 3–31; Bailey-Brock and Brock 1993, p. 354). In addition, in pools where invasive fish have been introduced, *H. rubra* exhibited strong diel (24 hour) activity patterns not seen in fishless pools (Capps et al. 2009, p. 16; see below). While invasive fish have not been documented to affect *V. chaceorum*, given their impacts to other anchialine pool shrimp species such as *Halocaridina rubra*, similar effects to *V. chaceorum* are likely.

Marine fish have also been detected in at least one anchialine pool within the Manukā pool complex; these fish are suspected to have been intentionally introduced by anglers (Table 3; Sakihara 2012, entire). Recreationalists use anchialine pools as “holding pools” for bait fish (e.g., nonnative freshwater fish like tilapia, mosquito fish, and marine fish like āholehole [*Kuhlia* spp.] and kūpīpī [blackspot sergeant; *Abudefduf sordidus*]) (Wada 2013 in litt., entire). While invasive fish remain the main threat, native fishes commonly found offshore such as āholehole or ulua/pāpio (*Caranx* sp.) can extirpate shrimp from anchialine pools if introduced naturally (e.g., hurricane, tsunami) or intentionally by humans (e.g., anglers) (Kinzie 2010 in litt., entire; Wada 2013 in litt., entire). The impact of native marine fish on *Vetericaris chaceorum* is undocumented but is likely similar to that of freshwater fish on other species of anchialine pool shrimp.

Invasive fish can alter the ecological succession of pools due to predation on detrital feeders (amphipods and isopods) and primary consumers such as *Halocaridina rubra* (Table 3; Brock 2004, p. i). Predation reduces and displaces hypogeal shrimp from the lighted sections of anchialine pools (Brock 2004, p. 16). As a result, a gradual succession of macroalgae establish and grow epiphytically on the benthic cyanobacterial crust (Brock 2004, p. 16). With herbivorous hypogeal shrimp present (*H. rubra*), these epiphytes never overpopulate the benthos (Brock 2004, p. 16). Without *H. rubra*, overgrowth by macrophytes leads to the loss of the

cyanobacterial crust (Brock 2004, p. 16). With this change in anchialine pool flora comes a significant change in the appearance of the anchialine pool system from one that has anchialine characteristics (i.e., clear well-flushed basins, cyanobacterial crusts, and a fauna dominated by hypogeal shrimp) to a system characterized by a mud substratum, poor water exchange, floating chlorophyte mats, and exotic fishes (Brock 2004, p. 16). These changes potentially increase the infilling and senescence of anchialine pools (Brock 2004, p. 16).

The Tahitian prawn (*Macrobrachium lar*) is another invasive predator of anchialine pool shrimp (Table 3). Tahitian prawns are known to prey on *Halocaridina rubra* (Chai et al. 1989, p. 6). Furthermore, as a primarily nocturnal species, the Tahitian prawn influences the activity and presence of *H. rubra* at night, causing reverse diel patterns compared to the effects of invasive fish (Carey et al. 2011, pp. 38–40). Although Sakihara (2017, p. 13) found that the effects of Tahitian prawn on anchialine pool shrimp diel activity was habitat dependent—*H. rubra* was not affected in pools that were dark and deep—the presence of Tahitian prawn in conjunction with invasive fish could severely restrict the overall activity of anchialine pool shrimp by making shrimp susceptible to both diurnal and nocturnal predation. While no studies have been done on the impact of Tahitian prawn on *Vetericaris chaceorum*, the Tahitian prawn has been documented in at least one pool adjacent to pools occupied by *V. chaceorum* and it is likely to affect the endangered anchialine pool shrimp in at least two ways (Sakihara 2012, p. 91). First, Tahitian prawn may prey on *V. chaceorum*. Second, as *V. chaceorum* preys on *H. rubra*, the Tahitian prawn may compete with *V. chaceorum* for food.

Factor D (Inadequacy of existing regulatory mechanisms)

Existing State and Federal regulatory mechanisms are not preventing the introduction of nonnative species into Hawai‘i or controlling the spread of nonnative species between watersheds or maintaining instream flow standards (Howarth and Medeiros 1989, entire; Staples and Cowie 2001, pp. 9–10). Existing mechanisms do not prevent the introduction of invasive freshwater or marine fish into anchialine pools, the intentional dumping of trash into anchialine pools, nor the intentional or accidental collection of the anchialine pool shrimp for the aquarium trade.

In addition to Federal regulations, all terrestrial and aquatic invertebrates (including *Vetericaris chaceorum*) are protected under (1) the State of Hawai‘i Revised Statutes (1993) chapter 195D-4-f license; and (2) DLNR chapter 124: Indigenous Wildlife, Endangered and Threatened Wildlife, and Introduced Wild Birds. State NARs were created to preserve and protect examples of Hawai‘i’s ecosystems and geological formations. Designation as a State NAR prohibits the removal of any native organism and the disturbance of pools (HAR 13-209-4), however, enforcement at remote locations is difficult. Despite protections, the National Park Service faces similar challenges in enforcing prohibition of anchialine pool shrimp collection and pool disturbance at Kaloko-Honokōhau National Historical Park. In addition, no State regulatory protection of *V. chaceorum* exists at Lua O Palahemo and the five anchialine pools adjacent to the Manukā NAR which means that they are not subject to the same protections from potentially harmful activity as the pools that are located within the NAR (Table 3; Conry 2012, in litt).

Hawai‘i Revised Statutes, Title 19. Health 342E, established a nonpoint source pollution management and control program. In 2021, the Hawai‘i State Department of Health (HDOH) finalized the Hawai‘i Nonpoint Source Management Plan 2021–2025 to guide the State’s nonpoint source pollution management efforts over a 5-year period (HDOH 2021, entire). The

plan proposes to establish a Department of Health Surface Water Protection Branch that will administer the Nonpoint Source Pollution Control Rules proposed under Hawai'i Administrative Rules Chapter 11-56 (HDOH 2021, p. 92–95). However, HDOH has not yet established a comprehensive nonpoint source pollution branch for control and enforcement against nonpoint source pollution. Until the Water Protection Branch is established and the nonpoint source pollution control and management Administrative Rules are finalized (HDOH 2022), nonpoint source pollution is a State-unregulated threat to anchialine pool shrimp.

Factor E (Other natural or manmade factors affecting the species continued existence)

Anchialine pools have been used by humans as baths, latrines, and dumps because of their depressional features, proximity to the beach, and their freshwater content (Table 3). Plastics, fishing line, bottles, cans, marine, and other debris increase the accumulation of sediment in pools by plugging cracks and trapping sediments, which affects water flushing rate and accelerates pool senescence (Kensley and Williams 1986, pp. 417–418; Bozanic 2004, p. 1; Brock 2004, pp. 13–17; Wada 2010 in litt., entire). Chemical contamination (including oil and grease) of anchialine pools has been documented on the island of Hawai'i (Brock 2004, pp. 15–16), which affects water quality and can result in the local extirpation of hypogean shrimp species. Fecal coliform bacteria can introduce disease and other pathogens (Chan 1995, p. 14; Brock 2004 p. 15). Human trampling, swimming, and bathing in and adjacent to anchialine pools can degrade anchialine pool habitat characteristics (Brock 2004, pp. 13–17, 26).

Use of off-road vehicles adjacent to anchialine pools can result in an increase of erosion and accumulation of sediment (Table 3). The negative impacts from sedimentation are discussed under *Anchialine Pool Shrimp Factor A* above (Richardson 2012 in litt., entire).

The persistence of *Vetericaris chaceorum* is tenuous as it occurs only in five pools at two sites on the island of Hawai'i (Table 3). The limited distribution of anchialine pool shrimp as well as the apparent small number of individuals increases the species' vulnerability to extirpation or extinction from demographic and environmental stochasticity as well as catastrophic events; inbreeding depression also could affect the species' reproductive success. In addition, small populations may suffer a loss of genetic diversity over time due to random genetic drift, resulting in a decreased evolutionary potential and lessened ability to cope with environmental change (Lande 1988, p. 1455). However, because the interconnectedness of pools supporting shrimp is currently unknown, the magnitude of this threat is difficult to quantify. The fact that *V. chaceorum* is currently not part of a captive breeding program also increases their vulnerability to stochastic events (Table 3).

Anchialine pool habitats are subject to gradual disappearance due to accumulation of wind-blown materials through a process known as senescence (Table 3; Maciolek and Brock 1974, entire; Brock 2004, p. 11). According to Brock (2004, p. 11), anchialine pools are ephemeral and senescence can occur in as little as 100 years after an anchialine pool is created. Conditions promoting rapid senescence include an increased amount of sediment deposition, exposure to light, shallowness, and a weak connection with the water table, resulting in sediment and detritus accumulating within the pool instead of being flushed away with tidal exchanges and ground water flow (Maciolek and Brock 1974, entire; Brock 2004, p. 16).

The proximity of existing anchialine pool complexes to the coast puts them at risk from coastal inundation associated with climate change (Table 3; Marrack et al. 2021, entire). Impacts from sea-level rise and coastal inundation may include: (1) complete inundation of pools and therefore elimination of entire anchialine pool habitats, particularly at Manukā, where low-lying areas for expansion of new pools does not occur (Marrack et al. 2021, entire); (2) an increase in the likelihood of exposure to predatory native marine fish not normally found in the anchialine pool ecosystem; (3) overtopping and movement of invasive fish from existing anchialine ponds and pools; and (4) increase in the deposition of coral rubble and other debris into anchialine pools due to increased storm intensity resulting in blockages of subterranean interconnections within pool complexes, blockage of pools from the ocean, and in-filling of the pools.

Table 3. Summary of habitats used by the two invertebrate species addressed in this recovery plan and their threats¹ organized by the five listing factors².

Species	Habitat ³	Factor A							Factor B	Factor C			Factor D	Factor E	
		Agriculture and Urban Development	Water Extraction	Ungulates	Nonnative Animals	Nonnative Plants	Fire	Stochastic Events	Overutilization	Disease	Predation by Nonnative Vertebrates	Predation by Nonnative Invertebrates	Inadequate Existing Regulatory Mechanisms	Other Species-specific Threats	Climate Change
<i>Drosophila digressa</i>	MF, WF	✓		C, G, M, P		✓	✓	Dr, F, H, LHP, V			CF (Pt)	A, PW, W	✓	B, CBS, LCF, LHP, LF, LN, LP, NC, ROD, We	✓
<i>Vetericaris chaceorum</i>	AP, CO	✓	✓	C, G	✓	✓ (Pt)		E, F, H, Ts, V	Aq, Co	P t	Fi	TP	✓	Hum, LN, LP, NC, NL, NS, RU, RV, SD, SLR, Tr, WQ	✓

¹Threats: A = ants; Aq = aquarium trade; B = beetles (damage to host plants); C = cattle; CBS = competition for breeding substrates; CF = coqui frog; Co = collection; Dr = drought; E = earthquakes; F = Flooding; Fi = fish; G = goats; H = hurricane/high winds; HD = human (contamination, dumping, fisheries, marine debris, and trash); LCF = limoniid crane flies; LF = lack of sufficient larval food resources; LHP = loss or lack of host plant substrate; LN = limited numbers of individuals; LP = low population number; M = mouflon; NC = not in captive rearing program; NL = nutrient loading; NS = natural senescence of pools; P = pigs; Pt = potential threat; PW = parasitoid wasps; ROD = Rapid 'Ōhi'a Death; RU = recreational use; RV = recreational vehicles; SD = sedimentation; SLR = sea level rise; TP = Tahitian prawn; Tr = trampling; Ts = tsunami; V = volcanic eruption; W = western yellowjacket wasps; We = weevils (damage to host plants); WQ = water quality reduction; ✓ = known threat to species, not itemized for brevity.

²Factor A = Present or threatened destruction, modification, or curtailment of the species habitat or range; Factor B = Overutilization for commercial, recreational, scientific, or educational purposes; Factor C = Disease or predation; Factor D = Inadequacy of existing regulatory mechanisms; Factor E = Other natural or manmade factors affecting the species continued existence.

³Habitats: AP = anchialine pools; CO = coastal; MF = mesic forest; WF = wet forest.

Picture-wing Fly

Factor A (Present or threatened destruction, modification or curtailment of its habitat or range)

The picture-wing fly depends on specific plant species to complete its life history, and those species can be negatively affected by nonnative ungulates. *Drosophila digressa* requires decaying stems or bark of *Charpentiera* spp., *Ceodes brunoniana*, and *Rockia sandwicensis* for oviposition and larval development (Montgomery 1975, p. 95; Magnacca 2012 in litt., entire). *Charpentiera* spp., *Ceodes brunoniana*, and *Rockia sandwicensis* are highly susceptible to damage from feral pigs, feral and domestic cattle, mouflon sheep, and goats (Table 3; Stone 1985, p. 271; Cuddihy and Stone 1990, pp. 63, 66; Foote and Carson 1995, pp. 369–371; Kaneshiro and Kaneshiro 1995, pp. 8, 39; Magnacca et al. 2008, p. 32; Magnacca 2012 in litt., entire; Science Panel 2005, pp. 1–23; Hess 2008, p. 3). Magnacca (2012 in litt., entire) observed the lack of regeneration of picture-wing fly host plants due to destruction of seedlings by pig rooting. Cattle browse *Charpentiera* spp., *Ceodes brunoniana*, and *Rockia sandwicensis* (Magnacca et al. 2008, p. 32; Magnacca 2012 in litt., entire). *Charpentiera* spp. appears to continue to decrease throughout its range due to browsing from mouflon sheep (Table 3; Science Panel 2005, pp. 1–23). Goats also occupy the habitats of the picture-wing fly where they access and forage in extremely rugged terrain and, like mouflon sheep, they have a high reproductive capacity (Table 3; Clarke and Cuddihy 1980, pp. C–19, C–20; van Riper and van Riper 1982, pp. 34–35; Culliney 1988, p. 336; Cuddihy and Stone 1990, p. 64; Hess 2008, p. 3; Kessler 2011 in litt., entire). *Charpentiera* spp. are shrubby trees and are very susceptible to browsing. As a result, the host plants of this picture-wing fly species have decreased throughout their range in areas that are not fenced and ungulate-free. Browsing also alters the essential microclimate in picture-wing fly habitat by opening the understory. This can lead to increased desiccation of soil and host plants and disruption of the host plants' life cycle and decay processes. This subsequently disrupts the picture-wing fly's life cycle, particularly oviposition and the availability of substrate for the larval development (Magnacca et al. 2008, pp. 1, 32).

