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Records of the Hawaii Biological Survey for 2019. Edited by Neal L. Evenhuis. *Bishop Museum Occasional Papers* 129: 1–2 (2020)

Twenty-Five Years of the *Records of the Hawaii Biological Survey*[1]

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In 1992, the State of Hawaii designated the Hawaii Biological Survey (HBS) as a program of the Bishop Museum. The Survey is an ongoing natural history inventory of the Hawaiian Archipelago and was created to locate, identify, and evaluate all native and non-native species of flora and fauna within the state and maintain the reference collections of that flora and fauna for a wide range of uses. As the primary state repository for all specimens and objects, the Bishop Museum also maintains up-to-date databases of all groups of plants and animals that occur within the state boundaries. Additionally, as part of our effort in disseminating the latest information on updates to those databases, the Bishop Museum annually publishes the *Records of the Hawaii Biological Survey*.

In 1995, we published the first of these *Records* (for the year 1994) in two volumes (Articles and Notes). Those first *Records* contained a total of 29 papers by 32 authors. Some 105 species of plants and animals were newly recorded for the State, including 3 new species-group taxa. The success of those first *Records* bade well for the ensuing years, in which numerous observations have been published by our many colleagues in Hawai'i, the nation, and worldwide.

Table . Twenty-five year summary of the *Records of the Hawaii Biological Survey*.

	animals			plants				
year	new state	new spp.	total	new state	naturalized	new spp.	total	grand total
1994	48	3	51	11	43		54	105
1995	15	2	17	12	4		16	33
1996	39	5	44	25	1		26	70
1997	81	2	83	46	5		51	134
1998	24		24	8	20		28	52
1999	44	1	45	4	8	1	13	58
2000	43		43	7	24		31	74
2001-2002	152	21	173	24	24		48	221
2003	14	1	15	53	23		76	91
2004-2005	22	4	26	6	40		46	72
2006	5	8	13	2	12		14	27
2007	1		1	8	21		29	30
2008	2		2	19	24		43	45
2009-2010	4	6	10	11	9		20	30
2011	5	5	10	18	92		110	120
2012	5	5	10	65	8		14	24
2013	15		15	2	12		14	29
2014	2	7	9	4	3		7	16
2015	1	1	2	4	9		13	15
2016	2		2					2
2017	3	3	6	1			1	7
2018	1	1	2	1	1		2	4
2019	2	3	5	12	13		25	30
25-year totals	530	78	608	343	396	1	681	1289
total non-native			530				680	1210

1. Contribution No. 2020-011 to the Hawaii Biological Survey.

During the last 25 years, some significant observations have been made (Table 1). Seventy-eight new species-group taxa have been discovered and described, including some surprising finds from well-travelled trails on O‘ahu, from ant-infested lowland areas, and from the Bishop Museum campus itself. There have been uplifting records of species thought to have been extinct or not seen for many years, but sadly also records of species thought be not be extant any longer. Although most records deal with new additions to the Hawaiian biota, here have also been corrections to our inventory and deletions of species thought to be here but were misidentified.

In its creation by the Hawaii State legislature, the Hawaii Biological Survey was tasked with undertaking a complete inventory of Hawaii’s biota. As a result, a number of papers have been published giving summary accountings by taxonomic group including an initial count (21,383 total species; 8,759 endemic in 1995), subsequent periodic updates and, in 2003, a detailed assessment of the numbers of species for every taxon in the State of Hawaii (25,615 total species; 9,975 endemic). At latest count (2015) we have a total of 26,608 species occurring in the State of Hawaii. Although some other state surveys in the nation are much older, we are still the only state in the country with an accurate accounting of every plant and animal (native and alien) within its borders.

As we celebrate 25 years of the *Records of the Hawaii Biological Survey*, we take this opportunity to thank the many who have helped us in this endeavor. There is still much to be done and we welcome the assistance of our colleagues in our ongoing process of taking stock of what living things we have surrounding us every day in these Hawaiian Islands.

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Everyone loves a cercus: the endemic Hawaiian genus *Uropachys* Parent (Diptera: Dolichopodidae), with descriptions of new species[1]

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Abstract. The endemic Hawaiian dolichopodid genus *Uropachys* Parent, endemic to the island of Kaua'i. is reviewed. Three new species, *Uropachys fleacercus* **n**. **sp**., *U. mediacercus*, **n**. **sp**., and *U. politicocercus*, **n**. **sp**., are described and illustrated. A key to species in the genus is given and previously described species are redescribed and the cercus of the male genitalia redrawn to correct errors and inconsistencies in previously published illustrations. Based on examination of the type series of *Uropachys pulvereus* (Hardy & Kohn) it is returned to *Eurynogaster* Van Duzee as *Eurynogaster pulverea* Hardy & Kohn, **stat**. **rev**.

Keywords: Diptera, Dolichopodidae, *Campsicnemus*, taxonomy, Hawaiian Islands, Kauai.

INTRODUCTION

Parent (1934) proposed the new genus *Pachyurus* based on a single species from Kaua'i, *P. hawaiensis* Parent, 1934. Realizing his genus was preoccupied by *Pachyurus* Agassiz, 1831, Parent (1935) proposed the new replacement name *Uropachys*. Hardy & Kohn (1964) synonymized *Uropachys* under a broad definition of *Eurynogaster* Van Duzee. This synonymy was maintained until Evenhuis (2005) re-examined the species in *Eurynogaster* and assigned various species to previously described genera and new genera. In that work, *Uropachys* was resurrected from synonymy. *Uropachys* is a monophyletic genus found only on the island of Kaua'i and is sister to another endemic Kaua'i genus *Arciellia* Evenhuis (cf. fig. 1 in Goodman *et al*. 2016). Previously, seven species were listed in *Uropachys*. This review describes and illustrates three new species, *Uropachys fleacircus* Evenhuis, **n**. **sp**., *U. mediacercus* Evenhuis, **n**. **sp**., and *U. politicocercus* Evenhuis **n**. **sp**., the suffix of the names deriving from the species-specific male cercus, which has diagnostic shape and setation. A key is given to the species of *Uropachys* and, based on study of the type series, *U. pulverea* Hardy & Kohn is transferred back to *Eurynogaster*, **stat**. **rev**.

MATERIAL AND METHODS

Material examined in this study derives from the following collections: BMNH = the Natural History Museum, London, UK; BPBM = Bernice Pauahi Bishop Museum, Honolulu, Hawai'i, USA; CNC = Canadian National Collection, Ottawa, Ontario, Canada; UHIM = University of Hawai'i Insect Museum, Honolulu, Hawai'i, USA.

1. Contribution No. 2019-010 to the Hawaii Biological Survey.

Confocal images of various morphological structures were accomplished by using a Leica M165C stereo dissecting scope via the Leica Microsystems LAS Multifocus software (v. 4.12.0) and using Zerene Stacker® software (v. 1.04) (Zerene Systems, LLC, Richmond, Washington, USA) to align and stack-focus each final image.

Morphological terminology follows Cumming & Wood (2017). Abbreviations used in text: I, II, and II = fore, mid, and hind legs, respectively (used in combination with abbreviations for coxa, femur, tibia, and tarsi); ac = acrostichal setae; C = coxa; dc = dorsocentral setae; F = femur; np = notopleural setae; oc = ocellar setae; pa = postalar setae; ph = posthumeral setae; sa = supraalar setae; sc = scutellar setae; Ti = tibia; t = tarsi; vt = vertical setae; WIP = Wing Interference Pattern.

TAXONOMY

Genus *Uropachys* Parent

Pachyurus Parent, 1934: 305. Type species: *Pachyurus hawaiensis* Parent, 1934, by monotypy. [Preoccupied by *Pachyurus* Agassiz, 1831.]

Uropachys Parent, 1935: 80 (new replacement name for *Pachyurus* Parent, 1934). Type species: *Pachyurus hawaiensis* Parent, 1934, automatic. Evenhuis, 2005: 56, 2009: 50; Zhang & Yang, 2011: 60. Bennett, 2012: 277; Grichanov, 2014: 20; Chursina *et al.,* 2016: 507; Goodman *et al.* 2016: 4.

Uropacys: Tenorio, 1969: 40 (incorrect subsequent spelling of *Uropachys*).

Van Duzee (1933) described the genus *Eurynogaster* to include three new species, all from the Hawaiian Islands. In the same paper, Van Duzee also proposed the genus *Sweziella*, for the single new Hawaiian species, *Sweziella albifacies* Van Duzee. He placed *Eurynogaster* in the Sympycninae and *Sweziella* in the Thinophilinae. The next year, Parent (1934) proposed the genus-group name *Pachyurus* Parent for the single species *Pachyurus hawaiensis*. He later (Parent, 1935) noted the generic name was preoccupied and proposed the replacement name *Uropachys* Parent. Subsequently, little study was undertaken on species in the genera *Eurynogaster*, *Sweziella*, and *Uropachys* until Hardy & Kohn (1964) and Tenorio (1969), in their respective works on the dolichopodids of Hawai‘i, treated *Sweziella* and *Uropachys* as junior synonyms under *Eurynogaster*. Hardy & Kohn described 32 new species of *Eurynogaster*, five of which were transferred to *Uropachys* in the study by Evenhuis (2005) who broke up the large genus *Eurynogaster* into seven genera (*Adachia* Evenhuis, *Arciellia* Evenhuis, *Elmoia* Evenhuis, *Eurynogaster*, *Major* Evenhuis, *Sweziella*, and *Uropachys*). A molecular study (Goodman *et al*. 2016) verified the monophyly of the genera proposed by Evenhuis (2005).

Uropachys is separated from related Hawaiian dolichopodid genera based on the characteristic prominent male cercus and large male hypopygium. The cercus is useful as a primary diagnostic character in separating species in the genus and the names for new species in this paper are proposed by adding prefixes to the suffix -*cercus* in keeping with other species in the genus so named [e.g., *U. crassicercus* (Hardy & Kohn), *U. fusticercus* (Hardy & Kohn)].

Included species: *Uropachys clavastyla* Hardy & Kohn, *U. crassicercus* Hardy & Kohn, *U. flavicrura* Hardy & Kohn, *U. fleacercus* Evenhuis, **n**. **sp**., *U. fusticercus* Hardy & Kohn, *U. hawaiensis* (Parent), *U. mediacercus* Evenhuis, **n**. **sp**., *U. palustricola* Hardy & Kohn, *U. politicocercus* Evenhuis, **n**. **sp**.

Diagnosis. *Uropachys* is easily separated from other genera of native Hawaiian Dolichopodidae by the absence of anterior preapical setae on all femora; the presence of 4 dc and absence of ac on the mesonotum; the hypopygium extremely large (larger than 1/2 length of abdomen); and cerci variably shaped, long (usually over three times width), sclerotized, possessing strong, modified bristles, especially at apex; aedeagal tip recurved, S-shaped in lateral view. As in *Sigmatineurum* Parent, what appears to be a long thin upper surstylar lobe is actually the apicoventral epandrial lobe.

Key to Species of *Uropachys* Parent Based on Males

1. Mid and hind femora predominantly all yellow except apices brown 2
–. At least mid (and often hind) femora brown to black on lateral surface, with metallic green highlights (seen best in dried specimens) 3

2. Fore coxa brown to black, gray pollinose (Fig. 3) ..... *flavicrurus* Hardy & Kohn
–. Fore coxa yellow (Fig. 4) ..... ***mediacercus*** Evenhuis, **n**. **sp**.

3. Femora and tibiae all brown to dark brown 4
–. Femora dark brown to black, tibiae contrastingly yellow 5

4. Halter knob yellow; cercus not extending to third abdominal segment 8
–. Halter knob dark brown; cercus elongate, extending at least to middle of third abdominal segment ..... *fusticercus* Hardy & Kohn

5. Wing uniformly smoky brown ..... ***politicocercus*** Evenhuis, **n**. **sp**.
–. Wing subhyaline 6

6 . Fore femur with basalmost two strong ventral bristles distinctly longer than remainder of stiff spines ..... *hawaiensis* Parent
–. Fore femora with strong ventral bristles short, all equal in length ....*clavastyla* Hardy & Kohn

7. Fore femur with strong ventral spines ..... *crassicercus* Hardy & Kohn
–. Fore femur without strong ventral spines or setae 8

8. Cercus extremely thin in lateral view, without pointed process basomedially (Fig. 8); mesonotum dark metallic green ..... ***fleacercus*** Evenhuis, **n**. **sp**.
–. Cercus much broader in lateral view, with small pointed process basomedially (Fig. 12); mesonotum pale brassy green ..... *palustricola* Hardy & Kohn

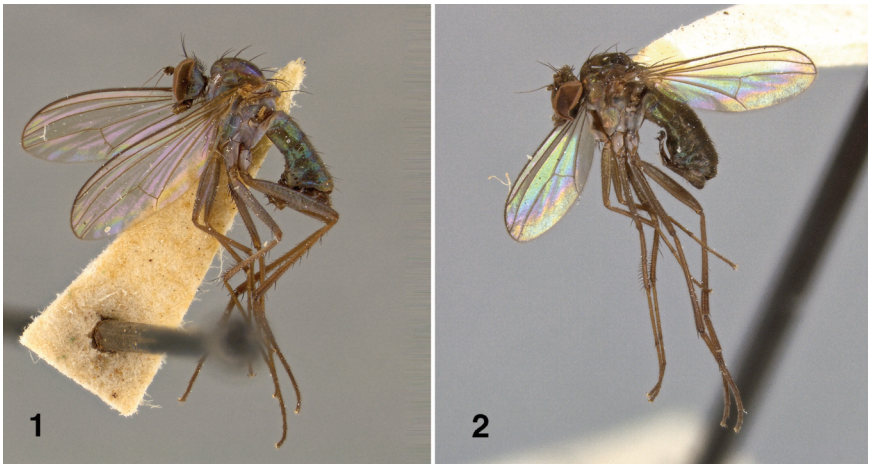
Uropachys clavastyla (Hardy & Kohn)
(Fig. 5)

Eurynogaster clavastyla Hardy & Kohn, 1964: 186. Tenorio, 1969: 41; Bickel & Dyte, 1989: 413; Nishida, 1992: 97, 1994: 91, 1997: 76, 2002: 94; Evenhuis & Thompson, 2004: 208; Anonymous, 2009: 87.

Uropachys clavastylus (Hardy & Kohn): Evenhuis, 2005: 57; Yang *et al.*, 2006: 519; Grichanov, 2014: 523, 2017: 538.

Uropachys clavastyla (Hardy & Kohn). Goodman *et al.* 2016: 3.

Diagnosis. Most similar to *U. hawaiensis*, but can be separated from it by the lack of two long strong basal ventral setae on the fore femur (present in *U. hawaiensis*).



Figures 1–2. *Uropachys* male habitus. **1**, *U. palustricola* (Hardy & Kohn); **2**. *U. fusticercus* (Hardy & Kohn).

Description. **Male**: Body length: 3.3 mm. Wing length: 3.5 mm.

Head. Frons gray pollinose with metallic green highlights; face and clypeus shining black; oc black, about two-thirds width of head; vertex black with green highlights; occiput gray pollinose; postgena with sparse short black hairs and green highlights; face slightly constricted below antennae, separated by width of five ommatidia; palpus small, brown; proboscis brown, extending below eye in lateral view; antenna with scape and pedicel dark brown; scape subcylindrical, length 1.5 × width; pedicel obconical, with ring of short spiky black setae subapically; postpedicel broken off and missing in holotype [noted in Hardy & Kohn, 1964: 186].