Ungulates also disperse nonnative seeds and create open, disturbed areas which facilitate the establishment of nonnative plants (Table 3). Nonnative plants adversely affect microhabitat by modifying the availability of light, shifting soil-water regimes, changing nutrient cycling processes, altering fire characteristics of native plant habitat, outcompeting natives, and inhibiting the growth of native plant species (Vitousek et al. 1987, p. 224). The picture-wing fly's host plants are susceptible to competition from nonnative plants (Table 3; Foote and Carson 1995, pp. 370–37; Starr et al. 2003, p. 3; Science Panel 2005, entire; USFWS 2021g, entire). As described above in the Plants section *Factor A*, invasive plant species compete for water, space, nutrients, and light. This results in the conversion of native habitat to one dominated by nonnative vegetation which does not support *Drosophila digressa* (Cuddihy and Stone 1990, p. 74; Vitousek 1992, pp. 33–35).

Severe to extreme drought over the past 20 to 30 years has impacted the mesic forest habitat of the picture-wing fly at Manukā NAR. This has resulted in overall habitat degradation and appears to alter decay processes of the picture-wing fly host plants. Drought also alters the entire plant community on which the fly depends. Virtually all of the 'ōhi'a canopy at the Manukā NAR died over the past 20 to 30 years, due to prolonged drought and this area previously

received most of its water from fog intercepted by tall ‘ōhi‘a trees (Magnacca 2012 in litt., entire). Although the dominant host plant of the picture-wing fly at this site, *Rockia sandwicensis*, has benefited from the increase in sunlight due to the ‘ōhi‘a dieback, the increase in *R. sandwicensis* seedlings and juveniles is unlikely to be sustained over time (Magnacca 2012 in litt., entire). Even if these host plants survive to maturity, it is unlikely that the much drier habitat conditions will support the picture-wing fly (Magnacca 2012 in litt., entire). The wet montane habitat of ‘Ōla‘a Forest within Hawai‘i Volcanoes National Park is also experiencing drought (NIDIS 2020, entire).

In addition to drought-caused mortality of picture-wing fly individuals or populations, extreme drought conditions are also contributing to the number and intensity of the wildfires on the island of Hawai‘i (USFWS 2013, pp. 64663–64664). Long-term drought has resulted in an increasing accumulation of dead trees in the Manukā NAR, which increases the fuel load and threat of wildfires in one of the two known occurrence location of the picture-wing fly (USFWS 2013, p. 64664). The extraordinary amount of dead wood accumulation in this mesic habitat means any fire that occurs there likely would be extremely damaging (Table 3). Fires result in a reduction of native plant cover and habitat, an increase in nonnative plant and animal species, and a reduction in availability of host plants for the picture-wing fly (Giambelluca et al. 1991, p. v; D’Antonio and Vitousek 1992, pp. 77–79).

Drought and the proximity of picture-wing fly habitat to areas with volcanic activity as well as to habitats dominated by nonnative grasses also increases the threat of fire to the persistence of *Drosophila digressa* (Table 3). The introduction of nonnative plants, especially grasses, has led to greater frequency, intensity, and duration of fires (Brown and Smith 2000, p. 172). Grass-fueled fire often kills most native trees and shrubs (D’Antonio and Vitousek 1992, pp. 70, 73–74). Fire is a threat particularly in the mesic portion of the picture-wing fly’s range at Hualālai due to the presence of nonnative plant species (Science Panel 2005).

Stochastic events such as hurricanes, high winds from severe storms, and volcanic eruptions can result in the direct loss of picture-wing fly individuals and/or extirpate a population (Table 3; Carson 1986, p. 7; Foote and Carson 1995, pp. 369–370). High winds can destroy host plants and dislodge fly larvae from their hosts exposing the fly larvae to predation by nonnative yellowjacket wasps (Carson 1986, p. 7; Foote and Carson 1995, p. 371).

Factor B (Overutilization for commercial, recreational, scientific, or educational purposes)

Overutilization is not known to be a threat.

Factor C (Disease and Predation)

Picture-wing flies evolved in the absence of predation and competition from ants, which can be particularly destructive predators because of their high densities, recruitment behavior, aggressiveness, and broad range of diet (Reimer 1993, pp. 13–17). Ants prey directly on the eggs and larvae of the picture-wing flies or exclude flies from breeding resources or shelter sites (Krushelnichy et al. 2005, p. 6). The threat of ant predation on the picture-wing fly is amplified by the fact that most ant species have winged reproductive adults (Borror et al. 1989, p. 738) and

can quickly establish new colonies in new locations (Staples and Cowie 2001, p. 55). These attributes allow some ants to extirpate geographically isolated populations of native arthropods (Nafus 1993, pp. 19, 22–23).

All ant species occurring in Hawai‘i are nonnative (Perkins 1913, p. xxxix) and at least five particularly aggressive species threaten the picture-wing fly. Big-headed ants (*Pheidole megacephala*), long-legged or yellow crazy ants, Papuan thief ants (*Solenopsis papuana*), tropical fire ants (*Solenopsis geminata*), and Argentine ants (*Linepithema humile*), are aggressive, generalist predators that have severely impacted the native insect fauna (Krushelnichy and Gillespie 2010, pp. 643–655; Reimer 1993, pp. 13–17). As a group, ants occupy most of the habitat types of Hawai‘i; however, many ant species are still invading the mid-elevation montane mesic forests where the picture-wing fly occurs. Few ant species have been able to colonize undisturbed montane wet ecosystems; rather, they are more likely to occur in mesic habitats (Reimer 1993, pp. 13–17). Of the five aggressive ant species, the Papuan thief ant is the only ant that has invaded intact mesic to wet forest and occurs in high densities. This species occurs on all the main Hawaiian Islands, and is still expanding its range (Reimer 1993, p. 14; Krushelnichy et al. 2017, entire). Thus, this ant is a major threat to the picture-wing fly throughout its range.

Coqui frogs, *Eleutherodactylus coqui*, were introduced to the State of Hawai‘i in the late 1980s (Woolbright et al. 2006, p. 122) and are widespread on the island of Hawai‘i (DLNR 2020). Based on the spatial patterns of the coqui frog foraging behavior and spread to higher elevations, the frogs pose a potential predation threat to the picture-wing flies (Table 3). The frogs have the ability to consume large numbers of insects each night and may prey on adult *Drosophila* species (Bernard and Mautz 2016, pp. 3413–3414). At present, dipterans, the soft bodied insect order that includes the picture-wing flies, represent 1.21 percent of the frog stomach content at lower elevations (Bernard and Mautz 2016, pp. 3413–3416). Though this proportion is low, the exposure and lengthy lekking (male territorial defensive displays with other males) and mating behaviors of the picture-wing flies leave them vulnerable to predation.

The western yellowjacket (*Vespula pensylvanica*) is an aggressive, generalist wasp that threatens the picture-wing fly (Table 3; Gambino et al. 1987, p. 170). This nonnative social wasp species was first reported on O‘ahu in the 1930s. An aggressive race became established in 1977 (Gambino et al. 1987, p. 170). This species is now particularly abundant between 1,969 and 5,000 ft (600 and 1,524 m) in elevation throughout the State (Gambino et al. 1990, pp. 1088–1095; Foote and Carson 1995, p. 371). It is widespread in mesic and montane wet habitats on Hawai‘i where the picture-wing fly species occur. In temperate climates, the yellowjacket has an annual life cycle; however, in Hawai‘i colonies often persist through a second year. This facilitates larger populations and thus a greater impact on prey populations (Gambino et al. 1987, pp. 169–170). The wasps have been observed carrying and feeding on adult Hawaiian picture-wing flies (Kaneshiro and Kaneshiro 1995, pp. 40–45). Native picture-wing flies may be particularly vulnerable to predation by wasps due to their conspicuous lekking behavior and courtship displays that can last for several minutes (Kaneshiro 2006, pp. 4–5; Kaneshiro 2006 in litt., entire). These wasps are also believed to feed on picture-wing fly larvae in their host substrate (Carson 1986, pp. 3–9). The concurrent arrival of the western yellowjacket and decline of picture-wing fly observations in some areas suggest the wasp may have played a significant

role in the decline of some picture-wing fly populations (Carson 1986, pp. 3–9; Foote and Carson 1995, p. 371; Kaneshiro and Kaneshiro 1995, pp. 40–45; Science Panel 2005, pp. 1–23).

The number of native parasitic wasps in Hawai‘i is limited, and only species in the family Eucilidae are known to use Hawaiian picture-wing flies as hosts (Table 3; Montgomery 1975, pp. 74–75; Kaneshiro and Kaneshiro 1995, pp. 44–45). Several species of nonnative, small parasitic wasps (Braconidae) were introduced to Hawai‘i to control nonnative fruit flies in the family Tephritidae (Funasaki et al. 1988, pp. 105–160). These parasitic wasps are also known to attack other species of flies, including native Tephritidae flies. While these parasitic wasps have not been recorded parasitizing Hawaiian picture-wing flies and, in fact, may not successfully develop in Drosophilidae, females will indiscriminately sting any fly larvae in their attempts to oviposit, resulting in mortality of the larvae (USFWS 2013, p. 64676). Because of this indiscriminate behavior, nonnative parasitoid wasps represent a threat to *Drosophila digressa*.

Factor D (Inadequacy of existing regulatory mechanisms)

As previously described in the *Plants* section *Factor D*, the loss of habitat and introduction of harmful nonnative species due to inadequate regulation and biosecurity is also a threat to *Drosophila digressa* (Table 3). Recovery of the species will require active management of protected areas, which will include exclusion and removal of feral ungulates, management and removal of invasive plants and insects, and the restoration and translocation of host plant species.

Factor E (Other natural or manmade factors affecting the species continued existence)

Competition for larval host substrate from several species of nonnative limoniid crane flies can adversely impact picture-wing flies (Table 3). The larvae of these crane flies feed in the decomposing bark of the host plants used by the picture-wing fly species (Science Panel 2005, pp. 1–23; Magnacca 2005 in litt., entire; Montgomery 2005 in litt., entire). This results in a reduction of available plant material for the picture-wing fly larvae. Competition between *Drosophila* spp. larvae and other fly larvae can exhaust food resources, which affects both the probability of picture-wing fly larvae survival and the body size of adults, resulting in reduced adult fitness, fecundity, and lifespan (Grimaldi and Jaenike 1984, pp. 1113–1120). Several species of soldier flies and flies in the family Neriidae may also pose similar threats to Hawaiian picture-wing flies (Science Panel 2005, pp. 1–23).

Stem- and bark-breeding picture-wing fly species, due to their dependence on older, senescent, or dying plants, are sensitive to declines in host plant populations (Table 3; Magnacca et al. 2008, p. 32). The loss or decrease in host plant resources and the degradation or loss of habitat providing the humidity requirements of the picture-wing fly and decay cycle of the plant hosts contribute to the decline in picture-wing fly populations. This subsequently disrupts the picture-wing fly’s life cycle, particularly oviposition and larval development, which are dependent on the availability of suitable decaying substrate (Magnacca et al. 2008, pp. 1, 32).

In addition to threats from ungulates, *Charpentiera* spp., one of two known host plants of *Drosophila digressa*, are threatened by the nonnative branch and twig borer beetle (*Amphicerus cornutus*), long-horned beetle (*Sybra alternans*), the black twig borer (*Xylosandrus compactus*),

and a weevil (*Oxydema fusiforme*) (Table 3; Medeiros et al. 1986, p. 29; Giffin 2003, p. 81). These insects directly damage *Charpentiera* spp. through their feeding and boring, and indirectly by increasing the susceptibility of the host species to other insects and/or diseases.

Rapid ‘Ōhi‘a Death as described in the *Plants* section *Factor C* is also an ongoing threat to *Drosophila digressa*. The disease is present throughout the range and current habitat of the picture-wing fly (Friday et al. 2022, entire). Like drought, the loss of canopy allows more sunlight to reach the forest floor, increasing the temperature and lowering the humidity and subsequently adversely affecting the picture-wing fly and its habitat (Table 3).

Threats to *Drosophila digressa* are likely exacerbated by the limited number of populations as well as the limited number of individuals comprising each population. For example, a single catastrophic event (e.g., hurricane, drought) may result in population extirpation and/or extinction (Table 3; USFWS 2013, pp. 64683–64684). Species with few populations are less resilient to threats that would likely have a relatively minor impact on widely distributed species. For example, the reduced availability of host-plant substrate or an increase in predation or parasitization would likely be inconsequential to a widely distributed species but could result in a significant decrease in survival or reproduction of a species with a limited distribution. The fact that *D. digressa* is currently not part of a captive breeding program also increases their vulnerability to stochastic events (Table 3).

Changes in environmental conditions that may result from global climate change include increasing temperatures, decreasing precipitation, and increasing storm intensities. The habitats of *Drosophila digressa* are likely to be negatively affected by changes in temperature, humidity, precipitation, and the frequency and severity of storms (Table 3; Clark et al. 2020, entire; Lowe et al. 2020, entire). These stressors may change the habitats on the island of Hawai‘i and exacerbate other threats degrading the habitats for the picture-wing fly, its host plants, or both. Additionally, changes in temperature and humidity may alter the decay cycle of the host-plant substrate the picture-wing flies require for egg laying and larvae development.

Summary of threats for plants, anchialine pool shrimp, and picture-wing fly

The most important threats to the 13 plant species are habitat destruction, herbivory by nonnative vertebrates and invertebrates, competition with nonnative species, natural catastrophes, effects of small population size, limited populations, and climate change (Table 2; USFWS 2013, USFWS 2021a–f, h–n). These threats also impact the invertebrate species recovery plan and their plant hosts (Table 3; USFWS 2021g, o). Additional threats to the anchialine pool shrimp include rarity of habitat, predation by fish, nonnative vertebrates and invertebrates, recreational vehicles, sedimentation, overutilization, and the intentional dumping of trash and the introduction of fish into anchialine pools, all of which exacerbate other threats (Table 3; USFWS 2013, USFWS 2021o). Additional threats to the picture-wing fly include loss or lack of host plants from ungulates, drought, fire, alteration of microclimate by invasive plants or ROD, predation and/or parasitization by nonnative ants and wasps, competition for breeding substrates with nonnative limoniid flies and other nonnative invertebrates, and the limited number of populations (Table 3; USFWS 2013, USFWS 2021g).

II. RECOVERY

A. RECOVERY VISION AND STRATEGY

A recovery vision is an explicit expression of recovery in terms of resiliency (the ability of a population to recover from periodic disturbance), redundancy (the number of populations of a species distributed across the landscape), and representation (the range of variation found within a species). It builds on the description of viability for the species and defines what recovery looks like for the species. The recovery strategy provides a recommended approach for achieving the recovery vision, and ultimately, the down- and delisting criteria.

1. Recovery Vision

Recovery of the 13 plant species entails each species having redundant populations distributed throughout their respective habitats. These populations should be self-sustaining, resilient, and represent the existing genetic diversity of the species. Habitats should be protected from ungulates, fire, and other forms of degradation. Nonnative plants, nonnative insects, and disease should be sufficiently managed, so that each species maintains stable, secure, and naturally reproducing populations.

Recovery of *Vetericaris chaceorum* entails the species having redundant populations distributed throughout coastal habitats in anchialine pool complexes on the island of Hawai‘i. Populations should be resilient, self-sustaining, and represent the existing genetic diversity of the species. Their anchialine pool habitats should be protected from ungulates, coastal development, human disturbance, sedimentation, and other forms of degradation. Predators, overcollection, and other threats should be managed such that the *V. chaceorum* maintains their presence at currently occupied anchialine pool complexes as well as expanding their range into unoccupied anchialine pool complexes.

Recovery of *Drosophila digressa* entails having redundant populations distributed throughout the mesic and montane wet habitats of the island of Hawai‘i. Populations should be self-sustaining, resilient, and represent the existing genetic diversity of the species. Habitats of each species should support connectivity between populations for genetic exchange, when possible. Their mesic and montane wet forest habitats should be protected from ungulates, fire, and other forms of degradation and provide sufficient host plant resources in the appropriate stage of decay to support picture-wing fly populations. All threats to the picture-wing fly and its host plants should be managed such that the picture-wing fly species and their plant hosts maintain a stable to positive growth rate.

2. Recovery Strategy

For the purposes of this document, conservation translocation (hereafter translocation) is defined as the deliberate movement of organisms from one site for release in another for a conservation benefit and includes population restoration (reinforcement and reintroduction) and conservation introduction (assisted colonization and ecological replacement) as defined in IUCN (2013, entire). If part of a species’ recovery strategy, translocations will follow the International Union

for Conservation of Nature (IUCN)/Species Survival Commission (IUCN 2013, entire) guidelines.

General Cross-Species Recovery Strategy

The 15 species addressed in this draft recovery plan use 8 natural habitat types. Large portions of these habitats have been destroyed, reduced in size, degraded such that the habitat no longer supports stable or growing populations, and need management and protection to support recovery of the 15 species (Ball et al. 2020; Browning et al. 2020; Clark et al. 2020; Javar-Salas et al. 2020; Kim et al. 2020; Lowe et al. 2020; Nelson et al. 2020; Pe‘a et al. 2020). Collectively, restoration and protection of the 8 habitat types would benefit all 15 species and is necessary for their recovery. Restoration and management of these habitats should be informed by science-based management plans. On private lands, such efforts may require conservation agreements with landowners.

Nonnative species, particularly invasive plants, herbivores, and predators affect all 15 species either by altering their habitats or by harming or killing individuals. Recovery of the 15 species will require monitoring and management of nonnative invasive plants, ungulates, other vertebrates, and invertebrates; and minimizing expansion of urban development into the habitats required for recovery. The microclimate needs of each species should be documented and modeled to determine how suitable microclimates will shift due to climate change. Hurricanes, tsunamis, volcanic eruptions, and floods will intermittently affect habitats to varying degrees. Mitigating the effects of these events requires conserving sufficient habitats to support redundant viable populations of the listed species throughout their respective ranges. Having species representation in genetic storage will provide a source for propagation of some species. *Ex situ* collections and captive propagation may be necessary as sources for translocation and to ensure preservation of genetic representation in the event that a species becomes extirpated from the wild. Recovery will require working with State, Federal, County, nonprofit, and private entities to reestablish the viability of each species across its range.

Recovery will require partnerships with stakeholders to prevent the introduction and establishment of new invasive species that negatively affect the 15 species, their habitats, or both, and impede recovery. These partnerships should work to expand and improve border inspections and implement the Hawai‘i interagency biosecurity plan (State of Hawai‘i 2017, entire). Biosecurity measures are critical to avoid introduction of new invasive species to the island of Hawai‘i, prevent reintroduction of invasive species if eradication programs are successful, and intercept or control invasive species that may be brought in from outside the State. New invasive species include invasive plants; invertebrates and vertebrates; and diseases of plants, anchialine pool shrimp, or picture-wing flies. Implementation of the biosecurity plan requires continued outreach to travelers to Hawai‘i and between islands, enforcement, and adaptation to address new introductions.

Monitoring and evaluation of the effects of actions implemented to achieve recovery are critical to inform and adapt future management. In addition, all populations will require monitoring to identify new threats, track demographic variables, water quality parameters, and resiliency, where feasible. Post-delisting monitoring will be needed to confirm delisted species continue to meet recovery criteria.

General Recovery Strategy

The recovery strategy for the 15 species entails five principal steps. For some species, the first three steps may be accomplished concurrently; for other species, the steps may need to be accomplished sequentially. Monitoring and evaluation throughout the five steps are important components associated with each action and its consequences within each of the five steps. The results of monitoring and evaluation form a continuous feedback loop for adaptively adjusting management strategies for each species in each step.

The first step to achieving recovery for each of the 15 species is identifying and prioritizing all populations, curtailing their decline, and stabilizing each species. Prioritization and population management should conserve the existing representation and diversity of each species. To stabilize populations of the 15 species, threats identified in recent Species Reports (USFWS 2021a through USFWS 2021o) need to be managed. Continuous monitoring will be necessary to identify any new or previously unrecognized threats. These threats must then be ameliorated. This will require working with State, Federal, County, nonprofit, and private stakeholders to protect and manage populations of the species across their ranges.

After halting population declines, the second step is to determine the status of each species' population(s) and their respective habitats and then prioritize, protect, and manage the habitats supporting these populations such that threats are ameliorated and the populations are stabilized or increasing.

Once populations are protected and managed and are stable or increasing, the third step is to increase redundancy and population resiliency throughout each species' range. For many species, this will require establishing new populations, using genetically appropriate individuals in occupied or unoccupied habitat to increase redundancy within each species' historical and/or current range, and/or reinforcing small populations to increase their resiliency. Populations of some species may be established outside their historical range via conservation introductions (e.g., translocating species outside their known historical range) in response to changing environmental conditions.

The fourth step is downlisting. Once a species has met all its downlisting criteria, the species can be considered for downlisting. The fifth step is delisting. Once a species has met all its delisting criteria, the species can be considered for delisting. An assessment of a species' status in relation to the five listing factors found in section 4(a)(1) and the definitions of "endangered" and "threatened" in section 3 of the Act, respectively, will be used to determine whether downlisting or delisting is appropriate. This subsequent review may be initiated without all the recovery criteria in this plan having been fully met. A decision to downlist or delist a species is informed by the recovery criteria but is ultimately based on an analysis of threats using the best scientific and commercial data available. However, recovery criteria are mileposts that measure progress toward recovery. Because we cannot envision the exact course that recovery may take, and our understanding of the vulnerability of a species to threats is likely to change as more is learned, it is possible that a status review may indicate that delisting is warranted although not all recovery criteria are met. Conversely, it is possible that recovery criteria could be met, but a status review

indicates that delisting is not warranted. For example, a new threat not addressed by the current recovery criteria could result in the species continuing to be threatened or endangered. Many aspects of the 15 species' life history, genetics, demographics and ecology, propagation and captive rearing, population viability, priority threats, and management needs are poorly understood. In addition, the effects of climate change on each species will need to be evaluated to plan for possible conservation introductions to new suitable habitats outside their historical range. Research on these topics will occur concurrently with each of the above five steps, and the results will inform management actions and recovery actions.

The general recovery actions for each of the identified threats of the three species groups (plants, anchialine pool shrimp, and picture-wing fly) are described below.

Recovery Strategy for Plants

For the 13 plant species, recovery will require protection from nonnative ungulates (Table 2). Construction and maintenance of ungulate-proof fencing around each population or habitats supporting multi-species should be considered in conjunction with lethal removal of ungulates. Ungulates must be removed from all fenced areas that are needed for the recovery of the plant species.

For the 13 plant species, recovery will require some degree of management and protection from invasive plants throughout their geographic range and new areas will be needed for recovery of each species (Table 2). Management or eradication of habitat-modifying invasive plants is necessary to enhance the habitat and improve the survival of the 13 plants. Research and development of new control tools should be considered. Measures are needed to prevent the spread of incipient invasive species into sites occupied by populations needed to achieve recovery. Hawai'i interagency biosecurity plan (State of Hawai'i 2017, entire) support is necessary to prevent the arrival and spread of invasive species to the State of Hawai'i and interisland movement of invasive species already established in the archipelago.

For at least three plant species, recovery will require fire management and prevention strategies (Table 2). Fire management plans and infrastructure should be developed for sites needed for recovery, including suitable but unoccupied sites. Plans should consider the likely increased risk of wildfire due to climate change. Management actions that reduce the likelihood of fire should be implemented to protect the occupied and suitable habitats of these plant species.

To minimize the effects of drought and stochastic events such as hurricanes, volcanic eruptions, floods, and landslides, these species will need resilient populations that are redundant and represented throughout their range and possibly outside of their historical range (Table 2). Redundant populations will incorporate each species existing genetic representation where possible within each population, as appropriate. Translocation supported by genetic facilities and *ex situ* propagation will be considered and implemented when needed. The feasibility and benefit of conservation introductions to mitigate for drought and stochastic events should be considered.

Recovery of plant species threatened by overutilization (*Prichardia lanigera*) by humans will require public outreach and education to promote and support native species awareness (Table

2). Protection is needed for plants affected by other anthropogenic threats such as koa logging (*Phyllostegia floridunda*) and nonnative game birds introduced for public hunting (*Schiedea hawaiiensis*). Development and implementation of specific actions to reduce these threats are needed.

Research will be conducted as needed to better understand threats such as plant diseases that may affect species' viability or their habitat as well as to develop tools to detect, manage, and eradicate diseases (Table 2). Plant diseases such as ROD, with the potential to degrade the habitats of all 13 plant species, need to be successfully managed. Populations of the 13 species will need to be monitored to detect diseases, assess their impacts, and control outbreaks as soon as possible.

Recovery of most of the plant species will require long-term management to control rodents, slugs, and insect herbivores (Table 2). A rodent control or eradication program will need to be developed and implemented to support reproduction, natural recruitment, and survival of each plant species. In addition to rodent control, protection of vulnerable plant species will require a slug control program to be developed and implemented. One plant species (*Pritchardia lanigera*) will require long-term management and protection against introduced beetles and leafhoppers, and new tools will need to be developed and implemented to effectively control these nonnative insects. Recovery of some plant species may also require long-term management and protection against introduced ants. In cases where native pollinators avoid plants occupied by ants, development and implementation of an ant control program will be necessary.

Recovery of plant species with the potential to hybridize or that are experiencing a lack of regeneration will require research to inform management (Table 2). Propagation of genetically appropriate individuals for genetic storage and translocation to augment populations that are not regenerating should be considered. Methods to monitor population growth and status, including the genetic composition of progeny for species threatened by hybridization, will need to be developed. Research on population genetics to identify hybrid individuals and adapt management actions to vulnerable plant populations will likely be needed. Removal of hybrid plants will need to be considered. Research on demographics, pollination, and propagule dispersal as well as the evaluation of genetic threats to species' viability, which may be necessary to inform management needed to increase population resiliency, may be required. Tools to control and manage limiting factors and enhance survival and reproduction will need to be developed and implemented.

Threats to over half of the plant species are exacerbated by limited numbers (Table 2). Translocation will be a crucial action to achieve recovery and will require species-specific plans. Plans will need to consider the genetic composition and number of founders, suitable source population(s), as well as the species' reproductive capacity and the suitability and availability of habitat. Plants propagated for translocation should be genetically representative of the source populations, and translocated individuals should represent the appropriate genetic composition for the habitat to which they are translocated. The selection of translocation sites will be prioritized based on a suite of factors including their conservation value to multiple species and the likelihood of successful threat management. If necessary, sites will be prepared for translocation. If necessary, the feasibility and conservation benefit of translocating species

outside of their known historical range (i.e., assisted colonization) will be considered to provide sufficient redundancy and representation.

Recovery of plant species susceptible to environmental changes related to climate change (Table 2) will require microclimate modelling and the identification of suitable habitat based on historical and existing species' distributions and potential future climate conditions. This information will be critical to expanding species' ranges using translocation to include new suitable habitat. Prior to establishing any populations outside of a species' known range, habitat suitability and existing and new threats need to be assessed and managed. Translocations should be informed by each species' life history, demographic viability, pollinators, natural recruitment, and other factors that could influence the likelihood of successful population establishment.

Recovery Strategy for Anchialine Pool Shrimp

The extent of the distribution of *Vetericaris chaceorum* is currently unknown. Systematic surveys throughout the species' known range are needed to identify populations (redundancy) and quantify genetic and environmental variation (representation) of occupied pools. The rarity and cryptic nature of the species may require development and implementation of new technologies (Breininger et al. 2019, entire).

For recovery, occupied anchialine pool complexes will need to be identified, actively managed, and protected to manage all threats. Research to determine what the species needs to achieve a stable or increasing presence, and to identify anchialine pool restoration methods, will be necessary to prevent extinction and ultimately support resilient populations.

Measures to enhance *Vetericaris chaceorum* survival and population growth should be developed and implemented. Little is known about the biology and life history of the species. At least 14 individuals have been observed: 5 during 1 survey period in 1985 at Lua o Palahemo, 7 individuals during surveys between 2009 and 2010 at Manukā, and 2 separate observations in 2013 and 2016 at Manukā—although no numbers were recorded for either of the latter sightings (Sakihara 2020 in litt., entire; Shizuma et al. 2016, p. 33). Like other anchialine pool shrimp species, *V. chaceorum* inhabits an extensive network of water-filled interstitial spaces (cracks and crevices) leading to and from the actual pool, which has precluded researchers from estimating population sizes (Holthuis 1973, p. 36; Maciolek 1983, pp. 613–616, Iwai et al. 2009, entire). Research still needs to be conducted on the range of suitable anchialine pool habitats and species-specific conditions required by the anchialine pool shrimp such as water quality, pH, dissolved oxygen, light, temperature, salinity as well as colonization abilities and population dynamics to inform management actions for each anchialine pool complex. Population viability analysis tools or other means of measuring population health and growth should be developed. Identification of methods to enhance the anchialine pool shrimp survival and reproduction will be necessary. A captive rearing program may be necessary to prevent extinction of the species and provide a future source for conservation translocation (population restoration and/or introduction). Populations must show evidence of growth before they can be used as source populations to initiate a captive rearing program or support translocation efforts.