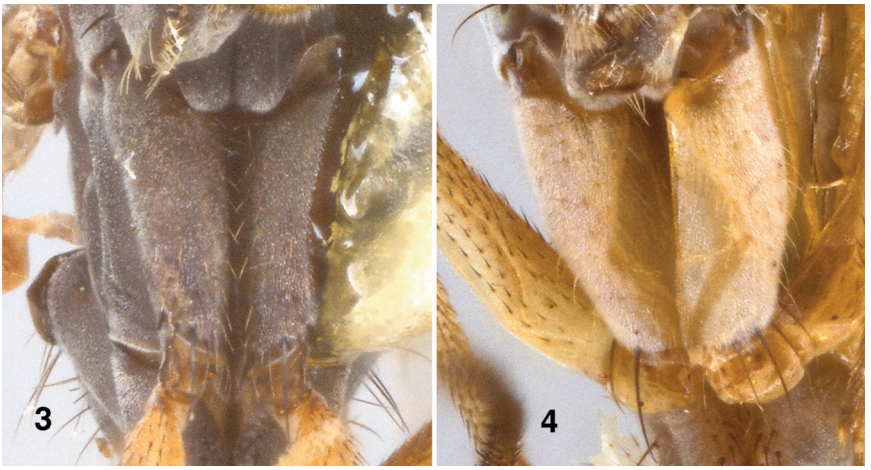
Thorax. Mesonotum brassy green and magenta on anterior half, dark metallic green on posterior half and scutellum; pleura gray pollinose except magenta anepisternum, and green katepisternum; thoracic setae black: 4 dc; 2 np; 2 ph; 1 pa; 1 sc; ac absent; halter stem and knob yellow.

Legs. Coxae brown, gray pollinose; femora metallic green, yellow ventrally; tibiae and tarsal segments 1–3 yellow, tarsal segments 4–5 brown; FI with row of 14–16 short, stiff spines ventrally; FII with two strong setae basoventrally, shorter, thinner stiff setae along entire venter; FIII with two rows of long fine hairs ventrally; fore and hind tibiae without MSSC; TiII with row of long stiff setae mesally; remaining leg segments without MSSC.

Wing (left wing broken off in holotype). Subhyaline, veins pale brownish; posterior crossvein length 1/4 apical segment of CuA_1.

Abdomen. Brassy green and dark metallic green; tergal vestiture sparse, black.

Genitalia. Hypopygium brown; cercus (Fig. 5) subrectangular, length ca. 3 × basal width, with broad flat apical peg (in lateral view) recurved apically (in dorsal view), with three extremely long, thick slightly wavy setae subapicoventrally, length ca. 2/3 length of cercus, with row of six long setae medioventrally, dense long fine hairs ventrobasally.



Figures 3–4. *Uropachys*, male fore coxa. **3**, *U. flavicrura* (Hardy & Kohn); **4**, *U. fleacercus* Evenhuis, n. sp.

Female: Unknown.

Material Examined. *Type*. HOLOTYPE ♂ (BPBM 4,160) from HAWAIIAN ISLANDS: **Kaua'i**: Mohihi Ridge, 15 Jul 1937, E.C. Zimmerman.

Remarks. The female listed under *clavastyla* in Hardy & Kohn (1964) could not be reliably associated with the male (the WIP is not the same pattern). It is placed here as *incertae sedis* in *Uropachys*. Also, the hypopygial drawing in Hardy & Kohn (1964: fig. 43b,c) is inaccurately drawn and wrongly depicts the apical peg and the lengths of the strong ventral setae.

Uropachys crassicercus (Hardy & Kohn)
(Fig. 6)

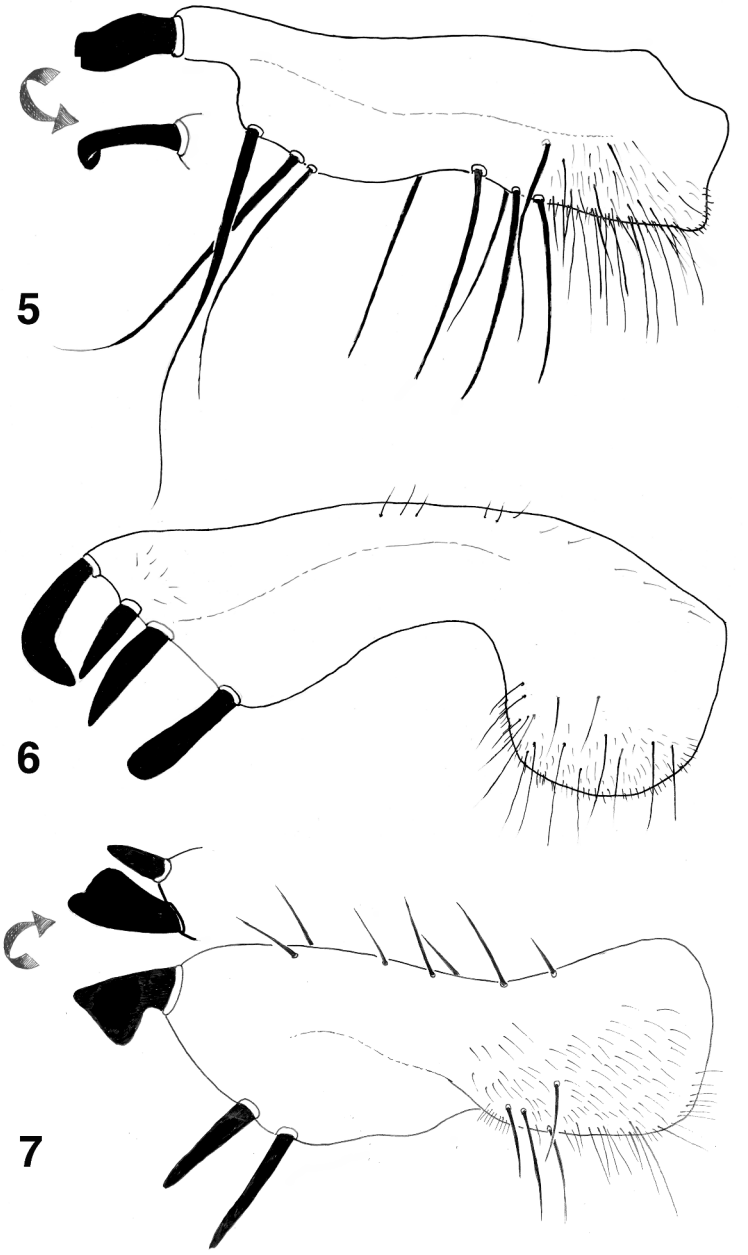
Eurynogaster crassicercus Hardy & Kohn, 1964: 190. Tenorio, 1969: 41; Bickel & Dyte, 1989: 415; Nishida, 1992: 97, 1994: 91, 1997: 77, 2002: 94; Evenhuis & Thompson, 2004: 208; Anonymous, 2009: 88.

Uropachys crassicercus (Hardy & Kohn): Evenhuis, 2005: 57; Yang *et al.*, 2006: 519; Grichanov, 2014: 523, 2017: 538.

Diagnosis. Easily separated from the congeners by the combination of brown tibiae, yellow halter knob and strong spines on the venter of the fore femora.

Description. **Male**: Body length: 3.6 mm. Wing length: 3.8 mm.

Head. Face, frons and clypeus black; vt black, slightly longer than antennal arista; occiput, and vertex black; postgena with sparse short black hairs and some green highlights; face constricted at middle, separated by width of four ommatidia; palpus small, black; proboscis brown, extending below eye in lateral view; antenna black; scape subcylindrical, length 1.5 × width; pedicel obconical, with ring of short spiky black setae subapically; postpedicel, subconical, length 1.5 × width, bluntly rounded apically; arista slightly longer than head height.



Figures 5–7. *Uropachys*, male cercus. **5**, *U. clavastyla* (Hardy & Kohn); **6**, *U. crassicercus* Hardy & Kohn; **7**, *U. flavicrura* (Hardy & Kohn).

Thorax. Mesonotum and scutellum black with dark green highlights; pleura dark gray pollinose except brassy anepisternum and katepisternum; thoracic setae black: 4 dc; 2 np; 2 ph; 1 pa; 1 sc; ac absent; halter stem and knob yellow.

Legs. CI and FI metallic green, CII and CIII brown, remainder of legs dark brown; FI with row of 8–10 short stiff spines ventrally; FII with dense cluster of 4–5 long, thick, stiff setae basoventrally; row of 12 very short spines on apicoventral half; FIII (broken off in holotype) without ventral setation; fore and mid legs without MSSC; TiII with two rows of stiff setae on apical 2/3; remaining leg segments unmodified and without MSSC.

Wing. Subhyaline, veins pale brownish; posterior crossvein length 1/4 apical segment of CuA_1.

Abdomen. Black with dark green highlights; tergal vestiture sparse, black.

Genitalia. Hypopygium brown; cercus (Fig. 6) fairly broad in lateral view with bulbous basal portion and broad apex, constricted medially and appearing curved, with thick strong apical peg slightly recurved apically, three subapical pegs roughly the same length, all straight to apex, two distalmost pointed apically, proximalmost rounded apically and flattened, dorsal edge with row of short hairs on basal half, sparse microsetae near apex, basal bulge without strong setae, but numerous long fine hairs and shorter microsetae.

Female: Unknown.

Material Examined. *Type*. HOLOTYPE ♂ (BPBM 4,162) from HAWAIIAN ISLANDS: **Kauaʻi**: Nualolo Valley, 3400 ft [ca. 1036 m], Jul 1952, D.E. Hardy. *Non-Types*: **Kauaʻi**: 1♂, Alakaʻi Swamp, Halepaʻakai Stream region, Pauiohi Field camp, 22.07999°N, 159.546896°W, 25 May 2005, R. Peck, Malaise #2.

Uropachys flavicrura (Hardy & Kohn)
(Figs. 3, 7)

Eurynogaster flavicrura Hardy & Kohn, 1964: 194. Tenorio, 1969: 41; Bickel & Dyte, 1989: 413; Nishida, 1992: 97, 1994: 91, 1997: 77, 2002: 94; Evenhuis & Thompson, 2004: 208; Anonymous, 2009: 88.

Uropachys flavicrura (Hardy & Kohn): Evenhuis, 2005: 57.

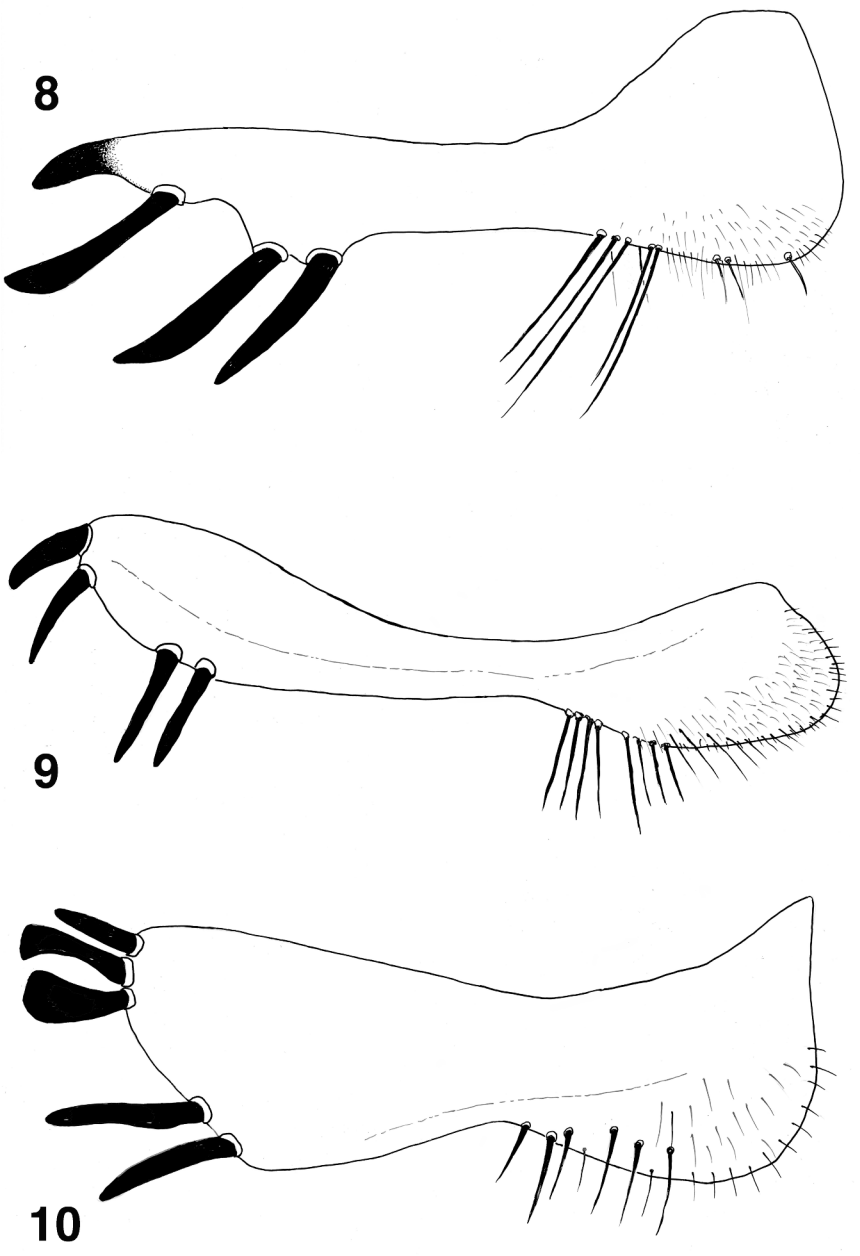
Uropachys flavicrurus (Hardy & Kohn): Yang *et al.*, 2006: 519; Grichanov, 2014: 523, 2017: 538; Chursina, 2016: 56.

Diagnosis. Similar to *U. mediacercus*, n. sp. by the predominantly yellow legs, but can be separated from it by the fore coxa with green highlights and all abdominal segments with green highlights (fore coxa and abdominal segments II and III yellow in *U. mediacercus*).

Description. **Male**: Body length: 4.0–4.2 mm. Wing length: 4.3–4.5 mm.

Head. Face, frons and clypeus black; vt black, slightly longer than antennal arista; occiput, and vertex black; postgena with sparse short black hairs and some green highlights; face constricted at middle, separated by width of four ommatidia; palpus small, black; proboscis brown, extending below eye in lateral view; antenna black; scape subcylindrical, length 1.5 × width; pedicel obconical, with ring of short spiky black setae subapically; postpedicel, subconical, length 1.5 × width, bluntly rounded apically; arista slightly longer than head height.

Thorax. Mesonotum and scutellum black with dark green highlights; pleura dark gray pollinose except brassy anepisternum and katepisternum; thoracic setae black: 4 dc; 2 np; 2 ph; 1 pa; 1 sc; ac absent; halter stem and knob yellow.



Figures 8–10. *Uropachys*, male cercus. **8**, *U. fleacercus* Evenhuis, n. sp.; **9**, *U. fusticercus* (Hardy & Kohn); **10**, *U. hawaiensis* (Parent).