Recovery of *Vetericaris chaceorum* will require protection from coastal development (e.g., filling pools, impacts to water quality, and dewatering) throughout its range, including long-term

land protections. Recovery of the anchialine pool shrimp species will require long-term protection from freshwater fluctuations from sub-surface water extraction, dewatering, and water diversion, which alter the freshwater availability for anchialine pool complexes and directly impact the species (Marrack 2016, p. 782). Protection of habitat around anchialine pools will prevent degradation and ensure that freshwater inputs to anchialine pool complexes are of sufficient quality to support anchialine pool shrimp survival. Monitoring and management of water quality factors such as nutrient concentrations, contaminants, pH, dissolved oxygen, salinity levels, temperature, and cyanobacteria will be needed.

Recovery of *Vetericaris chaceorum* will require protection from introduced ungulates in the vicinity of anchialine pool habitats throughout the species' range. Construction and maintenance of ungulate-proof fencing around habitats surrounding anchialine pools will need to be considered followed by lethal removal of ungulates from fenced areas if ungulates cannot be controlled by other means.

Recovery of *Vetericaris chaceorum* will require some degree of protection and management from invasive plants, especially kiawe and others, in and around anchialine pool habitats to decrease nutrient loading in, and senescence rates of, anchialine pools.

Recovery of *Vetericaris chaceorum* will require protection and management from invasive fish and invertebrates throughout their range. Once the distribution of the anchialine pool shrimp is known, determining the status of predators is critical to planning the next steps for recovery. Removal of invasive fish and invasive invertebrates will be needed at each occupied pool complex and at sites selected for reintroduction. Because existing invasive invertebrate eradication techniques could adversely impact *V. chaceorum*, novel and safe techniques to eradicate invasive invertebrates will need to be developed and tested. Removal of invasive fish and invertebrates with methods involving carbon dioxide, baited traps, hand nets, *Tephrosia purpurea* ('ahuhu), and/or rotenone should be considered at both occupied and unoccupied sites.

To minimize the effect of a catastrophic event such as a hurricane or volcanic eruption, the distribution of anchialine pool shrimp will need to be expanded via translocations to suitable existing anchialine pools or to anchialine pool complexes that have been restored or created outside of the species' historical range. Expanding the number and distribution of anchialine pool complexes occupied by the anchialine pool shrimp would increase species' overall redundancy and limit its vulnerability to catastrophic events. Created and/or restored anchialine pool complexes should be distributed to minimize the risk that a catastrophic event could result in the extirpation of a population. In addition, populations created or augmented via translocation should be representative of the species' existing genetic variation.

Diseases from invasive fish and fecal coliform are potential threats to the viability of the anchialine pool shrimp. The development of tools to avoid, detect, or treat diseases and other pathogens that could adversely affect both wild and captive anchialine pool shrimp should be considered.

Recovery of *Vetericaris chaceorum* will require the enforcement of Federal and State laws to protect the anchialine pool shrimp from illegal activities such as dumping, harassment, and collection. This will also require public outreach to promote awareness of, and support for,

native species; signage and education; and enforcement of penalties to prevent unpermitted activities in anchialine pools and illegal harassment and collection. Establishing a Hawai'i State Department of Health Water Protection Branch and finalizing the nonpoint source pollution control and management Administrative Rules are needed to regulate nonpoint source pollution affecting anchialine pool shrimp and their habitat.

The limited number of *Vetericaris chaceorum* populations restricted to a limited geographic area exacerbates threats to this species' persistence. Management to support breeding and population growth needs to be developed and implemented. Translocation from wild and captive populations to augment existing and establish new populations will likely be necessary to increase the number of individuals and populations. Establishing new populations via translocation should include the species' remaining genetic diversity where possible.

Climate change has the potential to adversely affect the anchialine pool shrimp. Recovery of *Vetericaris chaceorum* will require modeling of anchialine pools to identify suitable habitat based on the species' historical and current distribution and potential future climate conditions. Use of appropriate scale in the analysis will be necessary to identify microclimates that will be appropriate for sustaining the anchialine pool shrimp population in the long-term. Expanding the range of the anchialine pool shrimp through translocation to include new or unoccupied anchialine pools should be considered. Future translocations should be informed by research to assess habitat suitability, threats, and species viability.

Recovery Strategy for the Picture-wing Fly

Biology and population status of the picture-wing fly species are poorly known. Research on population needs and the restoration techniques necessary to prevent extinction and facilitate population growth should be a priority. Thorough, systematic surveys will be needed to identify populations and better understand the species' representation, redundancy, and plant hosts. All populations identified should be immediately protected and actively managed to control threats. A captive rearing program will be necessary to provide an insurance population in case of extirpation from the wild and to provide a future source of individuals for translocation (population restoration and/or conservation introduction). The habitat of the picture-wing fly and its host plants (*Charpentiera* spp., *Ceodes brunoniana*, and *Rockia sandwicensis*) will require some degree of immediate protection and/or restoration, depending on plant host species.

Picture-wing flies are sensitive to declines in their host plants which serve as substrates for their eggs and larvae. Mesic and wet forest habitats that support host plant populations as well as other resources needed to support *Drosophila digressa* populations, or that can be restored to provide these needs, should be identified, prioritized, and protected/restored throughout the species' range. Restoration and management plans will focus on actions that support stable to growing populations of the picture-wing fly and its host plants. This will entail identifying and managing existing populations of plant hosts, including augmenting existing populations or creating new populations via translocation. Conservation agreements and other modes of habitat conservation will be necessary to protect mesic and wet forest habitat to ensure long-term persistence of *D. digressa* and its habitat.

Drosophila digressa and its plant hosts will require protection from introduced ungulates throughout the species' range. Construction and maintenance of ungulate-proof fencing around picture-wing fly populations and their hosts will be needed if ungulates cannot be controlled by other means. Ungulates will then need to be removed from fenced areas that enclose habitats supporting picture-wing flies and their host plants.

The recovery strategy for *Drosophila digressa* and its habitat will require development of long-term fire management plans. This should include identifying specific fire management actions, developing infrastructure for protecting each picture-wing fly population, and initiating actions to reduce the likelihood of fire. Fire management plans will need to be adaptive to accommodate climate change and other stochastic changes that increase fire risk and fuel load.

Measures to enhance picture-wing fly population growth and size should be developed and implemented. Little is known about the biology and habitat requirements of *Drosophila digressa* other than the need to protect its egg laying and larval substrates as well as protecting all life stages from threats. Thus, research into the range of plant hosts and substrates used by this species; basic breeding needs including light, temperature, and humidity; dispersal and colonization; and population dynamics will be needed to inform management. Defining the specific microclimate needs of *D. digressa* will be necessary to effectively create and manage populations. Population viability analysis or other means of measuring population health and growth will be needed.

Drosophila digressa prefers shaded habitats with high humidity, although specific microhabitat needs are unknown, and its host plants are highly susceptible to competition from invasive plants. Thus, management or eradication of habitat-modifying invasive plants throughout the species' range will be necessary. Maintaining or restoring native forests at each picture-wing fly population will facilitate genetic exchange among populations.

Once existing populations are protected, management should focus on establishing additional populations throughout the species' known range as a buffer against stochastic (e.g., drought) and catastrophic events (e.g., hurricanes, high wind events, volcanic eruptions). Such events may cause the loss of picture-wing flies, their plant hosts, and/or modify the microclimate necessary for their breeding and survival. Expanding the number and distribution of picture-wing fly populations throughout its range will improve redundancy and limit their vulnerability to stochastic and catastrophic events. Populations created to increase redundancy will incorporate the species' remaining genetic diversity where possible, to minimize the loss of diversity. This could entail creating large contiguous populations throughout its range or a series of smaller, discrete populations. Research to identify dispersal distance and current and future range of the species will be needed.

At least five species of non-native ants threaten *Drosophila digressa* via predation or competition for resources. Recovery of the picture-wing fly will require identifying appropriate ant control or eradication methods, applying these methods, and monitoring the results. The management and control of ant predation of *D. digressa* will consider (1) the species of ant, (2) the methods available and the need to develop additional new control technology, and (3) the risk

that controlling one ant species will benefit another ant species. Research may be needed to identify appropriate ant control and/or eradication methods.

Predation by nonnative western yellowjacket is a threat to *Drosophila digressa* due to their conspicuous lekking and courtship displays. Considerations for management and control of western yellowjacket will be analogous to those described above for ant control. Programs to control predatory wasps will need to be developed and implemented if research indicates western yellowjacket or other nonnative predatory wasps are adversely affecting picture-wing fly populations.

Parasitization by nonnative parasitoid wasps is a threat to *Drosophila digressa*. Research to evaluate parasitization of each stage of the species' life will identify effects on populations and develop measures to manage impacts to *D. digressa*.

Competition for larval substrates of picture-wing fly from nonnative invertebrates poses a threat to the species. Research to quantify competition from nonnative Limoniid crane flies and other, yet unidentified, invertebrates will be needed. Techniques to control invertebrate competition for larval substrate resources will need to be developed and implemented. Competition for larval substrate resources should be considered during the development of any management plans for the picture-wing fly and its plant hosts. Plans should address the effects of increases in nonnative limoniid crane fly populations as host plant availability is increased (Science Panel 2005, pp. 1–23; Magnacca 2005 in litt., entire; Montgomery 2005 in litt., entire).

Management of picture-wing fly plant host resources will require control of invertebrate pests of the plant hosts. Several species of nonnative borer beetles and a weevil are known to damage *Charpentiera* spp. Research to identify control strategies to manage these invertebrate threats will be needed.

Management of picture-wing fly habitat will include maintaining, restoring, and protecting the understory microclimate conditions that support *Drosophila digressa* and its plant hosts. This will include managing ROD, which is an ongoing threat to 'ōhi'a, an important canopy tree in the mesic and wet habitats of the picture-wing flies. 'Ōhi'a is a major structural element of native forests. Rapid 'Ōhi'a Death creates canopy gaps that modify light and microclimate conditions in the understory and promote establishment of nonnative plants in otherwise intact native forest. Research into ROD control and prevention measures and replacement of overstory canopy will be necessary to create and maintain the microclimate required by the picture-wing flies and their plant hosts in mesic and wet forests.

Demography and breeding needs for *Drosophila digressa* should be researched. The persistence of the species is threatened by the limited number of populations (only two known populations). The dependence of the picture-wing flies on their native plant host resources leaves this species highly vulnerable to mortality, reproductive failure, and cyclical population variation related to fluctuations in breeding resources (Magnacca et al. 2008, p.32). This research would inform the management of existing populations, captive rearing programs, and future translocations.

Natural recolonization into suitable but unoccupied or restored habitats is likely to be slow or nonexistent, given the current condition of the species. Thus, conservation translocations will likely be necessary to establish additional populations. To design a successful translocation program, it will be necessary to document the species' current distribution and genetic structure as well as their breeding (e.g., mate selection) and dispersal behavior. A captive rearing program will be needed to provide the individuals necessary for reintroduction, reinforcement, and conservation introductions. Research will be conducted as needed to support these efforts.

Changes in environmental conditions resulting from climate change include increasing temperatures, decreasing precipitation, and increasing storm intensities. The habitats of all picture-wing fly species, including *Drosophila digressa*, are likely to be affected by changes in temperature, humidity, precipitation, and storm frequency and severity. These stressors may change the species' habitats and exacerbate other threats making the habitats unsuitable for the picture-wing fly, its host plants, or both. Additionally, changes in temperature and humidity may alter the decay cycle of the host plant substrate the picture-wing flies requires for breeding. The development of microclimate models and identification of suitable habitat based on the historical and current distribution of *D. digressa* and potential future climate conditions will be necessary. Expansion of the species' range to new areas due to climate change may be necessary.

Management plans will need to be adaptive and include monitoring to provide feedback to the plan and accompanying actions. Tools to effectively monitor and measure population growth and status should be developed and used to inform any management plans for the picture-wing fly, its host species, and habitat. Newly identified threats (existing or introduced) to each population will need to be identified and managed. This will include supporting implementation of an interagency biosecurity plan (State of Hawai'i 2017, entire) to prevent introduction of new pests and invasive species to the island of Hawai'i and into the habitat of the picture-wing fly.

B. RECOVERY CRITERIA

Section 4(f)(1)(B)(ii) of the Act states that each recovery plan shall incorporate, to the maximum extent practicable, "objective, measurable criteria which, when met, would result in a determination... that the species be removed from the List." Legal challenges to recovery plans (see *Fund for Animals v. Babbitt*, 903 F. Supp. 96 [D.D.C. 1995]) and a Government Accountability Audit (GAO 2006, entire) also have affirmed the need to frame recovery criteria in terms of threats assessed under the five listing factors.

Recovery criteria serve as objective, measurable guidelines to assist in determining when an endangered species has recovered to the point that it may be downlisted to threatened, or that the protections afforded by the Act are no longer necessary and the species may be delisted. Delisting is the removal of a species from the Federal Lists of Endangered and Threatened Wildlife and Plants (Lists). Downlisting is the reclassification of a species from endangered to threatened. The term "endangered species" means any species (species, subspecies, or distinct population segment) that is in danger of extinction throughout all or a significant portion of its range. The term "threatened species" means any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Recovery criteria represent our best assessment, at the time the recovery plan is completed, of the conditions that would likely result in a determination that listing under the Act as threatened or endangered is no longer required. However, revisions to the Lists, including delisting or downlisting a species, must reflect determinations made in accordance with sections 4(a)(1) and 4(b) of the Act. Section 4(a)(1) requires that the Secretary determine whether a species is an endangered species or threatened species because of threats to the species, based on an analysis of the five listing factors in section 4(a)(1). Section 4(b) requires that the determination be made “solely on the basis of the best scientific and commercial data available.” Thus, while recovery plans provide important guidance to the Service, States, and other partners on methods of minimizing threats to listed species and measurable criteria against which to measure progress towards recovery, they are guidance and not regulatory documents.

Thus, a decision to delist or downlist a species is informed by the recovery criteria but is ultimately based on an analysis of threats using the best scientific and commercial data available. All classification decisions consider an analysis of the following five factors: (1) is there present or threatened destruction, modification, or curtailment of the species’ habitat or range; (2) is the species subject to overutilization for commercial, recreational scientific or educational purposes; (3) is disease or predation a limiting factor; (4) are there inadequate existing regulatory mechanisms in place outside the Act (taking into account the efforts by States and other organizations to protect the species or habitat); and (5) are other natural or manmade factors affecting its continued existence. When delisting or downlisting a species, we first propose the action in the *Federal Register* and seek public comment and peer review of our analysis. Our final decision is announced in the *Federal Register*.

The species addressed in this draft recovery plan should be considered for downlisting and delisting when the following objective[s] and criteria have been met. Downlisting and delisting criteria are subject to change as additional information becomes available about species biology and threats. Monitoring and evaluation of each population is an essential part of assessing the viability needed to meet the recovery criteria of the 15 species addressed by this draft recovery plan. It will be necessary to (1) monitor the number of individuals and population distribution to determine population growth status and redundancy, (2) identify and evaluate new or existing threats and their management in each species’ habitat, (3) evaluate habitat management actions, and (4) use the evaluations to adapt the management actions. Evaluations will require the establishment of baselines against which each recovery criterion can be compared. As such, monitoring and evaluation is expected to be continuous and long-term.

Achieving the recovery criteria for the 15 species will contribute to each species’ redundancy by ensuring that multiple populations are distributed throughout each species’ range. Achieving the criteria will contribute to each species’ representation by ensuring that ecological and genetic diversity of the species is taken into account when establishing new populations or reinforcing existing populations. Achieving the recovery criteria will contribute to population resiliency by reducing threats and managing appropriate habitats. The recovery criteria are objective and measurable and population viability evaluations (plants), monitoring population occurrences (anchialine pool shrimp) or monitoring population indices (picture-wing fly) will be required to consider each species for downlisting or delisting.

1. Recovery Criteria — Plants

Objective — Manage threats and habitats to establish resilient and self-sustaining populations of each listed plant species on the island of Hawai‘i.

The Hawai‘i and Pacific Plants Recovery Coordinating Committee (HPPRCC), comprised of biologists from Federal and State agencies, private conservation organizations, botanical gardens, and universities, was established to advise the Service on the biology and management needs for recovery of listed plants. The HPPRCC has outlined general actions and targets for the stages leading towards recovery of listed Hawaiian plants (HPPRCC 2011, entire). Current information is lacking for many Hawaiian plant species with respect to the status of the species and their habitats, breeding systems, genetics, and propagule storage options. We have, therefore, adopted downlisting and delisting criteria for Hawaiian plants based on the revised general recovery objective guidelines developed by the HPPRCC (2011, entire). Many of the Hawaiian plant species persist at very low numbers. To assist in tracking progress toward recovery, we also developed conservation stages for preventing extinction and interim stabilization based on the recommendations of the HPPRCC. While these two “interim recovery stages” are not required under the ESA, they are critical to the recovery of these species. These stages are assessed on a species-by-species basis, as additional information becomes available, before considering downlisting and delisting.

In this draft recovery plan, a plant population is a group of conspecific individuals that are in close spatial proximity to each other (i.e., less than 3,280 ft [1,000 m] apart) and are presumed to be genetically similar and capable of sexual reproduction (HPPRCC 2011, p. 1). Since we do not have adequate data on most species to determine the effective population size, the number of reproducing individuals per population is used as a surrogate for effective population size (i.e., the number of individuals contributing to the next generation). The number of sexually mature (mature) individuals per population required to meet the preventing extinction goal (greater than 25 to 100 individuals) is based on the number of individuals needed to avoid immediate extinction due to demographic stochasticity as well as catastrophic events (HPPRCC 2011 pp. 4–5). The number of mature individuals per population required to meet the interim stabilization goal addresses the fact that numbers between 100 to 500 individuals are likely needed to avoid inbreeding, while numbers required to satisfy downlisting and delisting criteria addresses the fact that around 5,000 mature individuals are needed to maintain evolutionary potential, so that a species can adapt to changing environments (Reed et al. 2002, pp. 12-13; Traill et al. 2010, pp. 30, 32; HPPRCC 2011, pp. 7-10).

General distinctions made by the HPPRCC that are relevant to the 13 plants in this plan include the following:

- *Life span*: Long-lived perennials are known or believed to have life spans greater than 10 years; short-lived perennials are those with life spans greater than 1 year but less than 10 years; and annuals are those with life spans less than or equal to 1 year (Tables 4–7; referred to as ‘long’ and ‘short’, respectively). None of the 13 listed species are currently believed to be annuals. When a species’ life span was unknown, we erred on the side of caution and considered the species short-lived. We currently do not have the data to

determine the life span of most of these species. As more data is collected, we will update species' life span categorizations.

- *Reproduction strategies*: Obligate outcrossers are species that either have male and female flowers on separate plants or otherwise require cross-pollination to fertilize seeds, and therefore require equal numbers of male and female individuals contributing to reproduction, doubling the number of individuals needed per recovery stage (HPPRCC 2011, pp. 5, 6, 8, 10). The majority of genetic variation in a species that predominantly reproduces vegetatively or asexually (i.e., without the use of seeds) is typically found among populations versus within populations (HPPRCC 2011, p. 4). Therefore, species dependent on vegetative reproduction require additional populations. Whether *Stenogyne cranwelliae* reproduces vegetatively is unknown; however, other members of this genus reproduce vegetatively and thus we categorized it as such. This characteristic will be assessed as additional information becomes available.
- *Population size trends*: Species characterized by large fluctuations in the number of mature individuals or a known history of severe declines in the number of mature individuals in the population require a larger number of mature individuals (approximately 50 percent higher) than species without such fluctuations, for the population to persist during, for example, drought years and to recover during typical years (HPPRCC 2011, pp. 5–10). While our current understanding is that none of the 13 listed plants have populations that greatly fluctuate in size, should a species be identified as having this characteristic the minimum number of mature individuals needed in each of the stages would be increased by 50 percent.
- *Immediate vicinity*: Immediate vicinity of a population is defined as a 163 ft (50 m) buffer around the existing population, but depends on the threats specific to the population and on the response of the population to control of those threats, so will require adaptive management to ensure improving populations (HPPRCC 2011, p. 4).

The following targets for the preventing extinction and interim stabilization stages and the downlisting and delisting criteria were determined based on known biology of the 13 plants in this recovery plan considering the above general guidelines.

Interim Recovery Stages:

Preventing Extinction

To meet the preventing extinction goal, several conditions should be satisfied. The minimum number of populations and reproducing individuals per population identified in Table 4 should be realized. All major threats must be managed in the immediate vicinity of the populations. Each population must show evidence of natural reproduction (i.e., viable seeds, seedlings, saplings). And lastly, 50 mature individuals from each population, or the total number of individuals if fewer than 50 remain, must be represented in an *ex situ* collection that is secure and well managed as defined in the Center for Plant Conservation's guidelines (Guerrant et al. 2004, entire).

Table 4. Number of populations and individuals needed for each plant species to meet the Preventing Extinction goal based on population and life history characteristics.

Life Span	Population and Life History Characteristics	Number of Populations	Reproducing Individuals Per Population	Species
Long	No specific characteristics known	3	25	<i>Melicope remyi</i>
		3	25	<i>Pritchardia lanigera</i>
Long	Obligate outcrosser	3	50	<i>Pittosporum hawaiiense</i>
Short	No specific characteristics known	3	50	<i>Bidens hillebrandiana</i> ssp. <i>hillebrandiana</i>
		3	50	<i>Bidens micrantha</i> ssp. <i>ctenophylla</i>
		3	50	<i>Cyanea marksii</i>
		3	50	<i>Cyanea tritomantha</i>
		3	50	<i>Cyrtandra nanawaleensis</i>
		3	50	<i>Cyrtandra wagneri</i>
		3	50	<i>Phyllostegia floribunda</i>
		3	50	<i>Schiedea diffusa</i> ssp. <i>macraei</i>
		3	50	<i>Schiedea hawaiiensis</i>
Short	Vegetatively reproducing	6	50	<i>Stenogyne cranwelliae</i>

Interim Stabilization

To meet the interim stabilization goal, several conditions should be satisfied. The minimum number of populations and reproducing individuals per population identified in Table 5 should be satisfied. All major threats must be managed around the target populations. Populations should be successfully reproducing as demonstrated by the regeneration of seedlings and growth to maturity, and a replacement regeneration or age class distribution indicative of a stable population should be documented. Finally, the populations must be adequately represented in an *ex situ* collection that is secured and well maintained as defined in the Center for Plant Conservation's guidelines (Guerrant et al. 2004, entire). Reintroduced populations can be counted toward the minimum number of populations when it is demonstrated that they are producing viable seed or vegetatively regenerating.

Genetic analyses of wild, reintroduced, and *ex situ* populations of each species must be conducted to ensure maintenance of genetic variation within and between populations throughout controlled propagation efforts. The results of the genetic analyses will be used to develop translocation strategies to correct any genetic deficiencies and determine if translocated individuals should be sourced from one or multiple wild populations. Adequate monitoring should be in place to assess individual plant survival, population trends, trends of major limiting factors, and the response of populations to threat management.

Table 5. Number of populations and individuals needed for each plant species to meet the Interim Stabilization stage based on population and life history characteristics.

Life Span	Population and Life History Characteristics	Number of Populations	Reproducing Individuals per population	Species
Long	No specific characteristics known	3	100	<i>Melicope remyi</i>
		3	100	<i>Pritchardia lanigera</i>
Long	Obligate outcrosser	3	200	<i>Pittosporum hawaiiense</i>
Short	No specific characteristics known	3	300	<i>Bidens hillebrandiana</i> ssp. <i>hillebrandiana</i>
		3	300	<i>Bidens micrantha</i> ssp. <i>ctenophylla</i>
		3	300	<i>Cyanea marksii</i>
		3	300	<i>Cyanea tritomantha</i>
		3	300	<i>Cyrtandra nanawaleensis</i>
		3	300	<i>Cyrtandra wagneri</i>
		3	300	<i>Phyllostegia floribunda</i>
		3	300	<i>Schiedea diffusa</i> ssp. <i>macraei</i>
		3	300	<i>Schiedea hawaiiensis</i>
Short	Vegetatively reproducing	6	300	<i>Stenogyne cranwelliae</i>

Recovery Criteria:

Downlisting

To consider downlisting the 13 plant species from endangered to threatened, the following criteria should be met.

Downlisting Criteria

Criterion 1: In addition to meeting all the interim stabilization targets and achieving the minimum number of reproducing individuals per population identified in Table 6, at least 5 or 10 of these populations (depending on the species' life history characteristics) must be stable, secure, and naturally reproducing for a minimum of 10 years.

Downlisting should not be considered until an adequate PVA has been conducted to confirm the number of individuals needed to achieve a viable population. This analysis should be based on current management and monitoring data collected at regular intervals determined by the life history, threats, and management parameters of the species (i.e., major limiting factors, breeding system, population structure and density, and proven management methods of major threats). The results of the PVA should not be given more weight than other criteria in making a downlisting decision.

Criterion 2: Habitat around each population must be managed for threats to ensure that it will support the long-term persistence of the species.

To achieve this, each of the populations identified for downlisting will have an adaptive management and monitoring plan that will identify actions and procedures necessary to ensure that all habitat level threats (e.g., ungulates, invasive plants) are managed. The monitoring plan

will identify the tools, procedures, and schedules needed to track and assess the response of the species to management actions. Species-specific management actions may be necessary to ensure populations are stable even after each species is downlisted.

Table 6. Number of populations and individuals needed for each plant species to meet Downlisting Criterion 1 based on population and life history characteristics.

Life Span	Population and Life History Characteristics	Number of Populations	Reproducing Individuals per population	Species
Long	No specific characteristics known	5	200	<i>Melicope remyi</i>
		5	200	<i>Pritchardia lanigera</i>
Long	Obligate outcrosser	5	400	<i>Pittosporum hawaiiense</i>
Short	No specific characteristics known	5	500	<i>Bidens hillebrandiana</i> ssp. <i>hillebrandiana</i>
		5	500	<i>Bidens micrantha</i> ssp. <i>ctenophylla</i>
		5	500	<i>Cyanea marksii</i>
		5	500	<i>Cyanea tritomantha</i>
		5	500	<i>Cyrtandra nanawaleensis</i>
		5	500	<i>Cyrtandra wagneri</i>
		5	500	<i>Phyllostegia floribunda</i>
		5	500	<i>Schiedea diffusa</i> ssp. <i>macraei</i>
		5	500	<i>Schiedea hawaiiensis</i>
Short	Vegetatively reproducing	10	500	<i>Stenogyne cranwelliae</i>

Delisting

To consider delisting the 13 listed plant species, the above downlisting criteria should be met for a 10-year period, as well as the following criteria.

Delisting Criteria

Criterion 1: In addition to meeting the downlisting criteria and achieving the minimum number of reproducing individuals per population identified in Table 7, at least 10 or 20 populations (depending on the species' life history characteristics) needed for delisting must be stable, secure, and naturally reproducing for a minimum of 20 years within secure and viable habitats.

Criterion 2: Threats to the species' habitat and to populations are managed. Threats to the habitat of each population needed to meet *Delisting Criterion 1* are managed to ensure that the habitat will support the long-term persistence of the species.

For example, where ungulates are present, all of the populations needed for delisting will be within fenced areas free of ungulates, with agreements from conservation partners to maintain protections for the long-term persistence of the species. Monitoring the status and threats of each population is ongoing. Thorough population surveys and updates to the status of threats to these populations are completed annually during the 20-year period preceding delisting. Species-specific management actions (e.g., hand-pollination, propagation, and translocation) are no longer necessary, but an ongoing need for habitat-scale management actions may remain if long-term agreements are in place.

Table 7. Number of populations and individuals needed for each plant species to meet Delisting Criterion 1 based on population and life history characteristics.

Life Span	Population and Life History Characteristics	Number of Populations	Reproducing Individuals per population	Species
Long	No specific characteristics known	10	200	<i>Melicope remyi</i>
		10	200	<i>Pritchardia lanigera</i>
Long	Obligate outcrosser	10	400	<i>Pittosporum hawaiiense</i>
Short	No specific characteristics known	10	500	<i>Bidens hillebrandiana</i> ssp. <i>hillebrandiana</i>
		10	500	<i>Bidens micrantha</i> ssp. <i>ctenophylla</i>
		10	500	<i>Cyanea marksii</i>
		10	500	<i>Cyanea tritomantha</i>
		10	500	<i>Cyrtandra nanawaleensis</i>
		10	500	<i>Cyrtandra wagneri</i>
		10	500	<i>Phyllostegia floribunda</i>
		10	500	<i>Schiedea diffusa</i> ssp. <i>macraei</i>
		10	500	<i>Schiedea hawaiiensis</i>
Short	Vegetatively reproducing	20	500	<i>Stenogyne cranwelliae</i>

Rationale for Plant Recovery Criteria

The recovery criteria for the 13 plants are based on the currently known biology of the species from the latest respective Species Reports, the Hawai'i and Pacific Plants Recovery Coordinating Committee's Revised Recovery Objective Guidelines, and expert opinion (HPPRCC 2011, entire; Table 1).