Legs. CI (Fig. 3) brown with greenish highlights in some specimens, CII and CIII brown, remainder of legs yellowish with brown on dorsal surface of FI; FI with two rows of short stiff spines along entire venter; FII with dense cluster of 4–5 long, thick, black setae basoventrally, row of medium length stiff hairs from apical two-thirds to apex; FIII with row of six strong short setae on subapical one-third; TiII with stiff hairs along mesal surface, longest on apical two-thirds. Remaining leg segments unmodified and without MSSC.

Wing. Subhyaline, veins pale brownish; posterior crossvein length 1/4 apical segment of CuA_1.

Abdomen. Dark brown with green highlights; tergal vestiture sparse, black.

Genitalia. Hypopygium brown; cercus (Fig. 7) broadly subrectangular, length ca. 2.5 x basal width, two strong ventral spines subapically, apex with large spatulate peg in lateral view, obscuring smaller peg seen in dorsal view, dorsal edge with eight stiff setae, basoventral bulge with 4 strong setae and numerous fine hairs.

Female: Specimens identified as *U. flavicrura* by Hardy & Kohn cannot be reliably associated with this species as no characters have yet been found to separate females of *U. flavicrura* from other species in the genus except *U. mediacercus*, n. sp. See remarks below.

Material Examined. *Type*. HOLOTYPE ♂ (BPBM 4,165) from **Kaua‘i**: south Mohihi ridge, 15 Jul 1937, E.C. Zimmerman. *Paratypes*: **Kaua‘i**: 1♂, Koke‘e, 3,600 ft [ca. 1057 m], Jul 1952, D.E. Hardy (UH); 1♂, Alakai Swamp, 3,800 ft [ca. 1,158 m], Aug 1952, D.E. Hardy (UH).

Remarks. Hardy & Kohn (1964) listed ten paratypes (two males and eight females) of *U. flavicrura*. These specimens have been re-examined and those with a yellow fore coxa are transferred here as paratypes of *U. mediacercus*, n. sp. (*vide infra*). The remaining females may or may not belong to *U. flavicrura* and are left here as *incertae sedis* in *Uropachys*.

Uropachys fleacercus Evenhuis, **n**. **sp**.
(Fig. 8)

Diagnosis. Similar to *U. palustricola* in having brown tibiae, yellow halteres, and a lack of strong setae or spines ventrally on the fore femur. It can be separated from it by the male cercus having (1) a lack of a pointed process basodorsally (pointed process present in *U. palustricola*) and (2) the apical peg short and not curved (apical peg long and curved in *U. palustricola*).

Description. **Male**: Body length: 3.5 mm. Wing length: 3.8 mm.

Head. Face, frons and clypeus dark brown; vt black, about two-thirds length of antennal arista; occiput, and vertex black with dark green highlights; postgena with sparse short black hairs, dark green highlights; face constricted at middle, separated by width of three ommatidia; palpus small, black; proboscis brown, extending below eye in lateral view; antenna black; scape subcylindrical, length 1.5 × width; pedicel obconical, with ring of short spiky black setae subapically; postpedicel subconical, length 1.5 × width, rounded apically; arista slightly longer than head height.

Thorax. Mesonotum and scutellum black with dark green highlights; pleura dark brown except brassy anepisternum, brassy and purplish katepisternum; thoracic setae black: 4 dc; 2 np; 2 ph; 1 pa; 1 sc; ac absent; halter stem and knob yellow.

Legs. CI brown with green highlights, CII and CIII brown, FII dark brown remainder of legs brown; FII with dense cluster of 3 long, thick black setae basoventrally, medium length hairs ventrally with longest 5–6 at subapical third; TiII with stiff setae mesally, with longest 6–7 at apical fourth; remaining leg segments unmodified and without MSSC.

Wing. Subhyaline, veins pale brownish; posterior crossvein length 1/4 apical segment of CuA_1.

Abdomen. Brown with dark green and blue highlights; tergal vestiture sparse, black.

Genitalia. Hypopygium dark brown; cercus (Fig. 8) swollen basally, long, thin on apical 2/3, length ca. 3 × basal width, with short thick apical peg and three long thick pegs apicoventrally, five long stiff setae ventrally at basal one-third, shorter setae proximal to long setae, numerous fine hairs along edge and basoventrally.

Female: Unknown.

Material Examined. *Type*. HOLOTYPE ♂ (BPBM 17,998) and paratype ♂ from HAWAIIAN ISLANDS: **Kaua'i**: Alaka'i Swamp, Halepa'akai Stream region, Pauiohi Field camp, 22.07999°N, 159.546896°W, 25 May 2005, R. Peck, Malaise #2.

Uropachys fusticercus (Hardy & Kohn)
(Figs. 2, 9)

Eurynogaster fusticercus Hardy & Kohn, 1964: 197. Tenorio, 1969: 41; Nishida, 1992: 97, 1994: 91, 1997: 77, 2002: 94; Anonymous, 2009: 88.

Eurynogaster fusticerca: Bickel & Dyte, 1989: 415; Evenhuis & Thompson, 2004: 208.

Uropachys fusticercus (Hardy & Kohn): Evenhuis, 2005: 57; Yang *et al.*, 2006: 519; Evenhuis & O'Grady 2010: 37; Bennett *et al*. 2012: 276; Grichanov 2014: 523, 2017: 538; Goodman *et al*. 2016: 4.

Diagnosis. Easily separated from the congeners by the large cercus of the male genitalia, extending forward at least to the middle of the third abdominal segment (not extending as far forward in the congeners) and the dark brown halter knob (yellow to white in the congeners).

Description. **Male** (Fig. 2): Body length: 2.7–3.0 mm. Wing length: 2.5–2.8 mm.

Head. Face, front and clypeus dark brown; oc and vt black, about two-thirds length of antennal arista; occiput, and vertex black, the latter with bornze highlights; postgena with sparse short black hairs; face constricted at middle, separated by width of one ommatidium; palpus small, brown; proboscis brown, extending below eye in lateral view; antenna dark brown; scape subcylindrical, length 1.5 × width; pedicel obconical, with ring of short spiky black setae subapically; postpedicel subtriangular, length 2 x width, acute apically; arista slightly longer than head height.

Thorax. Mesonotum and scutellum subshining dark brown, with magenta, green, and bronze highlights; anepisternum and katepisternum as in mesonotum, remainder of pleura dull brown pollinose; thoracic setae black: 4 dc; 2 np; 2 ph; 1 pa; 1 sc; ac absent; halter stem pale brown, knob dark brown.

Legs. Coxae I as in anepisternum, CII–CIII dull brown, remainder of legs subshining brown; FI with greenish highlights; rest of fore legs and all of hind legs unmodified, without MSSC; FII with row of stiff black setae along entire ventral surface (MSSC); TiII slightly sinuous, medial surface with 10–12 stiff setae admixed with row or 8 shorter stiff setae (MSSC); Iit_1 subequal in length to TiII; remaining leg segments unmodified and without MSSC.

Wing. Subhyaline, veins pale brownish; posterior crossvein length 1/4 apical segment of CuA_1.

Abdomen. Subshining dark brown; tergites I–III with greenish highlights; tergites IV–VII with some magenta and greenish highlights; tergal vestiture sparse, black.

Genitalia. Hypopygium dark brown, large, extending forward almost to level of abdominal segment II; cercus (Fig. 9) very long, thin, length ca. 5.5 × basal width, constricted to thin strip medially, apex with two large thick pegs, distalmost the thickest, subapicoventrally with two strong thick peg-like setae, basal bulge with row of eight strong stiff setae ventrally, numerous fine hairs and microsetae basally.

Female: Specimens identified as *U. fusticercus* by Hardy & Kohn cannot be reliably associated with this species as no characters have yet been found to separate females of *U. flavicrura* from other species in the genus except *U. mediacercus*, n. sp. There are treated here as *incertae sedis* in *Uropachys* until reliable characters can be found to associate males and females.

Material Examined. HOLOTYPE ♂ (BPBM 4,168) from **Kaua'i**: Mt. Wai'ale'ale trail, 4,500 ft [ca. 1,370 m], Aug 1953, D.E. Hardy. *Non-Types*: **Kaua'i**: 2♂, Koke'e, Alaka'i Swamp Trail, 1228 m, 22°8.765'N, 159°39.016'W, 21 May 2007, G. Bennett (BPBM); 1♂, Alaka'i Swamp, Halepa'akai Stream region, Pauiohi Field camp, 22.07999°N, 159.546896°W, 25 May 2005, R. Peck, Malaise #1 (BPBM); 6m, Alaka'i Swamp, 29 Jul 1963, D.E. Hardy (UH); 8m, Mohihi Stream, 29 Jul 1963, D.E. Hardy (UH); 4m, Alaka'i Swamp, Aug 1953, D.E. Hardy (UH); 2m, Mt. Wai'aleale Trail, 4,500 ft [ca. 1,370 m], Aug 1953, D.E. Hardy (UH).

Uropachys hawaiensis (Parent)
(Fig. 10)

Gen. nov. et sp.: Grimshaw, 1901: 13. [The specimen referred to here was ultimately used as the type for *Pachyurus hawaiensis*.]

Pachyurus hawaiensis Parent, 1934: 305.

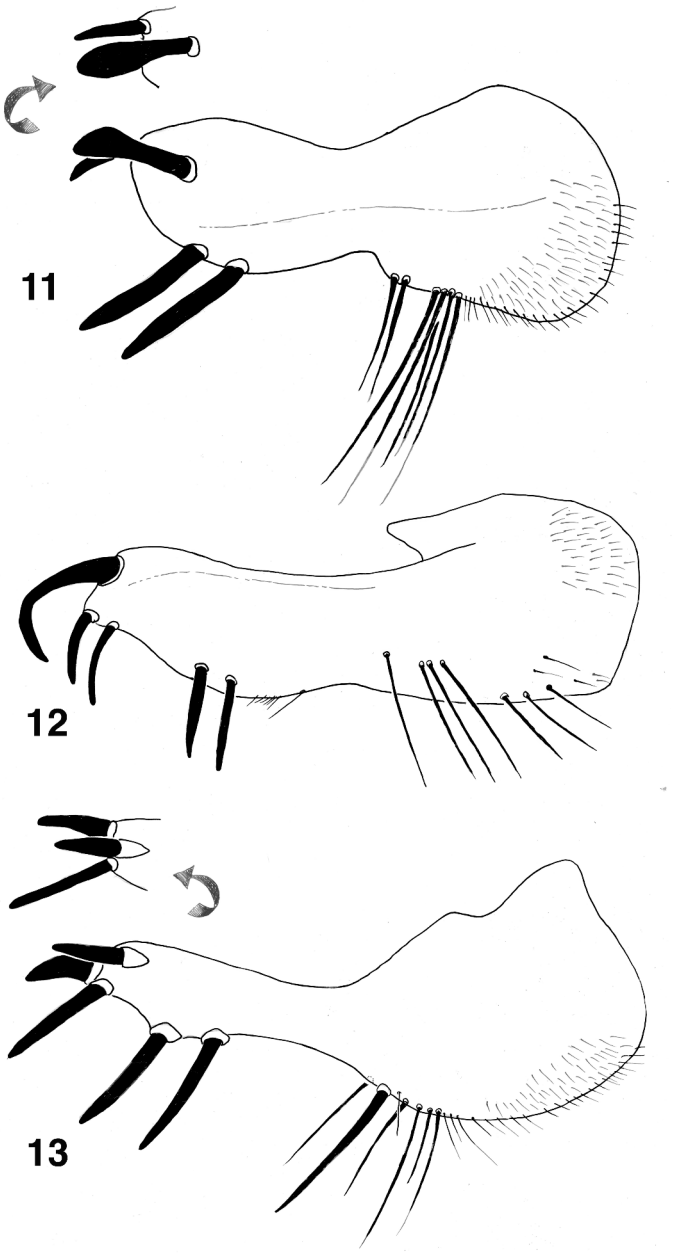
Uropachys hawaiensis (Parent). Parent, 1935: 80. Evenhuis, 2005: 57; Grichanov, 2014: 523, 2017: 538; Chursina *et al.,* 2016: 507.

Eurynogaster parenti Hardy & Kohn, 1964: 215 (new replacement name for *Pachyurus hawaiensis* Parent [at the time preoccupied by *Eurynogaster hawaiiensis* (Grimshaw, 1901)]. Tenorio, 1969: 41; Bickel & Dyte, 1989: 414; Nishida, 1992: 97, 1994: 91, 1997: 77; 2002: 94; Anonymous, 2009: 88.

Diagnosis. Most similar to *U. clavastyla* Hardy & Kohn by the possession of a brown hind basitarsus, but can be easily separated from it by the presence of the two basalmost bristles on the venter of the fore femur twice as long as the remainder (all ventral bristles the same length in *U. clavastyla*).

Description (from homotype male in UHIM). **Male**: Body length: 3.5 mm. Wing length: 4.0 mm.

Head. Face, front and clypeus black, with greenish highlights; oc and vt black, about two-thirds length of antennal arista; occiput, and vertex black, occiput gray pollinose along lateral eye margin; postgena with sparse short black hairs; face constricted at middle, separated by width of three ommatidia; palpus small, brown; proboscis brown, extending below eye in lateral view; antenna brown; scape subcylindrical, length 1.5 × width; pedicel obconical, with ring of short spiky black setae subapically; postpedicel



Figures 11–13. *Uropachys*, male cercus. **11**, *U. mediacercus* Evenhuis, n. sp.; **12**, *U. palustricola* (Hardy & Kohn); **13**, *U. politicocercus* Evenhuis, n. sp.

short, subtriangular, length ca. 0.5 × width, rounded apically; arista slightly longer than head height.

Thorax. Mesonotum subshining dark brown, with greenish highlights anteriorly; scutellum dark brown; anepisternum and katepisternum as in mesonotum, remainder of pleura dull brown pollinose; thoracic setae black: 4 dc; 2 np; 2 ph; 1 pa; 1 sc; ac absent; halter stem and knob yellow.

Legs. Predominantly brown, with hind femur and tibia yellowish on medial surface; FI with strong spines basally, basalmost 2 twice as long as remainder, otherwise fore and hind legs unmodified and without MSSC; FII with 2 long stiff black setae basally on ventral surface (MSSC); TiII with row of 9 stiff setae on medial surface (MSSC); IIt_1 2/3 length of tibia. Remaining leg segments unmodified and without MSSC.

Wing. Subhyaline, veins pale brownish; posterior crossvein length 1/4 apical segment of CuA_1.

Abdomen. Brown with greenish and bronze highlights dorsally; tergal vestiture sparse, black.

Genitalia. Hypopygium brown; cercus (Fig. 10) broad basally and apically, constricted medially, length ca. 3 x basal width, apex with cluster of three long pegs: dorsalmost acutely rounded apically, subdorsal peg flattened and slightly flared apically, lowermost flattened and broadly flared apically, apicoventral corner of cercus with two strong pegs, slightly longer than apical pegs, basal bulge with row of six strong spine-like hairs ventrally, numerous shorter, finer hairs basoventrally.

Female: Unknown.

Material Examined. *Non-Types*: **Kaua'i**: Kaunuohua Ridge, 21 Jul 1937, E.C. Zimmerman (UH).

Uropachys mediacercus Evenhuis, **n**. **sp**.
(Figs. 4, 11)

Diagnosis. Easily separated from the congeners by the yellow fore coxa (fore coxa brown with green highlights in the congeners).