Life history traits have been used to infer minimum viable population numbers (Pavlik 1996, entire). We used each species' life span and reproductive strategy to determine the number of populations and the number of mature individuals per population needed to progress from the preventing extinction stage to delisting. Suitable habitat is required to maintain viable populations, and long-term habitat maintenance and in some cases, habitat restoration will be necessary. Translocations, to augment existing populations and to create new populations, will be a crucial action to achieving recovery for many of these Hawaiian plants, especially to increase resiliency and redundancy in the face of increasing catastrophic events. Each translocation effort should consider the genetic composition of the founders, number of founders used, number of individuals from each founder, and the species' reproductive capacity and habitat availability.

The minimum number of populations and the number of reproducing individuals in each population needed to prevent extinction (and to meet the preventing extinction targets) are based on models that demonstrate loss of genetic variation in populations of various sizes. For example, a population of 25 individuals will lose approximately 25 percent of its genetic variation over 10 generations. Vegetatively-reproducing and dioecious species are believed to possess less genetic variation compared to sexually-reproducing and hermaphroditic or monoecious species, and hence the number of populations (for vegetatively-reproducing species)

or individuals per population (for dioecious species) need to be higher to minimize the loss of genetic variation (HPPRCC 2011, pp. 5–10; Hartl and Clark 1989, entire).

2. Recovery Criteria — Anchialine Pool Shrimp

Objective – Manage threats and habitats to establish resilient and self-sustaining anchialine pool shrimp populations on the island of Hawai‘i.

The term anchialine pool complex describes a group of pools that are connected hydrologically. Because hydrological connection is difficult to confirm, for the purposes of this recovery plan anchialine pool complexes will be determined by indicators of hydrology such as geographic region, distance between occupied pools, and other geographic, geological, and marine barriers. Because adult anchialine pool shrimp are not known to disperse outside of their anchialine pool complex (The Nature Conservancy 1987, p. 34), each distinct complex is considered to be a separate population.

Like other anchialine pool shrimp species, *Vetericaris chaceorum* inhabit an extensive network of water-filled interstitial spaces leading to and from the actual pool, which has precluded accurate population size estimates (Holthuis 1973, p. 36; Maciolek 1983, pp. 613–616; Iwai et al. 2009, p. 1). Thus, a population is defined based on presence/absence of the anchialine pool shrimp in the epigeal (above-ground) part of their habitat; a pool is either occupied by a population or it is not. Often surveys for rare species of anchialine pool shrimp, including *V. chaceorum* are restricted to presence/absence surveys with the aid of baiting (Iwai et al. 2009, p. 6; Wada 2016 in litt., entire). The absence, and presumably extirpation, of individuals from suitable habitat is likely the best or only measure of a species’ decline (Holthuis 1973, pp. 7–12; Maciolek 1983, pp. 613–616; Iwai et al. 2009, entire).

Downlisting

To consider downlisting *Vetericaris chaceorum* from endangered to threatened, the following criteria should be met.

Downlisting Criteria

Criterion 1. Occupied anchialine pool complexes are identified and protected. At least 6 anchialine pool complexes occupied by stable *Vetericaris chaceorum* populations are distributed within suitable coastal anchialine pool habitat.

Distinct anchialine pool complexes are delineated based on indicators of hydrological separation and assessed for occupation wherever possible. For a population in a complex to be considered persistent, presence/absence surveys must indicate a complex has been occupied for at least 15 of the past 20 years. Distinct occupied anchialine pool complexes should be broadly distributed to reduce vulnerability to catastrophic events.

Criterion 2. Each anchialine pool complex in *Downlisting Criterion 1* must be afforded land protections to ensure areas are available to support the long-term persistence of *Vetericaris chaceorum*.

A majority of the anchialine pool complexes that support populations in *Downlisting Criterion 1* must exist in a geological and spatial context that indicates subterranean hydrological connectivity to the Pacific Ocean to allow for natural dispersal and range expansion of the shrimp.

Criterion 3. Coastal habitat surrounding occupied anchialine pool complexes provides water of sufficient quantity and quality to maintain the water chemistry needed to support the species at all life stages and is protected from (1) habitat degradation and destruction from adjacent urban development, and other associated anthropogenic activities; and (2) habitat degradation by fish and nonnative plants, ungulates, and invertebrates.

Criterion 4. All major threats to individual shrimp are managed at each distinct anchialine pool complex in *Downlisting Criterion 1*.

Nonnative predators are absent from occupied anchialine pool complexes and other direct threats to shrimp are managed such that they are unlikely to have significant long-term impacts. Pools are managed and protected to prevent introduction of nonnative predators, competitors, or disease to the populations in *Downlisting Criterion 1*. Monitoring and management plans are completed and implemented.

Delisting

To consider delisting *Vetericaris chaceorum*, the above downlisting criteria should be met, as well as the following criteria.

Delisting Criteria

Criterion 1. In addition to the downlisting criteria being met, at least 11 distinct anchialine pool complexes occupied by stable *Vetericaris chaceorum* populations are distributed within suitable coastal anchialine pool habitat with priority given to those in the species' known historical range.

Hydrologic separation distance between anchialine pool complexes is assessed and used to delineate distinct occupied pool complexes whenever possible. For a population in a complex to be considered stable, presence/absence monitoring results must indicate that the complex has been occupied for at least 20 of the past 30 consecutive years. Distinct occupied anchialine pool complexes should be broadly distributed to reduce vulnerability to catastrophic events.

Criterion 2. Each anchialine pool complex identified in *Delisting Criterion 1* must be afforded land protections to ensure areas are available to support the long-term persistence of *Vetericaris chaceorum*.

Functioning anchialine pool complexes in *Delisting Criterion 1* must have subterranean hydrological connectivity to the Pacific Ocean to allow for natural dispersal and range expansion of *Vetericaris chaceorum*.

Criterion 3. Coastal anchialine pool habitat occupied by the anchialine pool shrimp provides water of sufficient quantity and quality to maintain the water chemistry needed to support all life stages of *Vetericaris chaceorum* and is protected from (1) habitat

degradation and destruction due to urban development, and other associated anthropogenic activities; and (2) habitat degradation by fish and nonnative plants, ungulates, and invertebrates.

Criterion 4. All major threats to individual anchialine pool shrimp are managed at each distinct anchialine pool complex in *Delisting Criterion 1*.

Nonnative predators are absent from functional habitat and threats are unlikely to have significant long-term impacts. Species-specific management actions may continue to be necessary. Pools are managed and protected to prevent introduction of nonnative predators, competitors, or disease to the anchialine pool complexes in *Delisting Criterion 1*. Monitoring of population status and threats is ongoing.

Rationale for Anchialine Pool Shrimp Recovery Criteria

The downlisting and delisting criteria for *Vetericaris chaceorum* are based on the most up-to-date information on the species biology, ecology, distribution, and threats (USFWS 2021o).

To prevent extinction of *Vetericaris chaceorum*, the current distribution of the species needs to be identified and occupied anchialine pool complexes need to be protected from threats, including invasive species (Table 3). The feasibility of captive breeding to support translocations needs to be determined. Systematic surveys of anchialine pool complexes for existing populations should be conducted to ensure that any unknown populations are protected. All threats in the immediate vicinity of each anchialine pool complex must be managed. This will require developing and implementing management plans and survey protocols. Unlike the other species covered in this plan, recovery of *Vetericaris chaceorum* will be based on the species' presence within anchialine pool complexes; presence will be a surrogate for resilient and self-sustaining populations.

To be considered for downlisting *Vetericaris chaceorum* must occupy at least 6 pool complexes for 15 of 20 years. To be considered for delisting the species should occupy at least 11 pool complexes for 20 of 30 years. Occupied anchialine pool complexes need to be distributed such that extinction as a result of stochastic events is minimized. Due to the difficulties of sampling this species, a pool complex will be deemed occupied if the species is present rather than by the documentation of a minimum number of individuals. Methods to determine the subterranean connectivity of anchialine pools will need to be developed to better identify distinct anchialine pool complexes. Methods to determine anchialine pool connectivity should use the best science available.

Occupied anchialine pool complexes require protection from ungulates, invasive fish and invertebrates, invasive plants, sedimentation, anthropogenic effects including development, dumping, dewatering and water diversion, and reductions in water quality. Protecting habitat adjacent to anchialine pool complexes via management, regulations and/or easements will be critical to recover the species.

Vetericaris chaceorum requires specific hydrologic conditions for survival. Threats that alter or modify anchialine pool salinity or that would render the habitat unsuitable will need to be identified and managed.

Downlisting and delisting will require a clear understanding of invasive fish and invertebrate distribution, abundance, and predator-prey dynamics within each anchialine pool complex. The presence of *Vetericaris chaceorum* in anchialine pool complexes will contribute to meeting downlisting and delisting criteria if pools are free of predators or they are managed to allow the anchialine pool shrimp to persist. Establishing methods to manage invasive fish and Tahitian prawns will be necessary for the recovery of the species.

3. Recovery Criteria — Picture-wing Fly

Objective – Manage threats and habitats to establish resilient and self-sustaining populations of *Drosophila digressa* throughout the island of Hawai‘i.

Downlisting

To consider downlisting *Drosophila digressa* from endangered to threatened, the following criteria should be met.

Downlisting Criteria

Criterion 1. Existing population(s) of the *Drosophila digressa* are identified and stabilized. The species should be represented by at least five stable to increasing populations distributed throughout the species’ historical range or in otherwise suitable habitat.

For each population, a population index based on repeated surveys with consistent methodology must indicate stable to increasing indices over at least 5 consecutive years immediately prior to consideration of downlisting. Each critical habitat unit is occupied by at least one population.

Criterion 2. The species is in a successful captive rearing program, existing genetic diversity of the species is represented, and the population(s) are reproducing at a rate that can support translocation.

Criterion 3. Systematic surveys and evaluation over at least 10 years indicate each population site in *Downlisting Criterion 1* includes viable populations of host plant species (*Charpentiera* spp., *Ceodes brunoniana*, *Rockia sandwicensis*, or other confirmed hosts) within the dispersal distance of *Drosophila digressa*.

Criterion 4. Within each of the population sites identified in *Downlisting Criterion 1*, the habitats are managed and afforded land protections to maximize long-term persistence of the species.

Threats to host plants and the environment from invasive plants, plant diseases, ungulates, and fire have been eliminated or managed such that the microclimate (e.g., humidity, temperature, canopy cover) and the breeding resources of the picture-wing fly are not adversely affected and can support the life cycle of the species.

Criterion 5. All major threats to individuals and populations in *Downlisting Criterion 1* are managed such that nonnative predators and competitors are absent, or predation and competition are unlikely to have significant long-term adverse impacts on picture-wing fly population indices.

Monitoring and management plans are completed and implemented and measures are in place to prevent the introduction of new nonnative predators, competitors, disease, or other threats to the plant hosts and picture-wing fly populations in *Downlisting Criterion 1*.

Delisting

To consider delisting *Drosophila digressa*, the above downlisting criteria should be met, as well as the following criteria.

Delisting Recovery Criteria

Criterion 1. An additional 10 years of systematic surveys have documented significant increases in the abundance and distribution of populations throughout the species' range. The species is represented by at least 10 populations (see below) distributed throughout its historical range or in otherwise suitable habitat.

Populations should exist within habitat that is capable of supporting natural dispersal, breeding, and expansion of occupied range. For each population, a population index based on repeated surveys must indicate stable to increasing indices over at least 7 of 10 years immediately before delisting.

Criterion 2. Systematic research, surveys, and evaluation over at least 10 years since downlisting indicate each picture-wing fly population site in *Delisting Criterion 1* includes viable, reproducing populations of the appropriate host plant species within dispersal distance of the picture-wing flies.

Criterion 3. Within each of the population sites identified in *Delisting Criterion 1*, habitats are managed, protected, and afforded land protections to maximize the long-term persistence of the species.

All major threats to host plants and habitats from invasive plants, plant diseases, ungulates, and fire have been eliminated or managed such that the microclimate (e.g., humidity, temperature, canopy cover) and the breeding resources of the picture-wing fly are not adversely affected and can support the life cycle of the species.

Criterion 4. All major threats to individual flies are managed and measures are in place to prevent introduction of new threats.

For each population site identified in *Delisting Criterion 1*, monitoring of threats and population status is ongoing. Results based on at least 4 years of the most recent monitoring data indicate that (1) nonnative predators are absent, or (2) that predation and competition are occurring at a level that will not have significant, adverse long-term effects on picture wing fly population indices.

Rationale for Picture-wing Fly Recovery Criteria

The downlisting and delisting criteria for the picture-wing fly are based on the most recent information about the species' biology, ecology, distribution, and threats (USFWS 2021g).

To prevent extinction of *Drosophila digressa*, all extant populations need to be identified, stabilized, and protected from threats that are suppressing and/or threatening the populations'

immediate survival. Systematic surveys of existing and for undocumented picture-wing fly populations should be conducted to ensure the broadest genetic representation of the species is protected in the wild and subsequently represented in captive populations. A captive rearing program should be established to prevent extinction and to support translocations. All threats in the immediate vicinity of each wild population require immediate management. This will require developing and implementing survey, monitoring, and management plans based on the identified needs of each species. Populations must show evidence of reproduction and replacement as a measurement of success.

Beyond *Drosophila digressa* being dependent on the decaying stems and bark of several host plants (see below), little is known about the biology and life needs of the species. Achieving the recovery criteria will require determining substantive biological and ecological information about the picture-wing fly to inform management. The recovery criteria consider all threats (existing and future) to the picture-wing fly species and its larval host. A decision to delist or downlist a species is informed by the recovery criteria but is ultimately based on an analysis of threats using the best scientific and commercial data then available.

Drosophila digressa should have at least 5 (downlisting) or 10 (delisting) populations that sustain stable to positive population indices for a minimum number of consecutive years to be considered for downlisting or delisting. These populations need to be distributed throughout their range to ensure genetic redundancy such that a catastrophic event would not likely lead to extinction of the species or a reduction in existing genetic diversity. Changes in listing status should be supported by population viability analyses or other analyses that are approved by the Service and considered the best science at the time downlisting and delisting are considered.

The decaying stems and bark of *Charpentiera* spp., *Ceodes brunoniana*, and/or *Rockia sandwicensis*, are required for egg laying and larval development. These species are long-lived trees that require protection from invasive plant competition, ungulates, and other threats to successfully reproduce. Recovery criteria include identifying, establishing, and protecting the host plants that *Drosophila digressa* requires for reproduction. A picture-wing fly may travel about 320 ft (~100 m) in search of an appropriate breeding substrate (Science Panel 2005, p. 5). Host plant populations within this distance should be sufficient to support egg laying and larval development of each picture-wing fly population for the long-term (20 to 40 years). The larval substrate must be sufficient to alleviate competition from other invertebrates or managed competition is absent. This will require management plans be developed and implemented to ensure appropriate larval substrates are available to maximize long-term persistence. To support these plans, research will be needed to determine the numbers and composition of plant hosts necessary to support a stable to growing populations of *D. digressa* given environmental fluctuations. The adequacy of host plant resources to meet recovery criteria will be assessed within the habitat of each breeding population using the best technology at the time downlisting or delisting are considered.

Protecting host plants from ungulates and fire will be necessary to ensure sufficient populations are available to support *Drosophila digressa* populations and to maintain the microclimate required by the plants and the picture-winged fly. Reinforcement and / or reintroduction of host plants may be needed to augment existing or establish new populations. Management to support

viable populations of host plants sufficient for not less than 10 picture-wing fly populations with stable to positive trends in population indices will be necessary.

Drosophila digressa requires specific environmental conditions for breeding (Magnacca et al. 2008, pp. 11, 13; Montgomery 1975, pp. 80, 84, and 95; Magnacca 2012 in litt., entire). Threats that alter or modify their host plants (i.e., larval substrate availability) or the species' required microclimate such as changes in canopy coverage, or other factors that would render the habitat unsuitable for *D. digressa* will require identification and management at each population.

Downlisting and delisting will require a clear understanding of nonnative predator distribution, abundance, and predator-prey dynamics within each population. The conspicuous lekking and breeding displays of adult *Drosophila digressa* and their undefended eggs, larvae, and pupae leave the species vulnerable to predators and parasitoids including nonnative ants, coqui frogs, western yellowjackets, parasitoid wasps, limoniid crane flies, and other insects. Populations of *D. digressa* will contribute to meeting downlisting and delisting criteria if they are successfully coexisting with predators, and showing stable to positive trends in population indices, with or without special management. Given the rarity of *D. digressa*, managing predators and parasitoids and reinforcing and reintroducing populations using captive-reared flies will be necessary for recovery of the species.

III. RECOVERY ACTIONS

This recovery plan identifies recovery actions needed to implement the recovery strategy and achieve the recovery criteria for each species. Implementation of a recovery action will depend on its priority, availability of funds and resources, coordination with partners, and complexity and logistical constraints. A broad action may have multiple components developed as needed to best accomplish recovery implementation. Specific project-level implementation of these actions will be accomplished through shorter-term activities, collectively referred to as the RIS, in coordination with recovery partners interested and willing to work on implementing the activities. Activities are intended to be adaptable and guide recovery partners to coordinate recovery implementation and further describe those responsible for each action described in the plan. Because the RIS is a short-term working document, activities described there can be modified as needed without requiring future revision of the recovery plan, so long as they remain consistent with the recovery plan.

As discussed in the Introduction, this recovery plan is a guidance document rather than being regulatory in nature. As such, implementation of recovery actions is voluntary and depends on the cooperation and commitment of numerous partners in this conservation effort. All Federal agencies, however, have an obligation under section 7(a)(1) of the Act to carry out programs for conservation of federally-listed species.

The actions needed to alleviate threats to all species and achieve recovery criteria are organized below into six categories: (1) Determine the current distribution and status of the species and their habitats, (2) Protect populations and manage threats to habitat, (3) Manage species-specific threats, (4) Expand the distribution of existing wild populations and establish new populations, (5) Conduct additional research essential to recovering the 15 species and restoring their habitats, and (6) Implement regulations and policy to support species recovery. Not all recovery actions may apply to all populations and all species. Development and implementation of a detailed monitoring plan for recovery actions is necessary to assess the effects of an action on each species, inform adaptive management responses, and evaluate progress towards recovery criteria. The applicability of each action to the three groups of species (plants, anchialine pool shrimp, and picture-wing fly) is summarized in Tables 8, 9, and 10, respectively.

1. Determine the current distribution and status of the species and their habitats.

- 1.1. Develop a systematic survey methodology for the species within their known and historical range.
- 1.2. Conduct range-wide surveys for listed plants and invertebrates to determine their current distribution and status.
 - 1.2.1. Identify and document current range for each population.
 - 1.2.2. Determine demographic structure of populations.
 - 1.2.3. Assess genetic diversity.

2. Protect populations and control or manage threats to habitat.

The habitats that support the species must be identified and protected from threats. Each species-specific site required for the species' recovery must have sufficient protected habitat to sustain the populations used to meet recovery criteria.

- 2.1. Identify sites to support populations of each species.
- 2.2. Prioritize and select sites based on factors including conservation value to multiple species and likelihood of success of threat control efforts.
- 2.3. Develop microclimate models to identify additional suitable habitat based on historical and current species' distributions and habitat that would be suitable under future climate conditions.
- 2.4. Ensure long-term protection of species-specific sites from threats. Protect sites via land acquisitions, conservation easements, landowner agreements, and/or regulatory mechanisms.
 - 2.4.1. Identify threats to sites that support or will support populations to satisfy recovery criteria for the species (hereafter recovery sites).
 - 2.4.2. Construct and maintain ungulate-proof fences around all recovery sites.
 - 2.4.3. Remove ungulates from fenced areas protecting recovery sites and keep these sites ungulate-free.
 - 2.4.4. Control or eradicate habitat-modifying invasive plants at all recovery sites.
 - 2.4.5. Control or eradicate rodents at all recovery sites.
 - 2.4.6. Provide wildfire protection.
 - 2.4.6.1. Develop and implement fire management plans for all recovery sites, especially in dry and mesic habitats.
 - 2.4.6.2. Assess the need for fire management plans in habitats affected by climate change.
 - 2.4.7. Protect recovery sites from human disturbance and development.
 - 2.4.8. Prevent incipient invasive species from arriving and establishing at recovery sites.
 - 2.4.9. Control other existing threats to recovery sites.
 - 2.4.10. Prevent sedimentation of anchialine pool complexes.
- 2.5. Monitor responses to management and use results to adapt management actions.

3. Control or manage species-specific threats.

Each species must be protected from various species-specific threats that affect their habitat and population viability.

- 3.1. Develop and implement control programs for nonnative slugs.
- 3.2. Develop and implement control programs for nonnative rodents.

- 3.3. Develop and implement control programs for nonnative ants (e.g., Argentine ant, big-headed ant, yellow crazy ant, Papuan thief ant, and tropical fire ant).
- 3.4. Develop and implement control programs for the nonnative western yellowjacket.
- 3.5. Develop and implement control programs for nonnative limoniid crane flies, and other invertebrates.
- 3.6. Develop and implement control programs for parasitoid wasps.
- 3.7. Develop and implement control programs for nonnative beetles and weevils.
- 3.8. Develop and implement control programs for nonnative leafhoppers.
- 3.9. Develop and implement control programs for invasive fishes.
- 3.10. Develop and implement control programs for Tahitian prawns.
- 3.11. Develop and implement control programs for nonnative game birds.
- 3.12. Mitigate sedimentation affecting anchialine pool complexes.
- 3.13. Monitor populations to detect disease, assess impacts, and control outbreaks.
- 3.14. Control other threats to specific species as appropriate.
- 3.15. Monitor the response to management and use these results to adapt management actions.
- 3.16. Develop and implement control programs for plant and invertebrate diseases.

4. Expand the distribution of existing wild populations and establish new populations.

Captive propagation or rearing programs for each species will be implemented to safeguard the species against catastrophic events affecting wild populations. Increasing the abundance of individuals in each population and the number of populations across the range of each species is needed to improve each species' resiliency, redundancy, and representation. Individuals to be used for translocations will be sourced from captive populations or from wild populations that have been determined to be stable enough to serve as donor populations.

- 4.1. Identify species suitable for translocation and develop and implement translocation plans for each according to IUCN Reintroduction Guidelines (2013).
- 4.2. Identify areas within each species' habitat appropriate for translocating individuals.
- 4.3. Select populations for translocation.
- 4.4. Prepare translocation sites within managed sites.
- 4.5. Establish and maintain *ex situ* captive propagation and/or rearing programs with genetically representative founders. For plants, propagate genetically appropriate individuals for genetic storage and translocation; for invertebrates, develop captive rearing programs and establish populations from appropriate genetic sources for translocation.
- 4.6. Translocate genetically appropriate individuals into managed sites.

- 4.7. Consider the feasibility and conservation benefit of translocating species outside of their known historical range as appropriate (e.g., assisted colonization or ecological replacement).
- 4.8. Monitor populations and use the results to adapt management actions.

5. Conduct additional research essential to recovering the 15 species and restoring their habitats.

Research and development of tools that assess species biology and ecology, ameliorate threats, establish, or improve propagation, captive rearing, or genetic storage, and inform improvements to species growth rate and viability, are necessary for species recovery.

- 5.1. Develop tools to enhance habitat and species survival and reproduction.
- 5.2. Develop tools to inform actions that will improve species *in situ* and *ex situ* viability.
- 5.3. Conduct long-term studies on range, demographics, and dispersal.
- 5.4. Conduct research on threats to the viability of all life stages of the species.
- 5.5. Develop tools for long-term monitoring of population growth and status as appropriate.
- 5.6. Conduct population viability analyses for each species as appropriate.
- 5.7. Conduct studies on optimizing conservation translocation survival and success.
- 5.8. Conduct long-term genetic studies on captive and wild populations as appropriate.
- 5.9. Monitor range-wide population, status, population trends, and distribution at time intervals appropriate for each species.
- 5.10. Monitor and maintain water quality for the entire lifecycle of the species.
- 5.11. Determine biological limitations for species' reproduction and survival (e.g. salinity, temperature, water quality, water quantity, and others).

6. Implement regulations and policy to support species recovery.

Recovery will require partnerships with State, Federal, County, and private stakeholders to prevent the introduction and establishment of new invasive species or other factors that will negatively affect the species, their habitats, or both.

- 6.1. Provide support to implement the Hawai'i Interagency Biosecurity Plan to prevent the arrival and spread of new invasive species into the Hawaiian Archipelago and interisland movement of invasive species already established.
- 6.2. Implement public outreach and education and enforce policies that prohibit species collection and harassment.
- 6.3. Resolve state restrictions for using piscicides and other invasive species removal techniques.
- 6.4. Provide land protections to anchialine pool complexes and aquifers.

- 6.5. Provide protections for anchialine pool complexes from dewatering and water diversion practices.

Table 8. Crosswalk relating threats, recovery criteria, and recovery actions for the 13 plant species.

Listing Factor	Specific Threat Under the Listing Factor	Recovery Criteria Numbers	Recovery Action Numbers
A Present or Threatened Destruction, Modification or Curtailment of its Habitat or Range	Agriculture and urban development	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.3, 2.4, 2.5, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.3, 5.4, 5.5, 5.6, 5.9, 6.1, 6.2
	Ungulates	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.6, 5.9, 6.1, 6.3
	Nonnative plants	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.6, 5.9, 6.1, 6.3
	Fire	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.6, 5.9, 6.1
	Stochastic events	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.6, 5.9, 6.1
B Overutilization	Overcollection	Downlisting 1 and 2; Delisting 1 and 2	1.2, 2.2, 2.4, 2.5, 3.14, 3.15, 5.1, 5.2, 5.4, 5.8, 6.2

Listing Factor	Specific Threat Under the Listing Factor	Recovery Criteria Numbers	Recovery Action Numbers
C Disease or Predation	Disease	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.13, 3.15, 3.16, 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 6.1, 6.2
	Predation / Herbivory by nonnative ungulates	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 6.1, 6.2, 6.3
	Predation / Herbivory by other nonnative vertebrates	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.2, 3.11, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 6.1, 6.2, 6.3
	Predation / Herbivory by nonnative invertebrates	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.1, 3.7, 3.8, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 6.1, 6.2, 6.3
D Inadequacy of Existing Regulatory Mechanisms	Inadequate existing regulatory mechanisms	Delisting 1 and 2	3.14, 6.1, 6.2, 6.3
E Other Natural or Manmade Factors	Other species-specific threats	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.14, 3.16 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 6.1, 6.2, 6.3
	Hybridization	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.14, 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 6.1, 6.2

Listing Factor	Specific Threat Under the Listing Factor	Recovery Criteria Numbers	Recovery Action Numbers
	No regeneration	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.14, 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 6.1, 6.2
	Limited number of individuals	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.14, 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 6.1, 6.2
	Limited number of populations	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.14, 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 6.1, 6.2
	Human (dumping of trash)	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.14, 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 6.1, 6.2
	Koa logging	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.14, 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 6.1, 6.2
	Climate change	Downlisting 1 and 2; Delisting 1 and 2	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.14, 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 5.9, 6.1, 6.2

Table 9. Crosswalk relating threats, recovery criteria, and recovery actions for the anchialine pool shrimp.