Description. **Male**: Body length: 2.8–3.1 mm. Wing length: 2.8–3.2 mm.

Head. Face, front and clypeus black; oc and vt black, about two-thirds length of antennal arista; occiput, and vertex black with purple highlights; postgena with sparse short black hairs; face constricted at middle, separated by width of three ommatidia; palpus small, brown; proboscis brown, extending below eye in lateral view; antenna with scape and pedicel yellowish brown; scape subcylindrical, length 1.5 × width; pedicel obconical, with ring of short spiky black setae subapically; postpedicel short, yellow with brown border, subspherical, length ca. 0.5 × width, blunt apically; arista slightly longer than head height.

Thorax. Uniformly brown; thoracic setae black: 4 dc; 2 np; 2 ph; 1 pa; 1 sc; ac absent; halter stem and knob white.

Legs. Coxae with CI yellow to yellowish white (Fig. 4), CII–CIII brown, remainder of legs yellowish white; fore and hind legs unmodified and without MSSC; FII with 3–4 long stiff black setae basoventrally, shorter setae elsewhere along medial portion of ventral surface (MSSC); IIt_1 2/3 length of tibia. Remaining leg segments unmodified and without MSSC.

Wing. Subhyaline, veins pale brownish; posterior crossvein length 1/4 apical segment of CuA_1.

Abdomen. Brown except yellow laterally on segments II–III, yellow color extending to sternites IIIII; tergal vestiture sparse, black.

Genitalia. Hypopygium brown; cercus (Fig. 11) broad basally, rounded apically, constricted medially, with two pegs apically, one normally shaped, the other spatulate apically, apicoventral corner of cercus with two long pegs, longer than apical pegs, basal bulge with row of six long stiff hairs ventrally, numerous microsetae basally.

Female: As in male except as follows: face wider, gray pollinose, not appreciably constricted medially; scutellum with brassy highlights; legs without MSSC; abdomen all brassy green.

Material Examined. *Type*. HOLOTYPE ♂ (BPBM 17,999) from HAWAIIAN ISLANDS: **Kaua'i**: Koke'e, Awe'awe'puhi trail, 21 May 2007, on *Charpenteria*, G. Bennett (BPBM); 1♂, Koke'e, Alaka'i Swamp Trail, 1228 m, 22°8.765'N, 159°39.016'W, 21 May 2007, G. Bennett (BPBM). *Paratypes*: **Kaua'i**: 1♀, s. Mohihi ridge, 8 Jul 1937, E.C. Zimmerman (BPBM), 2♂, s. Mohihi ridge, 15 Jul 1937, E.C. Zimmerman (UH); 2♀, Koke'e, 3,600 ft [ca. 1,057 m], Jul 1952, D.E. Hardy (UH); 2♀, Alaka'i Swamp, 10 Jul 1928, E.H. Bryan (UH).

Remarks. The type series of *U. mediacercus*, n. sp. includes some female paratypes of specimens originally identified as *U. flavicrura* Hardy & Kohn and *U. palustricola* Hardy & Kohn that have yellow fore coxae.

Uropachys palustricola (Hardy & Kohn)
(Figs. 1, 12)

Eurynogaster palustricola Hardy & Kohn, 1964: 214. Tenorio, 1969: 41; Bickel & Dyte, 1989: 414; Nishida, 1992: 97, 1994: 91, 1997: 77, 2002: 94; Evenhuis & Thompson, 2004: 209; Anonymous, 2009: 88.

Uropachys palustricola (Hardy & Kohn): Evenhuis, 2005: 57; Yang *et al.*, 2006: 519; Grichanov, 2014: 523, 2017: 538; Goodman *et al.* 2016: 3.

Diagnosis. Easily separated from the congeners by the cercus bearing a pointed process dorsobasally.

Description. **Male** (Fig. 1): Body length: 3.2–3.5 mm. Wing length: 3.3–3.9 mm.

Head. Face and clypeus silvery pollinose, front black; oc and vt black, about two-thirds length of antennal arista; occiput and vertex black; postgena with sparse short black hairs; face constricted, separated by width of two ommatidia; palpus small, dark brown; proboscis dark brown, extending below eye in lateral view; antenna dark brown; scape subcylindrical, length 1.5 × width; pedicel obconical, with ring of short spiky black setae subapically; postpedicel, conical, length subequal to width, blunt apically; arista slightly longer than head height.

Thorax. Mesonotum and scutellum dark brown with greenish highlights dorsally, magenta highlights and humeral corners; pleura dull black except subshining anepisternum and katepisternum with greenish highlights; thoracic setae black: 4 dc; 2 np; 2 ph; 1 pa; 1 sc; ac absent; halter stem and knob white.

Legs. Legs brown, CI with bluish and greenish highlights; FI and FII with greenish

highlights, otherwise fore and hind legs unmodified and without MSSC; FII with patch of 4 long stiff black setae basoventrally, short, stiff setae elsewhere along medial portion of ventral surface (MSSC); TiII (Fig. 1) with medial surface with row of 9 long thin setae and row of 8 shorter spiny setae (MSSC); IIt_1 subequal to length of tibia. Remaining leg segments unmodified and without MSSC.

Wing. Subhyaline, veins dark brown; posterior crossvein length 1/4 apical segment of CuA_1.

Abdomen. Brown , tergite I with brassy highlights, II–VII with greenish highlights; tergal vestiture sparse, black.

Genitalia. Hypopygium dark brown; cercus (Fig. 12) broad basally with thinner apical two-thirds to rounded apex, basal bulge with distinctive pointed dorsal process, apex with set of three strong downward curved pegs, uppermost curved more than other two, apicoventral corner with two strong pegs subequal in length to lowermost apical pegs and with small patch of short fine hairs proximally, basal bulge with row of six long stiff hairs, numerous microsetae basally.

Female: Unknown. The single female paratype tentatively identified as *U. palustricola* by Hardy & Kohn (1964) has all yellow legs and thus belongs to *U. mediacercus*, n. sp. to which it has been transferred.

Material Examined. *Types*. Holotype ♂ (BPBM 4178) from **Kaua'i**: Alaka'i Swamp, 10 Jul 1928, E.H. Bryan, Jr. Paratype ♂, same data (UH). *Non-Types*: **Kaua'i**: 5♂, Koke'e, Kalalau to Alaka'i, 9 Apr 1963, J.L. Gressitt (BPBM); 3♂, Alaka'i Swamp @ Pihea, 4,000 ft [ca. 1,220 m], 30 Jun 1985, R. Hurley (BPBM); 5♂, Koke'e, Pihea, Kaunuohua Ridge, 4,260 ft [ca. 1,298 m], 23 May 1979, D.E. Hardy (UH); 1♂, Alaka'i Swamp, 3,800 ft [ca. 1,000 m], 28 Jul 1963, D.E. Hardy (UH); 1♂, Alaka'i Swamp, 4,000 ft [ca. 1,220 m], 22 May 1966, K.Y. Kaneshiro (UH); 1♂, Pihea, 2,260 ft [ca. 689 m], 30 Jul 1964, D.E. Hardy (UH).

Uropachys politicocercus Evenhuis, **n. sp.**
(Fig. 13)

Diagnosis. Easily separated from the congeners by the smoky brown wings (subhyaline in the congeners); the cercus is similar in shape to *U. fleacercus*, n. sp. but can be separated from it by the three apical pegs set closely together (two apical pegs in *U. fleacercus*).

Description. **Male**: Body length: 4.8 mm. Wing length: 4.5 mm.

Head. Face and clypeus silvery pollinose, front black; oc and vt black, about two-thirds length of antennal arista; occiput, and vertex black; postgena with sparse short black hairs; face slightly constricted at middle, separated by width of 4 ommatidia; palpus small, dark brown; proboscis dark brown, extending below eye in lateral view; antenna dark brown; scape subcylindrical, length 1.5 × width; pedicel obconical, with ring of short spiky black setae subapically; postpedicel subconical, length ca. 0.75 × width, acute apically; arista slightly longer than head height.

Thorax. Mesonotum and scutellum brown; pleura dull dark brown except anepisternum and katepisternum subshining dark brown with magenta highlights; thoracic setae black: 4 dc; 2 np; 2 ph; 1 pa; 1 sc; ac absent; halter stem and knob white.

Legs. Coxae and femora brown, remainder of legs yellowish; fore legs unmodified and without MSSC; FII with 2–3 long stiff black setae basoventrally, shorter setae in row along medial portion of ventral surface (MSSC); TiII bent slightly beyond middle, entire medial surface with row of short black setae, patch of longer spiny setae on apical one-third (MSSC); IIt_1 slightly short than tibia; remaining leg segments unmodified and without MSSC.

Wing. Uniformly smoky brown, veins brown; posterior crossvein length 1/4 apical segment of CuA_1.

Abdomen. Brown, subshining brassy dorsally, fading to pale brassy laterally on tergites II–III; tergal vestiture sparse, black.

Genitalia. Hypopygium brown; cercus (Fig. 13) similar in shape to *U. fleacercus* with large basal bulge and tapering to long thin apical portion, apex with cluster of three thick pegs, lowermost ca. 1.5 × length of upper two, apicoventral corner of cercus with two log thick pegs, subequal in length to lowermost apical peg, basal bulge with row of five stiff hairs and one thick stiff hair ventrally, numerous shorter fine hairs ventrally and microsetae basally.

Female: Unknown.

Material Examined. *Type* (in fluid; taken out to dry to observe pollinosity for description and then immediately placed back in fluid). HOLOTYPE ♂ (BPBM 18,000) from HAWAIIAN ISLANDS: **Kaua‘i**: Alaka‘i Swamp, Halepa‘akai Stream region, Pauiohi Field camp, 22.07999°N, 159.546896°W, 25 May 2005, R. Peck, Malaise #2.

Species removed from *Uropachys* Parent

Eurynogaster pulverea Hardy & Kohn, **stat**. **rev**.

Eurynogaster pulverea Hardy & Kohn, 1964: 216. Tenorio, 1969: 41; Bickel & Dyte, 1989: 414; Nishida, 1992: 97, 1994: 91, 1997: 77, 2002: 94; Evenhuis & Thompson, 2004: 209; Anonymous, 2009: 88.
Uropachys pulverea (Hardy & Kohn): Evenhuis, 2005: 57.
Uropachys pulvereus (Hardy & Kohn): Yang *et al.*, 2006: 520; Grichanov, 2014: 523, 2017: 538.

Re-examination of the type series of *Eurynogaster pulverea* Hardy & Kohn shows it to not belong to *Uropachys* but is a typical *Eurynogaster*. The male genitalia are concealed and previous examination mis-interpreted the shape and size of the cercus. It is actually short, squarish (not elongate) and possesses a patch of apical hairs. The species is only known from the holotype male, hence, the genitalia have not been dissected and further information of the genitalic structures could not be ascertained.

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New Hawaiian plant records from Lāna‘i for 2019

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Since the mandatory cutoff for incorporation of new information and inclusion in the landmark *Manual of the Flowering Plants of Hawai‘i* in 1987, and its subsequent publication in 1990, there has been intensive field work and collection effort throughout the Hawaiian Islands. However, new naturalized taxa continue to be found, as well as new distributional records of plants established on other neighbor islands, including native species. In this paper we document and share this information with the broader botanical and conservation community. We discuss 14 taxa in 13 families. All are non-native.

Information regarding the formerly known distribution of flowering plants is based on the *Manual of the Flowering Plants of Hawai‘i* (Wagner *et al*. 1990) and information subsequently published in the *Records of the Hawaii Biological Survey*.

All voucher specimens are deposited at B.P. Bishop Museum *Herbarium Pacificum* (BISH), Honolulu, with a duplicate deposited at the National Tropical Botanical Garden (PTBG), Lāwa‘i, Kaua‘i, unless otherwise indicated. In the latter case, the herbarium acronym is cited following the voucher data.

Apocynaceae

Stapelia gigantea N.E. Br. **New island record**

Previously documented from O‘ahu, Moloka‘i, both East and West Maui, Kaho‘olawe, and Hawai‘i (Wagner *et al*. 1999: 241; Oppenheimer *et al*. 1999: 7; Wysong *et al*. 2007: 2; Oppenheimer 2010: 33; Parker & Parsons 2012: 57; Starr & Starr 2017: 3), this succulent species was found on Lāna‘i recently, where it was locally common. It was also observed in Lōpā Gulch on the east side of the island.

Material examined. **LĀNA‘I:** Ka‘a, near road to Ka‘ena, locally common succulent in dry area, 180 m, 19 Apr 2018, *Oppenheimer & K. Bogner #H41807.*

Cactaceae

Cylindropuntia fulgida Engelm. **New naturalized record**

The jumping cholla or hanging chain cholla is native to Sonora, Mexico and the southwestern United States. This cactus seems to have escaped from a nearby residence, where several naturalized succulent species have originated. Sections of the rounded stem are easily detached and dispersed when the long spines come in contact with people or animals. Axis deer in the area are likely dispersal agents. Pūlama Lāna‘i has initiated control efforts.

Material examined. **LĀNA‘I:** Kaumalapau, on roadcuts and cliffs, 18 m, 24 Oct 1999, *Oppenheimer H109918* (BISH); *loc. cit.,* 1 Mar 2010, *Duvall & Costales s.n.* (BISH).

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Convolvulaceae

Ipomoea ochracea (Lindl.) G. Don **New island record**

This morning glory has been documented from Kauaʻi, Oʻahu, Maui, and Hawaiʻi (Wagner *et al.* 1999: 559). It was recently collected on Lānaʻi.

Material examined. **LĀNAʻI:** vicinity of Lānaʻi Airport, 380 m, naturalized vines growing in waste area on *Lantana camara* and *Urochloa maxima*, 14 Mar 2019, *Oppenheimer, K. Bogner & K. Bustamente #H31918.*

Cyperaceae

Cyperus fulvus R. Br. **New state record**

This species, known as sticky sedge, is native to New Guinea and northern and eastern Australia. It has not been previously recorded in Hawaiʻi. Over 100 plants were found scattered across several sites in degraded *Dodonaea* Lowland Dry Shrubland, and with more search effort additional plants probably could be found.

Material examined. **LĀNAʻI:** Kaʻa, vicinity of Kapukaloa, 530 m, 11 Oct 2018, *Oppenheimer, K. Bogner, & M. Kier #H101808* (BISH, US).

Cyperus meyenianus Kunth **New island record**

[Syn. *Mariscus meyenianus* (Kunth) Nees]

Previously documented as a naturalized species on Kauaʻi, Oʻahu, Molokaʻi, Maui, and Hawaiʻi (Wagner *et al.* 1999: 1420; Hughes 1995: 4; Oppenheimer 2003: 10; Oppenheimer 2006: 12), this plant was recently found on Lānaʻi, where it grew with *C. fulvus* R. Br. (see above discussion). How two weedy Cyperaceae taxa came to be growing together in the same area on a new island is of some interest regarding dispersal and pathways.

Material examined. **LĀNAʻI:** Kaʻa, vicinity of Kapukaloa, 540 m, 11 Oct 2018, *Oppenheimer, M. Kier, & K. Bogner #H101809* (BISH, US).

Euphorbiaceae

Euphorbia antiquorum L. **New naturalized record**

Native to India, where it grows in dry scrub habitats (Staples & Herbst 2005: 285), this erect cactus-like species known as Malayan spurge tree, is similar to *E. lactea* Haw. but differs in the lack of mottled white patches on the flat sides of the 3-angled branches. Like *E. lactea,* it also seems to be able to spread and reproduce vegetatively (Frohlich & Lau 2012: 35) and appears to have escaped from a nearby residence, where several other succulents have originated.

Material examined. **LĀNAʻI:** Kaumalapau, 1 Mar 2010, *Duvall & Costales s.n.* (BISH).

Orchidaceae

Arundina graminifolia (D. Don) Hochr. **New island record**

Documented from Kauaʻi, Oʻahu, East and West Maui, and Hawaiʻi (Wagner *et al*. 1999: 1471; Oppenheimer & Bartlett 2000: 7), this orchid was recently found on Lānaʻi growing along an unpaved road. Only a single large clump was observed and removed, and no plants have been subsequently found.

Material examined. **LĀNAʻI:** Munro Trail, 1000 m, 28 Sep 2016, *Oppenheimer & M. Padgett #H91644* (BISH).

Papaveraceae

Argemone mexicana L. **New island record**

Naturalized on Kauaʻi, Oʻahu, Molokaʻi, and Maui (Wagner *et al*. 1999: 1005; Wysong *et al.* 2007: 6), Mexican poppy was recently found on Lānaʻi. All plants were removed by Pūlama Lānaʻi staff at Nininiwai Hill and the site is being monitored for recruitment and continued control. Single immature plants have also been found and removed near Naio Gulch, in Kuahua Gulch, and along Polihua Road. The Keōmuku Road site has several hundred plants, mostly immature, and control efforts are being evaluated.

Material examined. **LĀNAʻI:** mauka of Lānaʻi City, near Kaiholena and Iwiʻole Gulches, north of Nininiwai Hill, naturalized at edge of waste area with other weeds from discarded yard clippings, 545 m, 18 Jun 2018, *K. Bogner KKB0021*; Keōmuku Rd., north of ʻĀwehi Rd., sandy soil along unpaved roadside, 5 m, 3 Apr 2019, *Oppenheimer & K. Bogner #H41901* (BISH).

Poaceae

Urochloa distachya (L.) T.Q. Nguyen **New island record**

Tropical signalgrass is known to be naturalized on Kauaʻi, Oʻahu, Maui, and possibly Molokaʻi (Wagner *et al.* 1999: 1503; Lorence *et al.* 1995: 44; Frohlich & Lau 2014: 13). It has been known as both *Brachiaria distachya* (L.) Stapf and *B. subquadriparia* (Trin.) Hitchc.

Material examined. **LĀNAʻI:** Mānele, 10 m, 12 Dec 2008 *Oppenheimer #H120825*.

Pontederiaceae

Eichhornia crassipes (Mart.) Solms **New island record**

Introduced as an ornamental, water hyacinth has been known in Hawai`i from the islands of Kauaʻi, Oʻahu, Maui, and Hawaiʻi, where it is naturalized and locally abundant in 9tanding or slow-moving water (Wagner *et al.* 1990: 1604–1606). On Lānaʻi this species covers at least 75% of an old water feature in a former golf course.

Material examined. **LĀNAʻI:** Kōʻele, west of Nininiwai Hill, 550 m, 27 Sep 2018, *Oppenheimer & K. Bogner #H91802*.

Solanaceae

Solanum torvum Sw. **New island record**

Known from Kauaʻi, Oʻahu, East and West Maui, and Hawaiʻi (Wagner *et al*. 1999: 1276; Oppenheimer *et al.* 1999: 10; Starr *et al*. 2003: 32; Frohlich & Lau 2012: 48), this thorny shrub or small tree was recently found in two locations on Lānaʻi, both sites adjacent to golf courses. Efforts to control or eradicate it have been initiated by Pūlama Lānaʻi staff.

Material examined. **LĀNAʻI:** mauka of Lānaʻi City, between Kaiholena and Kapano Gulches, vicinity of Nininiwai Hill, naturalized among new and old, neglected landscaping trees and weeds such as *Acacia confusa*, *Eucalyptus* sp., *Psidium cattleianum*, & *Schinus terebinthifolius*, 520 m, 27 Jun 2018, *Oppenheimer & K. Bogner #H61810*.

Verbenaceae

Stachytarpheta cayennensis (Rich.) Vahl **New island record**

[Syn.: *S. dichotoma* (Ruiz & Pav.) Vahl; *S. urticifolia* (Salisb.) Sims]

Naturalized on Kauaʻi, Oʻahu, Molokaʻi, Maui, and Hawaiʻi (Wagner *et al.* 1999: 1322; Herbst & Wagner 1999: 32; Staples & Herbst 2005: 555), this is a widespread species on Lānaʻi.

Material examined. **LĀNA‘I:** Kanepu‘u Preserve, ‘Ahakea Unit, in remnant dry forest, 520 m, 22 Jan 2015, *Oppenheimer #H11505*; Munro Trail, between Ha‘alelepa‘akai and Lāna‘ihale, 1000 m, 3 Jun 2015, *Oppenheimer #H61502.*

Zingiberaceae

Alpinia zerumbet (Pers.) B.L. Burtt & R.M. Sm. **New island record**

Shell ginger is a common ornamental and already reported as naturalized on Kaua‘i, O‘ahu, Moloka‘i, and Maui (Flynn & Lorence 2002: 16; Oppenheimer 2008: 35; Oppenheimer 2010: 38–39; Frohlich & Lau 2014: 15). On Lāna‘i scattered individuals were observed in shady understory of landscaping and neglected waste areas.

Material examined. **LĀNA‘I:** Kō‘ele, 500 m, 27 Sep 2018, *Oppenheimer & K. Bogner #H91803* (BISH).

ADVENTIVE SPECIES SHOWING SIGNS OF NATURALIZATION

Crassulaceae

Kalanchoe crenata (Andrews) Haw.

Widespread across tropical Africa to South Africa, where it is used medicinally, this succulent species with yellow flowers was observed outside its cultivated location under hedges in neglected areas. As with other Crassulaceae, it is called mother-of-millions as well as never-die, referring to the numerous bulbils on the leaves from which new plants arise. Subsequent observations show that plants persisted for several years but seem to have died out lately. It is apparently naturalized in Egypt, tropical America, India, and Malaysia (Hyde *et al*. 2018).

Material examined. **LĀNA‘I:** Lāna‘i City, 490 m, 11 Dec 2008, *Oppenheimer & S. Perlman #H120822*.

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New Plant Records from Maui Nui

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The following contributions include new plant records from the islands of Maui and Moloka'i. All records are for nonindigenous species. Voucher collections mentioned are housed in Bishop Museum's *Herbarium Pacificum* (BISH), Honolulu, Hawai'i.

Combretaceae

Conocarpus erectus L. **New island record**

Conocarpus erectus, button mangrove, is previously known in Hawai'i from all the main islands except Kaho'olawe and Moloka'i (Wagner *et al.* 1999; Staples *et al.* 2002; Oppenheimer & Bartlett 2002; Staples & Herbst 2005; Parker & Parsons 2012). Recently, it was found by Arleone Dibben-Young to be naturalized on the south shore of Moloka'i at Puko'o Lagoon, where it was growing along the high-water mark.

Material examined. **MOLOKA'I**: Puko'o Lagoon, at high water mark, coastal strand in association with coconut (*Cocos nucifera*) and ironwood (*Casuarina equisetifolia*), many saplings and seedlings, 1 ft [0.3 m], 21.07063°N, 156.79941°W, 03 Sep 2019, *A. Dibben-Young* sub *Starr & Starr 190903-01*.

Fabaceae

Desmodium intortum (Mill.) Urb. **New island record**

Desmodium intortum, tick clover, is previously known in Hawai'i from the islands of Kaua'i, O'ahu, and Hawai'i (Wagner *et al.* 1999; Herbarium Pacificum Staff 1998; Imada *et al.* 2000; Staples *et al.* 2003). Tick clover was first introduced to the state of Hawai'i by the Hawai'i Agriculture Experiment Station in 1947 (USDA-NRCS 2012). Several cultivars were considered outstanding in the field and were further developed and increased. Most are adapted to areas in Hawai'i with rainfall greater than 60 inches (152 cm), ranging from sea level to 2,500 ft (762 m) (USDA-NRCS 2012). On Maui, this robust sprawling vine is dominant in pastures and found in nearby areas, such as parks, gulches, and house lots. In addition to the collections below, it grows vigorously at the author's house in Olinda, elevation 2,700 ft (823 m).

Material examined. **MAUI**: East Maui, Makawao, Kahakapao Rd. near Makawao Forest Reserve, scrub pasture/roadside, in association with gorse (*Ulex europaeus*), Guinea grass (*Megathyrsus maximus*), and guava (*Psidium guajava*), 2,500 ft [762 m], 20.8372°N, 156.2797°W, 30 Oct 2001, *Starr & Martz 011030-02*; East Maui, Pukalani, Pukalani Community Center, crawling aggressively on vegetation and in lawn, urban landscaping, in association with Kikuyu grass (*Cenchrus clandestinus*) and Formosan koa (*Acacia confusa*), 1,375 ft [419 m], 20.8383°N 156.3427° W, 15 Feb 2002, *Starr & Martz 020215-01*; East Maui, Makawao, Eddie Tam Park, growing on fence and in abandoned pasture, urban scrub and pasture, in association with Kikuyu grass and glycine (*Neonotonia wightii*), 1,600 ft [488 m], 20.8508°N, 156.3161°W, 15 Feb 2002, *Starr & Martz 020215-02*.

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Rubiaceae

Galium divaricatum Pourr. ex Lam. **High elevation record**

Galium divaricatum, bedstraw, is previously known from the islands of Hawai‘i and Maui (Wagner & Herbst 1995; Wagner *et al.* 1999). On Maui, *G. divaricatum* is previously known from the Kanaio, Kula, and Olinda areas. The previous highest known collection on Maui was made by the authors in Pōhakuokalā Gulch at 4,500 ft (1,372 m). On Hawai‘i Island, *G. divaricatum* has been collected in the Pōhakuloa Training Area, along Saddle Road (Wagner & Herbst 1995). Though there is no elevation specified for the Hawai‘i Island collection, the highest point along Saddle Road is 6,600 ft (2,012 m). In 2013, this low-growing, mat-forming herb was located on the island of Maui during invasive species early detection surveys at Haleakalā National Park, Leleiwi Overlook parking lot at an elevation of 8,800 ft (2,680 m), where a few small plants were found growing in a crack in the road. The plants were pulled, though they had already gone to seed. This is the highest elevation at which *G. divaricatum* has been found in the state of Hawai‘i.

Material examined. **MAUI:** East Maui, Haleakalā National Park, growing in a crack between the sidewalk and the road, in subalpine shrubland in association with māmane (*Sophora chrysophylla*) and pilo (*Coprosma montana*), 8800 ft [2680 m], 2296279N, 788413W, 01 Aug 2013, *Starr & Starr 130801-05*; East Maui, Pōhakuokalā Gulch, scrub forest consisting of native koa (*Acacia koa*), and ‘ama‘u (*Sadleria* sp.), and non-natives including St. John’s wort (*Hypericum canariense*), faya tree (*Morella faya*), and daisy fleabane (*Erigeron karvinskianus*), 4,500 ft [1,372 m], 05 Aug 2003, *Starr & Starr 030805-01*.

Galium parisiense L. **New state record**

The low-growing annual herb, *Galium parisiense*, was recently found at Haleakalā National Park, Haleakalā Visitor Center (HVC), near the summit of the East Maui. Wall bedstraw is native to the Mediterranean area and has naturalized in North America, mostly in coastal states. This species is typically found in rocky disturbed sites and is a wall specialist, hence its common name, wall bedstraw (Wikipedia 2020). On Maui, a few small plants were initially found during invasive species early detection surveys in 2013 just off the parking lot at HVC. The plants were pulled, but seeds had spread to nearby areas, especially above the visitor center septic system. Control has been ongoing by Park staff for years, and this species is currently thought to be restricted to very few individuals, or at times just a seed bank. *Galium parisiense* has previously not been recorded from Hawai‘i. It is similar in appearance to other *Galium* species, but can be distinguished by the following characters—Habit: annual, erect, 15–68 cm tall, the stems slender, often retrorse-scabrous on the angles. Leaves: in whorls of 5–8, often 6, 4–9 mm long, linear to lanceolate to oblanceolate, generally reflexed in age, 1-nerved, antrorsely scabrous on the margins. Inflorescence: flowers in small cymes ending the mostly numerous branches, panicle open, few-flowered, pedicels threadlike. Flowers: minute, bisexual, corolla basally rotate, white to purple, lobes erect, glabrous to sparsely hairy. Fruit: nutlet hairs short, hooked, or granular roughened (Soza 2012; Gleason *et al.* 1991). The hooked hairs on the fruit of *G. parisiense* help distinguish it from the similar *G. divaricatum*, which has no hairs on the fruit.

Material examined. **MAUI:** East Maui, Haleakalā National Park, Haleakalā Visitor Center, near parking lot, a few small patches by the recycling bins, in sparse subalpine rock land, in association with ‘āhinahina (*Argyroxiphium sandwicense* subsp. *macrocephalum*) and kūpaoa (*Dubautia menziesii)*, 9,730 ft [2,966 m], 2293043°N, 786363°W, 23 Jul 2013 (*Starr & Starr 130723-02*) & 01 Aug 2013 (*Starr & Starr 130801-03*).

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New plant records for Nihoa, 2019

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This report documents two new island records for Nihoa, collected on a U.S. Fish and Wildlife Service expedition from September 17 to September 23, 2019. Both species were pulled, and best management practices were implemented to make sure they do not re-establish.

Information regarding the formerly known distribution of flowering plants is based on the *Manual of the Flowering Plants of Hawai'i* (Wagner *et al.* 1999) and information subsequently published in the *Records of the Hawaii Biological Survey*. All supporting voucher specimens are deposited at Bishop Museum's *Herbarium Pacificum* (BISH), Honolulu, Hawai'i.

Fabaceae

Canavalia cathartica Thouars **New island record**

Canavalia cathartica has been collected as naturalized in most of the main Hawaiian Island chain, except for Ni'ihau, Lāna'i, and Kaho'olawe (Wagner *et al.* 1999). This voucher represents the first collection of this species from Papahānaumokuākea. It is unknown how this 5 × 6 meter patch arrived in this upland location on Nihoa island, but due to its large seed size, it is unlikely to have arrived as a contaminant on field equipment or other human-facilitated pathway. The patch was found in West Palm Valley and was flowering and fruiting at the time of collection. The patch was pulled and left on nearby rocks, and all seed pods were collected, bagged, and removed from the island. The site will be monitored during future visits to ensure no new plants can become established.

Material examined. **NIHOA**: Growing inland above *Pritchardia remota* forest, vining over bare rock and *Solanum nelsonii* in full sun, flowers bright pink, pods bright green, inflated, 21 Sep 2019, *D. Frohlich & I. Cole s.n*. (BISH 778278).

Poaceae

Eleusine indica (L.) Gaertn. **New island record**

Eleusine indica has been collected as naturalized in most of the main Hawaiian Island chain and on Midway, French Frigate Shoals, and Kure in Papahānaumokuākea. A total of 282 individuals of this species were found on the island of Nihoa near a rocky outcropping in the *mauka* portion of the island. All individuals were pulled and bagged in an effort to stop further spread, and the site will be monitored during future surveys to make sure the species does not become reestablished.