Listing Factor	Specific Threat Under the Listing Factor	Recovery Criteria Numbers	Recovery Action Numbers
A Present or Threatened Destruction, Modification or Curtailment of its Habitat or Range	Agriculture and urban development	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 4.1, 4.2, 4.3, 4.4, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.7, 5.9, 5.10, 5.11, 6.1, 6.2, 6.4, 6.5
	Ungulates	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	2.1, 2.2, 2.4, 2.5, 3.9, 3.10, 3.12, 3.13, 3.14, 3.15, 4.1, 4.4, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.7, 5.9, 5.10, 6.1, 6.4
	Invasive animals	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.13, 3.14, 3.15, 4.1, 4.3, 4.4, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.7, 5.9, 6.1, 6.2, 6.3, 6.4, 6.5
	Nonnative plants	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.14, 3.15, 4.1, 4.3, 4.4, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.7, 5.9, 6.1, 6.4, 6.5
	Stochastic events	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.13, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 6.1, 6.2, 6.3, 6.4, 6.5
B Overutilization	Aquarium trade and collection	Downlisting 4; Delisting 4	2.4, 6.2
C Disease or Predation	Disease	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 3.12, 3.13, 3.14, 3.15, 3.16, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8,

Listing Factor	Specific Threat Under the Listing Factor	Recovery Criteria Numbers	Recovery Action Numbers
			5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 6.1, 6.2, 6.3, 6.4, 6.5
	Predation by invasive vertebrates	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.12, 3.14, 3.15, 4.1, 4.4, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.9, 5.10, 6.1, 6.2, 6.3, 6.4, 6.5
	Predation by nonnative invertebrates	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.10, 3.12, 3.14, 3.15, 4.1, 4.4, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.9, 5.10, 6.1, 6.2, 6.3, 6.4, 6.5
D Inadequacy of Existing Regulatory Mechanisms	Inadequate existing regulatory mechanisms	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.14, 3.15, 4.1, 4.2, 4.4, 4.6, 4.7, 4.8, 5.4, 5.5, 5.10, 6.1, 6.2, 6.3, 6.4, 6.5
E Other Natural or Manmade Factors	Human (contamination, dumping, fisheries, marine debris, and trash)	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.12, 3.14, 3.15, 4.1, 4.4, 5.4, 5.10, 6.2, 6.4, 6.5
	Limited number of individuals	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.13, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.1, 6.2, 6.3, 6.4, 6.5
	Limited number of populations	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.13, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8,

Listing Factor	Specific Threat Under the Listing Factor	Recovery Criteria Numbers	Recovery Action Numbers
			5.9, 6.1, 6.2, 6.3, 6.4, 6.5
	Not in captive rearing program	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 4.5, 4.6, 5.1, 5.2, 5.8
	Nutrient loading	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.14, 3.15, 4.1, 4.4, 4.6, 4.7, 4.8, 5.1, 5.2, 5.4, 5.5, 5.7, 5.8, 5.10, 5.11, 6.2, 6.4, 6.5
	Natural senescence of pools	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.14, 3.15, 4.1, 4.4, 4.6, 4.7, 4.8, 5.1, 5.2, 5.4, 5.5, 5.7, 5.8, 5.10, 5.11, 6.2, 6.4, 6.5
	Recreational use	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.14, 3.15, 4.1, 4.4, 4.7, 4.8, 5.9, 5.10, 6.1, 6.2, 6.4, 6.5
	Recreational vehicles	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.14, 3.15, 4.1, 4.4, 4.7, 4.8, 5.9, 5.10, 6.1, 6.2, 6.4, 6.5
	Sedimentation	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.14, 3.15, 4.1, 4.4, 4.6, 4.7, 4.8, 5.1, 5.2, 5.4, 5.5, 5.7, 5.8, 5.10, 5.11, 6.2, 6.4, 6.5
	Sea level rise	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.13, 3.14, 3.15, 4.1, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8,

Listing Factor	Specific Threat Under the Listing Factor	Recovery Criteria Numbers	Recovery Action Numbers
			5.9, 5.10, 6.1, 6.2, 6.3, 6.4, 6.5
	Trampling	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.14, 3.15, 4.1, 4.4, 4.7, 4.8, 5.9, 5.10, 6.1, 6.2, 6.4, 6.5
	Water quality reduction	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.14, 3.15, 4.1, 4.4, 4.6, 4.7, 4.8, 5.1, 5.2, 5.4, 5.5, 5.7, 5.8, 5.10, 5.11, 6.2, 6.4, 6.5
	Climate change	Downlisting 1, 2, 3 and 4; Delisting 1, 2, 3 and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.9, 3.10, 3.12, 3.13, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11, 6.1, 6.2, 6.3, 6.4, 6.5

Table 10. Crosswalk relating threats, recovery criteria, and recovery actions for the picture-wing fly.

Listing Factor	Specific Threat Under the Listing Factor	Recovery Criteria Numbers	Recovery Action Numbers
A Present or Threatened Destruction, Modification or Curtailment of its Habitat or Range	Agriculture and urban development	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	1.1, 1.2, 2.1, 2.2, 2.4, 2.5, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.4, 6.1
	Ungulates	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	2.1, 2.2, 2.4, 2.5, 3.13, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.4, 5.7, 6.1, 6.2, 6.3
	Nonnative plants	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	1.1, 1.2, 2.1, 2.2, 2.4, 2.5, 3.13, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.4, 5.7, 6.1, 6.2, 6.3
	Fire	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.4, 5.7, 6.1, 6.2
	Stochastic events	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.4, 5.7, 6.1
B Overutilization	Not applicable		
C Disease or Predation	Predation by nonnative invertebrates	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	2.1, 2.2, 2.4, 2.5, 3.3, 3.4, 3.6, 3.13, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.4, 5.7, 6.1, 6.2, 6.3
D Inadequacy of Existing Regulatory Mechanisms	Inadequate existing regulatory mechanisms	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	3.14, 4.7, 6.1, 6.2, 6.3

Listing Factor	Specific Threat Under the Listing Factor	Recovery Criteria Numbers	Recovery Action Numbers
E Other Natural or Manmade Factors	Competition	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	1.1, 1.2, 2.1, 2.2, 2.4, 2.5, 3.5, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.1, 6.2, 6.3
	Lack of sufficient egg laying and larval resources	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.5, 3.7, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.1, 6.2, 6.3
	Beetles and weevils (damage to host plants)	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	1.1, 1.2, 2.1, 2.2, 2.4, 2.5, 3.7, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.9, 6.1, 6.2, 6.3
	Diseases of host plants or important canopy plants	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.13, 3.14, 3.15, 3.16, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.9, 6.1, 6.2, 6.3
	Limited number of individuals	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.3, 3.4, 3.5, 3.6, 3.7, 3.13, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.1, 6.2, 6.3
	Limited number of populations	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 3.3, 3.4, 3.5, 3.6, 3.7, 3.13, 3.14, 3.15, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6.1, 6.2, 6.3
	Not in captive rearing	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	1.1, 1.2, 4.5, 4.6, 5.1, 5.2, 5.8

Listing Factor	Specific Threat Under the Listing Factor	Recovery Criteria Numbers	Recovery Action Numbers
	Climate change	Downlisting 1, 2, 3, 4, and 5; Delisting 1, 2, 3, and 4	1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10

IV. TIME AND COST ESTIMATES

Achieving the recovery criteria for these 15 species is expected to require, at a minimum, approximately 50 to 95 years.

Presented below are site-specific recovery actions and their estimated costs of implementation, projected to the estimated date of delisting (Table 11). The cost table contains the estimated costs for each action. Estimated costs include contract, staff, or operations costs in excess of base budgets for the PIFWO (i.e., agency staff salaries). This draft recovery plan does not commit the Service or any partners to carry out a particular recovery action or expend the estimated funds.

Estimated costs include planning, design, implementation, research, monitoring, and evaluation costs associated with specific actions (Table 11). Through adaptive management, species' responses to implemented recovery actions will be evaluated to ensure that they are effectively mitigating threats to the species and meeting the objectives of this draft recovery plan. If management actions are not effective, changes in management will be implemented; additional planning and research may be necessary.

Table 11. Priority and estimated cost of recovery actions for all 15 species included in this recovery plan.

Recovery Actions	Priority	Estimated Total Cost	Notes ¹
1. Determine the current distribution and status of the species and their habitats.	1	\$15,330,000	Develop survey methodology for all species (\$730,000); identify range, demographics, and genetic diversity (\$14,600,000)
2. Protect populations and manage threats to habitat.	1	>\$499,343,600	Identify sites (\$1,600,000); prioritize sites (\$1,600,000); develop microclimate models (\$5,300,000); ensure long-term protection of species-specific sites from threats (\$478,003,600); monitor and adaptively manage populations (\$12,840,000)
3. Manage species-specific threats.	1	>\$159,456,400	Develop and implement control programs for slugs (\$19,650,000), rodents (\$31,250,000), ants (\$10,000,000), predatory wasps (\$5,000,000), limoniid crane flies, and other invertebrates (\$5,000,000), parasitoid wasps (\$6,200,000), nonnative beetles and weevils (\$13,500,000), leafhoppers (\$8,500,000), invasive fishes (\$9,158,000), Tahitian prawns (\$6,000,000), game birds (\$1,000,000), remove sedimentation (\$3,198,400), and monitor and control diseases

Recovery Actions	Priority	Estimated Total Cost	Notes ¹
			(\$2,550,000); control other species-specific threats (TBD); monitoring and adaptive management (\$38,450,000)
4. Expand the distribution of existing wild populations and establish new populations.	1	\$231,669,500	Identify appropriate species (\$4,700,000); identify translocation sites (\$2,600,000); select populations based on IUCN standards (\$4,250,000); prepare sites (\$1,995,500); <i>in situ</i> propagation and captive rearing (\$207,575,000); translocation (\$6,349,000); evaluate feasibility of translocation outside historical habitat (\$1,200,000); monitor populations (\$3,000,000)
5. Conduct additional research essential to recovery of the 15 species and restoring their habitats.	1	\$105,890,000	Develop tools to enhance habitat and species survival and reproduction (\$25,000,000) and improve species viability <i>in situ</i> and <i>ex situ</i> (\$9,500,000); maintain studies on range, demographics, and dispersal (\$19,000,000); threats to viability research (\$11,000,000); develop tools for monitoring growth and status (\$4,650,000); population viability analyses (\$3,300,000); optimize translocation survival and success (\$7,500,000); long-term genetic studies (\$15,000,000); long-term monitoring of range, status, and trends (\$5,900,000); monitor and maintain water quality (\$5,040,000)

Recovery Actions	Priority	Estimated Total Cost	Notes ¹
6. Implement regulations and policy to support species recovery.	2	\$13,150,000	Program support for biosecurity (\$1,500,000); public outreach, and enforcement of prohibited actions (\$1,650,000); resolve state restrictions on invasive species removal (\$4,000,000); provide land protections to anchialine pool complexes (\$3,000,000); protections from dewatering and water diversion (\$3,000,000)

¹Complete recovery actions can be found above in section III. RECOVERY ACTIONS.

Priority 1 - an action that must be taken to prevent extinction or prevent the species from declining irreversibly in the foreseeable future.

Priority 2 - an action that must be taken to prevent a significant decline in species population or habitat quality.

Estimated cost through date of recovery (50 to 95 years by species) is estimated to be at least: \$1,024,839,500. Prorated by species based on estimated time to recovery, annual costs are estimated at \$1,009,694.

Cost estimates are preliminary. Project-level details of recovery action implementation will be developed with partners in the RIS that will accompany this draft recovery plan. Implementation is subject to availability of funds and is at the discretion of partners.

Date of Recovery

If all actions are fully funded and implemented, we estimate the earliest that the delisting criteria could be met would be between 2077 and 2117 for the various plant species, 2082 for the anchialine pool shrimp, and not likely before 2072 for the picture-wing fly.

For the 13 plant species, delisting is likely to require between 55 to 95 years, depending on the lifespan and recovery potential of each species. Short- and long-lived plants are identified in section II.B.1 (*Recovery Criteria – Plants*; Tables 4 to 7) and a species' recovery potential is identified by its recovery priority number (Table 1).

- For short-lived plants with a high recovery potential (recovery priority number 3), delisting criteria could be achieved within 55 years: *Bidens micrantha* ssp. *ctenophylla*.
- For short-lived plants with a low recovery potential (recovery priority numbers 5 and 6), delisting criteria could be achieved within 65 years: *Bidens hillebrandiana* ssp. *hillebrandiana*, *Cyanea marksii*, *Cyanea tritomantha*, *Cyrtandra nanawaleensis*, *Cyrtandra wagneri*, *Phyllostegia floribunda*, *Schiedea diffusa* ssp. *macraei*, *Schiedea hawaiiensis*, and *Stenogyne cranwelliae*.
- For long-lived plants with a high recovery potential (recovery priority number 2), delisting criteria could be achieved within 85 years: *Pittosporum hawaiiense*, *Pritchardia lanigera*.

- For long-lived plants with a low recovery potential (recovery priority number 5), delisting criteria could be achieved within 95 years: *Melicope remyi*.

For each plant species, life span and biological requirements were factored into the estimated time to delisting. The delisting time for long-lived species is longer due to the time needed for plants to reach maturity as well as the time it takes for these species to be grown in nurseries. In contrast, the delisting time for short-lived species is shorter due to the time needed for plants to mature and reproduce both in the wild and in nurseries. Species with a low recovery potential may require additional time to restore habitat, reduce threats, or both, as well as additional time to allow these species to reach the population numbers specified by the recovery criteria. On the other hand, plants with high recovery potential may require less time for habitat restoration and threat control. The estimated time to recover these species includes a 10-year monitoring period for downlisting and a 20-year monitoring period for delisting during which populations must be stable, secure, and naturally reproducing.

For *Vetericaris chaceorum*, delisting is not likely to be achieved for at least 60 years and will require restoring anchialine pool complexes throughout the species' range. The estimated time to recover this species includes 20 years of monitoring for downlisting and 30 years for delisting, during that show populations have been persistent and stable. Recovery of the anchialine pool shrimp is not likely to be achieved before 2082.

For *Drosophila digressa*, recovery is not likely to be achieved for at least 50 years and will require managing habitat, host plants, and predators throughout the species' range. The estimated time to recovery this species includes monitoring periods of at least 5 years for downlisting and at least 10 years for delisting that show populations are stable to increasing. Recovery of the picture-wing fly is not likely to be achieved before 2072.

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APPENDIX

Appendix. Associated Species Reports and Habitat Status Assessment(s), by Species.

Species	Species Report	Habitat Status Assessment(s)
<u>PLANTS</u>		
<i>Bidens hillebrandiana</i> ssp. <i>hillebrandiana</i>	USFWS 2021a	Kim et al. 2020
<i>Bidens micrantha</i> ssp. <i>ctenophylla</i>	USFWS 2021b	Pe‘a et al. 2020; Javar-Salas et al. 2020; Phillipson et al. 2020
<i>Cyanea marksii</i>	USFWS 2021c	Clark et al. 2020
<i>Cyanea tritomantha</i>	USFWS 2021d	Clark et al. 2020; Nelson et al. 2020
<i>Cyrtandra nanawaleensis</i>	USFWS 2021e	Lowe et al. 2020; Ball et al. 2020; Clark et al. 2020
<i>Cyrtandra wagneri</i>	USFWS 2021f	Clark et al. 2020
<i>Melicope remyi</i>	USFWS 2021h	Clark et al. 2020
<i>Phyllostegia floribunda</i>	USFWS 2021i	Lowe et al. 2020; Ball et al. 2020; Clark et al. 2020; Nelson et al. 2020
<i>Pittosporum hawaiiense</i>	USFWS 2021j	Javar-Salas et al. 2020; Lowe et al. 2020; Clark et al. 2020
<i>Pritchardia lanigera</i>	USFWS 2021k	Ball et al. 2020; Clark et al. 2020; Nelson et al. 2020
<i>Schiedea diffusa</i> ssp. <i>macraei</i>	USFWS 2021l	Clark et al. 2020
<i>Schiedea hawaiiensis</i>	USFWS 2021m	Javar-Salas et al. 2020
<i>Stenogyne cranwelliae</i>	USFWS 2021n	Clark et al. 2020
<u>INVERTEBRATES</u>		
<i>Drosophila digressa</i>	USFWS 2021g	Clark et al. 2020; Lowe et al. 2020
<i>Vetericaris chaceorum</i>	USFWS 2021o	Browning et al. 2020; Kim et al. 2020