Material examined. **NIHOA**: Bunching grass ca. 0.25 m tall, growing in soil near rocky outcropping, associated with *Eragrostis variabilis, Panicum torridum, Solanum nelsonii*, 20 Sep 2019, *D. Frohlich, E. Sachs, & J. Vetter s.n.* (BISH 765243).

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New records of Sciaroidea (Diptera: Mycetophilidae, Keroplatidae) in the Hawaiian Islands[1]

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Three new records of sciaroid flies in the families Mycetophilidae and Keroplatidae are recorded from the Hawaiian Islands. Most immatures of Mycetophilidae are fungus breeders while most of the immatures of Keroplatidae are predaceous, with some being fungus breeders. The biology of two of the three (*Neoempheria carinata* Sueyoshi, *Sciophila* sp.) are known to be fungus breeders, the former is potentially damaging to mushroom cultivation in Japan (and thus also possibly in Hawai'i), the latter is unknown as to its pestiferous status. The biology of the keroplatid (*Apyrtula sastrei* Matile) is unknown as only adults have been collected.

Abbreviations used for collections: BPBM (Bernice Pauahi Bishop Museum, Honolulu, Hawai'i, USA); CNCI (Canadian National Collection of Insects, Ottawa, Ontario, Canada); HDOA (Hawaii State Department of Agriculture, Honolulu, Hawai'i, USA); USNM (National Museum of Natural History, Washington , DC, USA).

Mycetophilidae

Neoempheria carinata Sueyoshi — New National and State Record

(Fig. 1)

This species was only recently described from mushroom hothouses in Japan (natural provenance unknown) by Sueyoshi (2014). It is easily distinguished from other mycetophilids by the contrasting back and yellow striped pattern of the scutum (Fig. 1B). It was originally found as immatures in webs made by the larvae in polypore fungi in a eucalyptus woodchip pile in rural Honoka'a on the island of Hawai'i, and some specimens were collected and reared to adult. Knowing of it being a potential pest of cultivated mushrooms in Japan (Sueyoshi *et al*. 2015), an illustrated information sheet was made by Hawaii State Department of Agriculture staff for residents and farmers in the Hamakua area of the Big Island to be on the lookout for the species. No other specimens have yet been collected beyond the original collecting site near Honoka'a.

This marks the first state record of this species in Hawai'i and the first record of it in the United States.

Material examined. HAWAIIAN ISLANDS: **Hawai'i**: 2♂, 7 larvae, 2 pupal exuviae, Ahualoa, nr. Honoka'a, 1 Jul 2019, Mallion, N. Evenhuis; 4♀, same data, 1 Oct 2019, Mallion, S. Chun (BPBM, HDOA, USNM).

1. Contribution No. 2020-001 to the Hawaii Biological Survey.

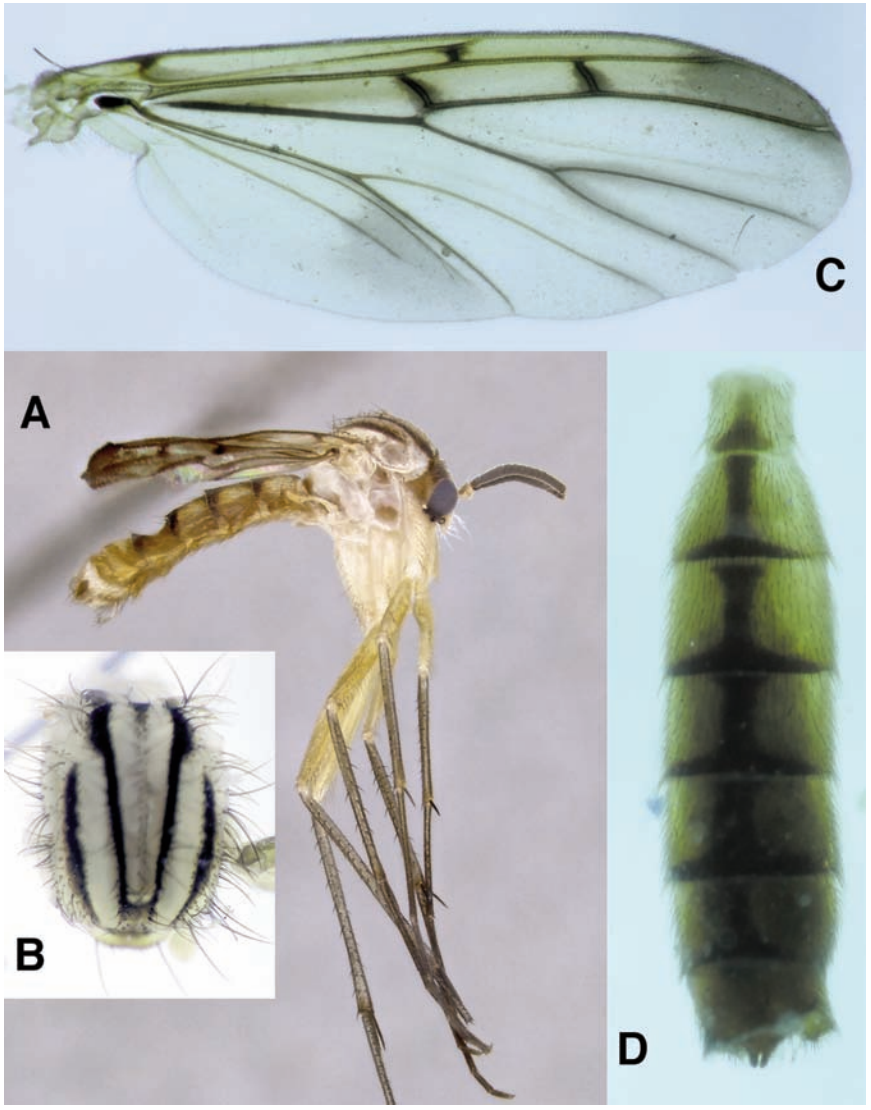

Fig. 1. *Neoempheria carinata* Sueyoshi. **A**. Female habitus. **B**. Mesonotum, dorsal view (teneral specimen). **C**. Wing. **D**. Abdomen.

***Sciophila* sp.** **New Island Records**

This species was first recorded by Howarth & Preston (2006) from a specimen collected in 2000 in the Kahului Airport environs and Krushelnycky *et al.* (2014) listed the first

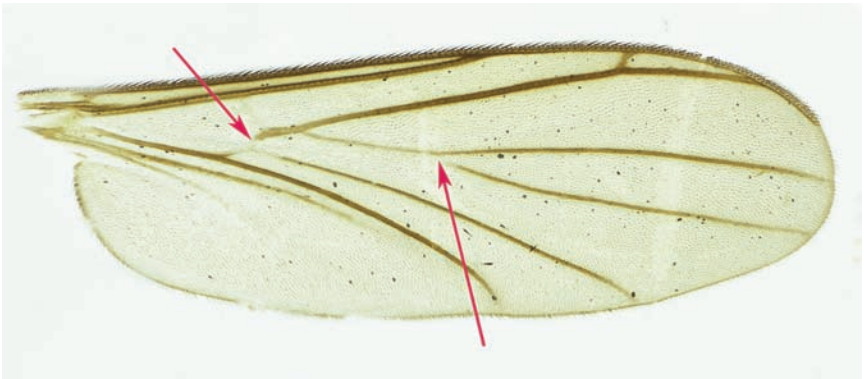

Fig. 2. *Apyrtula sastrei* Matile wing. Arrows point to effaced areas at base of indicated veins.

record of it on the Big Island (Pu‘u Ahumoa on the southwestern flank of Mauna Kea). The new island records here extend that distribution to Kaua‘i and Kaho‘olawe; and another collection of it more northerly on the island of Hawai‘i. That it has been in the Hawaiian Islands for the last 20 years or more, but relatively undetected, is probably attributable to the cryptic existence of immatures in webs in shelf and polypore fungus in localized conditions. The species identity remains unknown but it appears to be a member of species allied to *Sciophila lutea* Macquart, which is a Palaearctic species, but other members of the group extend into the Oriental Region.

Material examined. HAWAIIAN ISLANDS: **Hawai‘i**: 1♂, Ahualoa, nr. Honoka‘a: 1 Oct 2019, Mallion, S. Chun (BPBM). **Kaho‘olawe**: 1♀, Lua Makika, 29 Mar 2004, F. & K. Starr, swept from foliage (BPBM). **Kaua‘i**: 1♂, 2♀, Na Pali-Kona Forest Reserve, Kahua Ridge Trailhead, 1,070 m, 22.11495°N, 159.61523°W, larva collected 29 Oct 2019, adult emerged 8 Nov 2019, W. Haines, reared from larvae collected from shelf fungus on koa (BPBM).

Keroplatidae

***Apyrtula sastrei* Matile** **New National and State Record**

(Fig. 2)

Previously known only from 5 specimens (1♂, 4♀) from the Caribbean island country of Dominica. This marks the first record for the State of Hawai‘i and for the United States. Before Matile’s (1982) description of *A. sastrei*, the genus *Apyrtula* Edwards was known only from two species from Brazil (an undescribed species from Peru is has also been seen by me in CNCI): *A. abbrevinervis* Edwards, and *A. spatulata* Edwards. *Apyrtula sastrei* can be distinguished from the other two by the combination of the more yellowish mesonotum, the base of M_4 effaced, and the costal vein ending at the midway point between the end of veins R_{4+5} and M_1 (see Fig. 2).

Material examined. HAWAIIAN ISLANDS: **O‘ahu**: and 3♂, 1♀, 1 indet. sex, West O‘ahu [exact locality kept private by land owner request], 13 Apr 2018, R. Peck, yellow pan traps (BPBM); 1♀, 1 indet. sex, same data except, 16 Apr 2018, R. Peck, yellow pan traps (BPBM). Vouchers in BPBM, HDOA.

ACKNOWLEDGMENTS

Many thanks to Mallion for generously allowing access to the property where two of the species in this review were collected and/or observed and for her enthusiasm in wanting to better understand the invertebrates that inhabit her environs. Thanks to Janis Matsunaga, Darcy Oishi, and especially Stacey Chun (HDOA) for following up on the discovery at Ahualoa, and liaising with the mushroom farmers and enthusiasts, and with producing and passing out the illustrated information sheet asking folks to be on the look-out for *Neoempheria*. Sarah Oliveira is thanked for discussions concerning the identity of *Neoempheria carinata*. Will Haines is thanked making available for study the immature and adult specimens of *Sciophila* he collected on Kaua‘i, the significance of which were brought to his attention by the postings by Mallion and others on the Hawaiian Entomology Society Facebook site. Scott Fitzgerald is thanked for his review of the manuscript and comments and corrections that helped improve it.

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Hawaiian Lava Tube Cave Associated Lepidoptera from the Collections of Francis G. Howarth and Fred D. Stone[1]

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Abstract. The lepidopteran fauna of caves remains poorly known largely because of the difficulty in collecting specimens suitable for identification in the physically demanding environment. Here we provide the results of biological surveys spanning more than 40 years in Hawai'i. Lava tube caves are an important landform throughout the islands and especially on the younger islands of Maui and Hawai'i. These caves support communities of a diverse array of organisms including Lepidoptera. We list 25 morphospecies of moths now known occur in Hawaiian caves. Of these, six are nonnative and mostly are found only in the entrance and twilight zones. Three native species are typical surface species, that probably entered caves accidentally. Three species of endemic *Mestolobes* seek shelter in caves and other dark habitats, and some may be associated with caves. *Schrankia altivolans* are occasionally found living in caves. The remaining species display behavioral or morphological adaptations to utilize cave habitats. The speciose endemic genus *Hyposmocoma* is represented in caves by at least six species. Four species of large native moths were known historically to use caves for communal daytime roosts including *Hypocala velans* and three species of *Peridroma*; these emerge at dusk and fly long distances to forage and reproduce, and then return to the same caves at dawn. Most interesting are three species (*Schrankia howarthi, Pseudoschrankia nohoana*, and *Orthomecyna* species) that live and reproduce deep in caves and show some morphological features characteristic of obligate cave animals. These results indicate that Lepidoptera are an important component of cave ecosystems and should be included in faunal surveys of caves. We also provide a brief biography of our co-author and dear friend, Dr. Fred D. Stone 1938–2018.

INTRODUCTION

Lepidoptera are rarely included in faunal surveys of caves, especially in the permanently dark deeper passages. Most historical accounts have recorded the few moth and butterfly species that habitually enter caves for estivation or shelter during seasonal climate shifts

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(Capuse & Georgescu 1962–1963; Vandel 1965; McKillop1993; Warrant *et al*. 2016). A few moth species inhabit the entrance and twilight zones; i.e., the parietal biotope (Vandel 1965), where they scavenge on nest debris of cave roosting vertebrates and organic material falling into entrances. A predisposition for hypogean living has been documented in *Schrankia* Hübner including Japanese populations of *S. costaestrigalis* (Stephens), which readily colonize railroad tunnels and other underground spaces at all life stages (Yoshimatsu 1995) and an unidentified species of *Schrankia* from lava tubes in Queensland, Australia (Howarth & Stone 1990). In addition, individuals of many surface-inhabiting species occasionally enter caves accidentally. Moths in the family Tineidae are frequent scavengers on guano in caves, especially in tropical Southeast Asia (Robinson 1980). Thirty-six species have been collected in caves, of which 20 maintain permanent cave populations. Eleven species are known only from caves, of which one, *Tinea microphthalma* Robinson, from the Philippines, has reduced eyes and is considered an obligate cave dweller (= troglobite).

The first accounts of moths in caves in Hawai‘i were made by R.C.L. Perkins, who conducted a monumental insect survey of the islands from 1892 to the early 1900s (Perkins 1913). Perkins observed that native *Hypocala velans* Walker utilized caves and crevices in lava as daytime roosts. These moths sometimes emerged in the evening in great numbers (Perkins 1913; Zimmerman 1958a). The surprising discovery of obligately cave-adapted arthropods in young lava tubes on Hawai‘i Island (Howarth 1972) led to a multi-year project to survey the fauna of Hawaiian caves by Howarth and a team of collaborators, including the late Dr. Fred D. Stone. Among the insects collected in total darkness were specimens of a species of *Schrankia*, which had reduced wings and eyes, and unmarked pale grey coloration. Their larvae feed on plant roots that penetrate the lava and enter caves (Howarth 1973).

Schrankia howarthi Davis & Medeiros is the second known lepidopteran that lives permanently underground and displays the typical adaptations found in other obligate cave species. Its discovery intrigued Don R. Davis, of the Smithsonian Institution, who visited the islands in 1974 and 1977 and collected additional specimens for species description. However, the kaleidoscopic variation in morphology displayed by specimens from different caves defied sorting by conventional taxonomic methods. Species determination was further complicated by the existence of populations of related moths with normally developed eyes, wings and bodily color that inhabited twilight areas in the same caves. Subsequently, one of us (MJM) joined the project and used DNA analysis to assist with classifying the various populations. Remarkably, all specimens belonged to a single polymorphic species with an obligate cave form occurring in darkness; a volant, sighted population occurring in the twilight zone; and occasional hybrids between them (Medeiros *et al.* 2009). Additional surveys have revealed the existence of a diverse moth fauna in Hawaiian caves, which is the subject of the current review.

The cave environment is zonal with three main zones recognized based on the presence of light: these are the “entrance zone” a lighted zone where the surface and cave environments mix; a “twilight zone” where light is progressively diminished from the limit of conspicuous green plants to complete darkness; and a “dark zone” where light is absent. The dark zone can often be subdivided into subzones based on the physical environment: a “transition zone” where the atmosphere within the passage is subjected to frequent disturbances resulting from weather and diurnal events occurring on the surface; a

"deep zone" where the air remains permanently saturated or supersaturated with water vapor; and a "bad air zone" where air exchange with the surface is restricted and decomposition gases can accumulate. The presence and extent of each of these zones is delineated by the size and shape of the entrance(s) and passages (Howarth 1980, 1987).

Animals found in caves can be classified into four main categories based on their theorized relationship to cave life. These are "troglobites" (species obligately adapted to live only in deep and stagnant air zones); "troglophiles" (species able to live and reproduce in caves as well as in similar damp, dark habitats on the surface); "trogloxenes" (species that habitually use caves for roosting or shelter and return to the surface for food and dispersal); and "accidentals" (species accidentally entering caves but that cannot survive there) (Howarth 1983; Howarth & Moldovan 2019).

METHODS

Biological inventory of caves is often logistically and physically challenging (Wynne *et al*. 2018). This is especially true for Lepidoptera, which require special handling to ensure suitable specimens are collected and preserved for taxonomic study (Robinson 1980). In the current project, as many caves as possible on each island were sampled. Caves were explored using accepted precautions for safety and protection of speleological resources; e.g. biologic, geologic, archaeologic, and paleontological deposits. Cave passages were surveyed visually for animals. Surveys were often concentrated in passages that contained promising habitats, especially those with potential food resources (e.g., root curtains, flood detritus, etc.). Baits (sprouted grain, tubers, meat, and cheese) were placed in various locations throughout caves. Adult moths rarely came to baits, but larvae responded to sprouted grain and rotting plant material. Adult moths were coaxed into individual vials and kept alive until they could be curated outside the cave. Larvae and pupae were also collected into individual vials but kept alive to rear adults. Larvae not reared were stored in 90–95% ethanol. Because many of the caves are considered "culturally and/or biologically significant," precise locations are treated as confidential; therefore, locality information is rounded to general area only. Precise locality data are archived with the agency responsible for managing each cave.

Genitalia were prepared and mounted on slides using the following protocol: Abdomens were soaked in simmering 10% potassium hydroxide solution for one hour, genitalia were removed, stained with lignin pink and/or Chlorazol black, then soaked in a sequence of 30% ethyl alcohol, 90% ethyl alcohol, 100% isopropyl alcohol and Euparal essence, and then spread on microscope slides and mounted in Euparal. Unless otherwise noted, digital photographs of genitalia and adults were taken with a digital imaging system mounted on a Nikon SMZ25 stereo microscope. All of the following specimens and associated genitalia slides are deposited in the Entomological Collection, Bernice Pauahi Bishop Museum, Honolulu, Hawai'i.

RESULTS

Twenty-five morphospecies of Lepidoptera are herein recorded from Hawaiian caves. Nineteen are endemic to the islands and six are nonnative. As expected, most native species and all of the non-native species occur in caves opportunistically as troglophiles, trogloxenes, or accidental waifs and display no morphological or behavioral adaptations

to underground life. Several endemic species in five genera are obligately associated with caves. Two remarkable endemic species, *Schrankia howarthi* and an undescribed *Orthomecyna* sp., are obligate cave dwellers. Surprisingly, *S. howarthi* is polymorphic with populations obligately adapted to living permanently in caves on Hawai‘i and Maui islands. Additional populations less specialized for cave life, which occur in the twilight zones of caves, are able to disperse outside caves. Larvae of the *Orthomecyna* species are blind, pale, and feed on flushing root tips in the deep zone of caves. Adults of *Pseudoschrankia nohoana* Medeiros & Howarth occur throughout caves, but most frequently in the twilight zone. They are volant and presumably can disperse on the surface when climatic conditions allow. The presumed larvae are blind and adapted to cave habitats. In addition, *Hypocala velans* and several species of *Peridroma* Hübner are obligately associated with caves as daytime roosts. They leave their caves in huge numbers at dusk and, and then return to the same caves at dawn. Finally, several endemic species in *Hyposmocoma* Butler and *Mestolobes* Butler appear to be closely associated with cave habitats, but their biology and status in caves remain poorly known.

ANNOTATED CHECKLIST

The following is a list of the 25 moth morphospecies found in Hawaiian caves with notes on their biology, association with the cave habitat, and localities. Taxa are arranged as in Nishida (2002); i.e., each species listed alphabetically within its genus, which is listed alphabetically within its family.

Autostichidae

1- *Oecia oecophila* (Staudinger, 1876). Nonnative: **Troglophile?**

HAWAI‘I I, N. Kona, Kīholo Bay, 0–3 m from entrance of Ana Lima Kipo Lava Tube, entrance zone. 19.8°N; 155.9°W. 10 Jan 1982. F. Howarth. The larvae feed on dried feces and probably other decaying organic matter (Nasu *et al*. 2016). Dry rat feces from *Rattus rattus* Linnaeus are often common in the twilight and transition zones of caves and provide food for this and other scavenging species. Slide LB78, male. See Zimmerman (1978) for illustrations and more information.

Cosmopterigidae

Differences in wing pattern suggest each of the following entries represent different species of *Hyposmocoma*.

2 - *Hyposmocoma (Euperissus)* sp. A. Endemic: **Troglophile?**
(Fig. 1A, B)

HAWAI‘I I, Hawai‘i Volcanoes National Park, “HAVO, Chain of Craters Rd, 19.3°N; 155.2°W. 750 m elev. ~800 m from entrance of Keahou Trail Cave # 3, deep zone. 5 May 2006, F.G. Howarth & F.D. Stone. Slide LB66, male. Genitalia are similar to those of *Hyposmocoma (Euperissus) chilonella* Walsingham.

3 - *Hyposmocoma* sp. B. Endemic: **Troglophile?**

MAUI: Haleakalā, Ulupalakua, Thaumatogryllus Cave #2, 20.6°N; 156.4°W. 700 m elev. deep zone. 16 Jul 2002, F.G. Howarth & W. McDowell. Female, not illustrated.

4 - *Hyposmocoma* (*Hyposmocoma*) sp. C. Endemic: **Troglophile?**
(Fig. 1C, D)

HAWAI'I I, Hawai'i Volcanoes National Park: Mauna Loa Strip Road. 5000-Foot Cave. 19.5°N;155.3°W. 1,500 m elev. transition zone. 12 May 2005, F.G. Howarth & F.D. Stone. Slide LB75, male. Genitalia are very simple, and similar to *Hyposmocoma (H.) nohomeha* Medeiros, Haines, & Rubinoff.

5 - *Hyposmocoma (Hyposmocoma)* sp. D. Endemic: **Troglophile?**
(Fig. 1E, F)

HAWAI'I I, Pōhakuloa Training Area, Bobcat Trail, 19.7°N; 155.7°W. 1,600 m elev. Dead Cat Cave Entrance, T28, transition zone. 9 Mar 2017, M.J. Medeiros. Slide 17A18, male. This specimen is not *Hyposmocoma (H.) malornata* Walsingham, though the genitalia are similar.

6 - *Hyposmocoma* sp. E. Endemic: **Troglophile**

HAWAI'I I, Pōhakuloa Training Area, Bobcat Trail Cave #10265-T-40DE. 19.7°N; 155.7°W. 1,600 m elev. Deep zone. 30 Dec 1994. F.G. Howarth. Two pupae were collected that were suspended horizontally in loose silk hammocks strung between walls in a narrow crack (approx. 3–5 cm wide) in the deep zone. They were kept alive, and one female with brown wings with two dark spots emerged on 24 Jan 1995. This may be the same species as *Hyposmocoma* species D, as the two caves are in the same lava flow and separated by ~200 m. Not illustrated.

Crambidae

7 - *Eudonia* species: Endemic: **Accidental**
(Fig. 1G, H)

HAWAI'I I, Hawai'i Volcanoes National Park, Kalanaokuaiki Pali, 19.4°N; 155.2°W, 1,000 m elev. Cave #1, twilight zone. 4 Jul 1976, F.G. Howarth. Slide LB72, male. Genitalia in this genus are extremely similar (Zimmerman 1958b). This specimen's scales are badly rubbed, so it is difficult to ascertain which species this may be, or whether it is a new species. Nearby, flying along the surface of an area close to many lava tubes, was found the following specimen: Hawai'i Volcanoes National Park, Mauna Ulu Lava flows, 950 m, 31 Dec 1981. "Flying over 'barren' lava." FG Howarth, BPBM Acc #1982.6. Slide LB68, male. Based on wing pattern alone, this specimen appears closest to *Eudonia isophaea* (Meyrick), or perhaps *E. peronetis* (Meyrick), though this specimen is also somewhat rubbed. These two moths may or may not be the same species.

8 - *Mestolobes olali* Medeiros & Howarth 2017. Endemic: **Trogloxene**

HAWAI'I I, Locality data are provided in Medeiros & Howarth (2017). This species is known from several caves on the Big Island and has metallic bands running from the costal to anal margin of the forewing. It is possibly resident in the entrance and twilight zones. See Medeiros & Howarth (2017) for description and photographs.

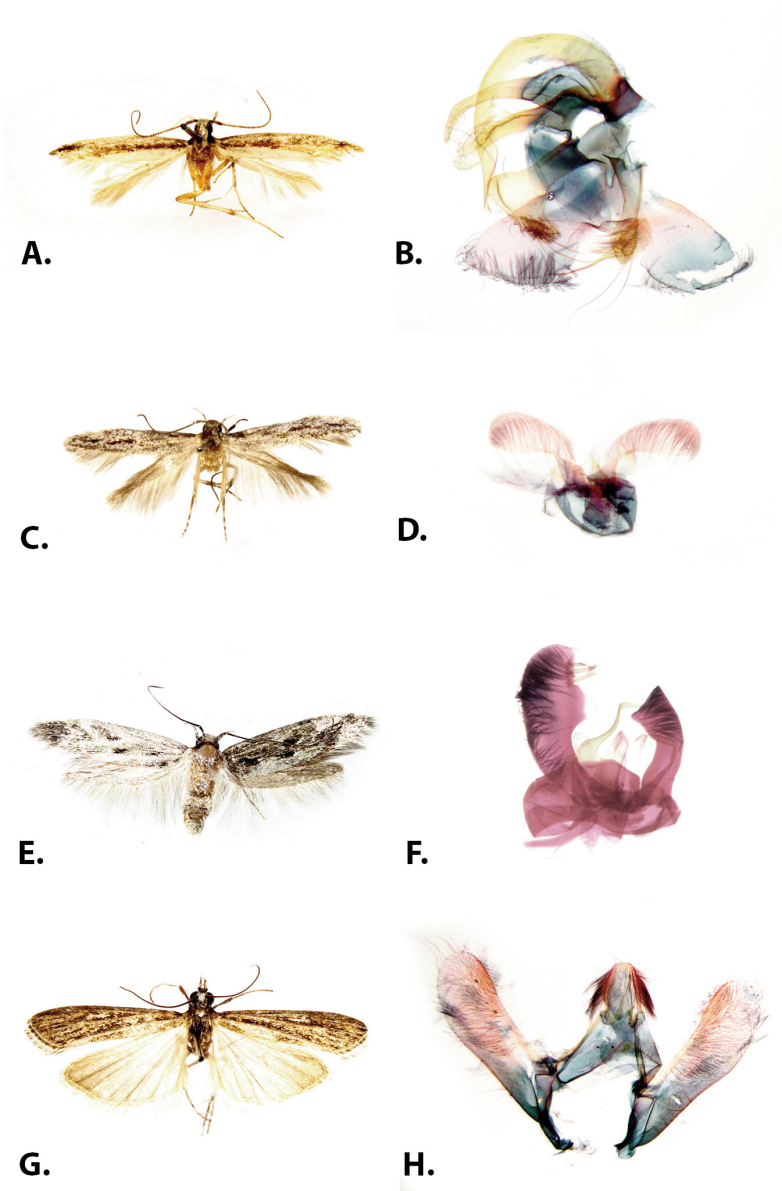

Figure 1. **A.** adult *Hyposmocoma (Euperissus)* sp., specimen LB66, wingspan 11 mm. **B**. male genitalia of specimen LB66. **C**. *Hyposmocoma* (*Hyposmocoma*) sp., specimen LB75, wingspan 10 mm. **D**. male genitalia of specimen LB75. **E**. *Hyposmocoma* (*Hyposmocoma*) sp., specimen 17A18, wingspan 15 mm. **F**. male genitalia of 17A18. **G**. *Eudonia* sp., specimen LB68, wingspan 15 mm. **H**. male genitalia of LB68.

9 - *Mestolobes* undescribed species: Endemic: **Trogloxene**
(Fig. 2 A, B)

MOLOKA'I, Kalaupapa National Historical Park, 21.2°N; 157°W. 5 m elev. Fisherman's Shack Cave #1 (Kaupikiawa Cave), entrance and twilight zones. 2 Jun 2010, F.G. Howarth & F.D. Stone. Slide LB67, male. Compared to other known *Mestolobes*, the valvae are shorter and wider, and the gnathos is more blunt. This specimen appears closest to *M. pessias* Meyrick, or *M. minuscula* (Butler). This and other species of *Mestolobes* typically fly at dusk and apparently hide in darkness at other times (FGH, unpubl. observ.).

10 - *Mestolobes* sp.: Endemic: **Trogloxene**
(Fig. 2 C, D)

HAWAI'I I, Hawai'i Volcanoes National Park: Mauna Loa Strip Road. 5000-Foot Cave. 19.5° N;155.3° W. 1,500 m elev. Twilight zone. 10 May 2006, F.G. Howarth & F.D. Stone. Slide LB69, male. This specimen is either closely related to, or is actually, *Mestolobes minuscula* (Butler). However, this species is poorly delineated (Zimmerman 1958b).

11 - *Omiodes localis* (Butler, 1879): Endemic: **Accidental?**

HAWAI'I I, Hawai'i Volcanoes National Park Cave Survey, Mauna Loa Strip Road. "Fred's Cave" (= segment of 5000-Foot Cave). 19.5°N; 155.3°W. 1,500 m elev. Twilight zone. 22 Mar 2005, F.G. Howarth & F.D. Stone. 1 female. Larvae feed on grasses and probably are residents of the entrance zone. See Zimmerman 1958b for illustrations and additional information.

12 - *Orthomecyna* species. Endemic, **possible Troglobite?**
(Fig. 2E)

HAWAI'I I, south slope of Mauna Loa, Keahou Ranch, 19.5°N; 155.34°W. 1,700 m elev. Keamoku Cave, deep zone. 8–11 July 1976, F.G. Howarth. Seven blind larvae on tree roots. Hawai'i Volcanoes NP. Mauna Loa, Frank's Cave in Spur Road Cave System, deep zone. 5–7 May 2005, F.G. Howarth & F.D. Stone. Several dead adults and live larvae. Hawai'i Volcanoes NP. Mauna Loa, 5000-Foot Cave System, 1,525 m, deep zone. 10 May 2006, F.G. Howarth & F.D. Stone. One dead moth. The larva is unusual and displays some troglomorphies (Fig. 2E). It lacks pigmentation and any trace of eyes. Antennae are relatively robust, porrect. Head is nearly prognathous. All larvae so far known were found feeding on swollen flushing etiolated root tips in the deep zone of caves.

13 - *Udea* species. Endemic: **Accidental?**
(Fig. 2 G and H)

HAWAI'I I, Hawai'i Volcanoes National Park Cave Survey, Mauna Loa Strip Road. Keana Kīpuka Pua'ulu # 1 (a.k.a. Bird Park Cave #1), 19.4°N, 155.3°W, 1,220 m, entrance zone. 9 Dec 1976, D & M Davis. LB70, male. Based on genitalic and wing pattern similarities visible in Zimmerman (1958b), this specimen is quite similar to

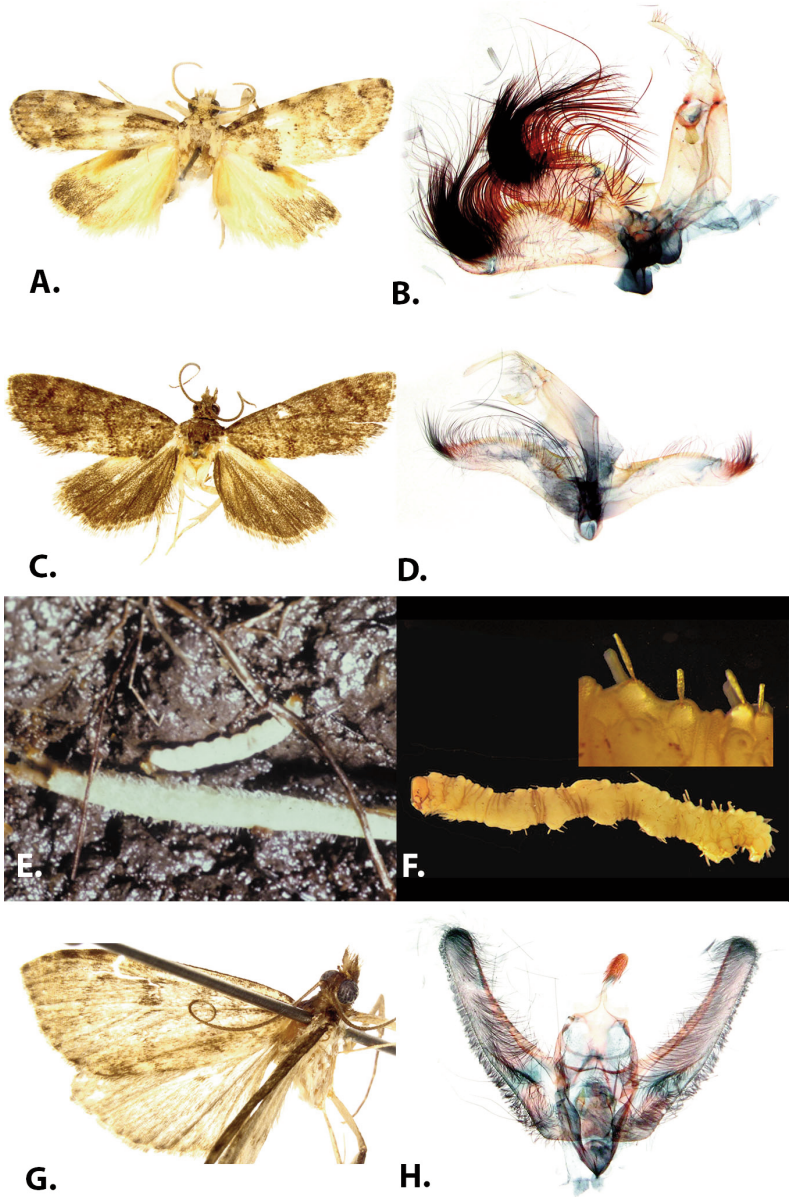

Figure 2. **A**., *Mestolobes* undescribed species, specimen LB67, wingspan 13 mm. **B**. male genitalia of LB67. **C**. *Mestolobes* sp., specimen LB69, wingspan 13 mm. **D**. male genitalia of LB69. **E**. larva of *Orthomecyna* sp. next to etiolated root tip on floor in Keamoku Cave, at 1,700 m on Hawai‘i I. Note feeding damage at left of image. Photo by D.R. Davis. **F**. Likely *Pseudoschrankia nohoana*, larva. **G**. *Udea* sp., specimen LB70, left wing length 8 mm. **H**. male genitalia of specimen LB70.

Udea despecta (Butler) but may be *U. liopis liopis* (Meyrick) or *U. pyranthes* (Meyrick) as these species are difficult to differentiate.

Erebidae

14 - *Hypocala velans* Walker, 1857: Endemic: **Trogloxene**

HAWAI'I I, Pōhakuloa Training Area, Kona Highway Cave, 19.76°N; 155.69°W. 1,400 m elev. transition / deep zone, Aug 1994. Single adult collected while roosting. This is the only cave specimen found during our surveys, but Perkins (1913) reported the native *Hypocala velans* commonly frequented caves and rock crevices during the day and emerged in great numbers at sunset. Although Perkins (1913) recounted that the species was more abundant in the lowlands, he noted that this moth used an unnamed cave at 9,000 feet [~2,750 m] on Haleakalā, Maui. Zimmerman (1958a) and Ziegler *et al*. (2016) summarized observations of cave moth roosts in Hawai'i. However, this species is now either rare or possibly extinct.

15 - *Pseudoschrankia nohoana* Medeiros & Howarth, 2017: Endemic: **Troglophile** (Fig. 2F)

HAWAI'I I. Hawai'i Volcanoes National Park, 19.4°N; 155.2°W. 750 m elev. Ainahou Cave, below entrance #22, deep zone. 13 Jun 2005, F Howarth & F Stone, 1 male, slide LB65. *Pseudoschrankia nohoana* has been recorded from several caves on the Big Island and is most abundant in the twilight zone. See Medeiros & Howarth (2017) for more information. The species has not been reared, and the larval habitat is unknown. However, an undetermined hypenodine larva occurs in many of the same caves as *P. nohoana* and most likely is this species. The larva is similar to larvae of *Schrankia howarthi*, but differs significantly in the form of its setae and integument. *S. howarthi* has elongate, simple acuminate setae, whereas the unknown larva has enlarged flattened rod-like setae that are slightly wider near the middle (Fig. 2F). Also, the integument is strongly shagreened rather than smooth like *Schrankia* larvae. No *P. nohoana* larvae have been collected on plant roots, and all reared adults from roots were *Schrankia*. However, it is possible that *P. nohoana* also feeds on roots, but were missed during our surveys since the larvae of the two species are similar in life. *Pseudoschrankia nohoana* does respond to baits, including sprouting grain and rotting vegetable matter, suggesting that it has a different behavior than *Schrankia*; it may also pupate in crevices rather than on plant roots.

16 - *Schrankia altivolans* (Butler, 1880): Endemic: **Troglophile**

MAIN HAWAIIAN ISLANDS FROM KAUA'I TO HAWAI'I. This moth is found widely on all the main Hawaiian Islands as a surface dweller, but has been recorded in four caves on Maui and six caves on the Big Island (Medeiros *et al.* 2009). This species has been found in caves near sea level to over 1,200 m elevation and in all cave zones from the entrance to deep zones. *Schrankia* species that feed on plant roots are able to colonize caves and other underground spaces where roots occur. Other cave inhabiting *Schrankia* populations have been reported from Japan (Yoshimatsu 1995) and Australia (Howarth & Stone 1990). Medeiros *et al.* (2009) illustrated both sexes of adults and discussed its phylogeny and great morphological variation.

17 - *Schrankia howarthi* Davis & Medeiros, 2009: Endemic: **Troglobite & Troglophile**

HAWAI'I & MAUI islands. *Schrankia howarthi* is widely distributed in caves on Hualālai, Mauna Loa, and Kīlauea volcanoes on the Big Island from sea level to over 1,500 m elevation and from all cave zones. It is expected to occur in any lava tube that contains suitable plant roots and environment. It is also known from two caves on the south slope of Haleakalā on Maui (Medeiros *et al.* (2009). This species is polymorphic, with very pale individuals found in the deep zone of caves on Maui and the Big Island, and slightly more pigmented individuals found closer to cave entrances and on the surface. Some individuals of both morphs are flightless, though flightlessness is most common in deep zone females. Pale adults in the deep zone often lack eye-shine, whereas more pigmented adults display a distinct pink glow in a bright beam of light. Larvae feed on tree roots that dangle into caves. The conspicuous pupal cocoons are composed of silk and short root fragments and are attached to the host root. Larvae, pupae, and adults are commonly found in caves with suitable living roots. *Schrankia howarthi* is the most commonly encountered Lepidoptera found in Hawaiian caves. See Medeiros *et al.* (2009) for description, illustrations and distribution.

Noctuidae

18 - *Peridroma albiorbis* (Warren, 1912): Endemic: **Trogloxene**

HAWAI'I: northern slope Mauna Loa, ~3,000 m elev, in the dark zone of Big Red Cave. Jan 2000, D. Bunnell and J. Giffin. Dead *Peridroma albiorbis* adult. The cave also contained large numbers of *Lasiurus cinereus semotus* (Allen) (Hawaiian Hoary Bat) remains (Bunnell & Giffin 2000). See Zimmerman 1958a for illustrations and additional information.

19 - *Peridroma* sp. A. Endemic: **Trogloxene**

HAWAI'I: Hawai'i Volcanoes National Park, ~4,000 m elev, Mauna Loa Lava Tube, transition zone. 1980s, F.G. Howarth. A huge colony of moths numbering tens of thousands were roosting in the cave. This colony persisted for several years then disappeared. On 28 Sep 2005, a second colony was discovered in a nearby cave at 3,800 m elevation by F.D. Stone & F.G. Howarth. The second colony was smaller numbering a few hundred individuals. An accurate count was not possible since the moths were packed together in crevices on the walls and ceiling (Howarth & Stone 2020). The floors of both caves were paved with a thick layer of permanent ice. Illustrated in Howarth & Stone (2020).

20 - *Peridroma* sp. B. Endemic: **Trogloxene**

MAUI, Haleakalā National Park, Haleakalā Crater, Crystal Cave, 20.7°N; 156.2°W, 2,300 m elev. Twilight zone. 23 Jun 1976, F.G. Howarth. Fragments of moths found on the cave floor. The wide low cave entrance leads to a single room 10 to 15 m in diameter, which is all in twilight. At the time of the survey, the dry floor was entirely covered with a several centimeter-deep layer of moth fragments. The wing shape and color pattern matched *Peridroma*. No living moths were found. The volume of fragments indicate that the cave once housed a huge colony of moths. Rat feces were also abundant, which suggest the reason for the collapse of the colony of moths.

Oecophoridae

21 - *Hofmannophila pseudospretella* (Stainton, 1849) nonnative: **Troglophile**

HAWAI‘I I. Pōhakuloa Training Area, Dan’s Cave, Multi-Purpose Range Complex, 19.66°N; 155.70°W, ~2,000 m, twilight zone 23 Sep 1994. FG Howarth. Known as the “brown house moth,” this stored product pest is native to Asia but has been widely distributed by commerce. In Hawai‘i, it is known from high-elevation buildings. The twilight zone of caves provides a similar habitat. Not illustrated.

Pterophoridae

22 - *Stenoptilodes,* probably ***taprobanes*** (R. Felder & Rogenhofer, 1875). Nonnative: **Accidental**

HAWAI‘I I, Big I, Pōhakuloa Training Area, 19.64°N; 155.54°W, Pu‘ukoli Trench Cave 11D, 2 070 m, twilight zone. 1 Aug 1994, FG Howarth, FD Stone, ED Toole. Specimen at BPBM. This or related species has been observed in Long Cave (20.7°N; 156.2°W) in Haleakalā Crater on Maui. See Zimmerman 1958b for illustrations and additional information about *Stenoptilodes taprobanes*.

Pyralidae

23 - *Pyralis manihotalis* Guenée, 1854: Nonnative: **Troglophile**

HAWAI‘I I. Pigeon Cave off the Saddle Road near Pu’u Wa‘awa‘a 19.8°N; 155.8°W. 29 Apr 1974. Entrance and twilight zone, DR Davis and FG Howarth. This species is a scavenger on dry pigeon feces in the entrance and twilight zones of caves. It is not common in Hawaiian caves as there are no guano deposits, but it may be found wherever dry dung accumulates, such as beneath chicken coups. See Zimmerman 1958b for illustrations and additional information.

Tineidae

24 - *Monopis crocicapitella* (Clemens, 1859). Nonnative; **Troglophile**

HAWAI‘I I, Hawai‘i Volcanoes National Park: Mauna Loa Strip Road, 19.5°N;155.3°W. 1,500 m elev. 5000-Foot Cave, transition zone. 12 May 2005, FG Howarth & FD Stone. Slide LB74, female. **MAUI**, Ahihi-Kinau Natural Area Reserve, 20.6°N; 156.4°W, 120 m elev, Kalua O Lapa Cave; transition zone, 22 May 1988, FG Howarth. Slide LB73, female. It may be the same or a closely related species. See Zimmerman 1978 for illustrations and more information.

25 - *Phereoeca allutella* (Rebel, 1892): Nonnative; **Troglophile**

HAWAI‘I I. N. Kona; Pigeon Cave off the Saddle Road near Pu‘u Wa‘awa‘a. 19.8°N; 155.8°W. Entrance and twilight zone. 29 Apr 1974, DR Davis. Specimens were reared from pigeon feces collected from within the entrance and twilight zones. The larvae of this moth are scavengers feeding on fungi and organic matter in the entrance and twilight zones of caves. The characteristic purse-shaped larval cases are commonly seen attached to walls in the twilight zone in dry lowland caves on all the main Hawaiian Islands. See Zimmerman 1978 for illustrations and more information.

DISCUSSION

Of the 25 morphospecies of Lepidoptera recorded herein from Hawaiian caves; nineteen are native and six are nonnative. Five nonnative species are synanthropic and were introduced through commerce. The drier twilight and transition zones within caves often provide similar habitats for these household pests. The sixth nonnative species, a pterophorid, was inadvertently introduced to Hawai‘i by humans and is probably an accidental visitor within caves. Three of the native species are typical surface species, that probably also enter caves accidentally. The three species of endemic *Mestolobes* listed may habitually enter caves. Additional *Mestolobes* species will certainly be found in caves during further surveys. Their larval habits are poorly known, and some species (e.g., *M. olali)* may be residents (i.e., troglophilic) in caves.

The remaining species display behavioral or morphological adaptations to utilize cave and other subterranean habitats. The endemic genus *Hyposmocoma* is incredibly speciose with more than 350 species known from the Hawaiian Islands (Zimmerman 1978). Their ecology is equally diverse; they feed on lichens on the driest lava flows, submerged algae in streams, and all parts of living plants in the wettest rainforests (Rubinoff & Schmitz 2010). A few are even predatory (Rubinoff & Haines 2005). Many more species than the five listed here probably occur in Hawaiian caves. Their function within cave ecological communities is unknown but likely unique.

At least four species of large native moths historically were known to use caves for communal daytime roosts: an underwing, *Hypocala velans*, and three species of *Peridroma* cutworms (Perkins 1913; Zimmerman 1958a, Ziegler *et al.* 2016). They emerge at dusk and fly long distances to forage and reproduce, and then return to the same caves at dawn. Their remarkable ability to navigate between roosting and feeding sites is analogous to behavior of the Bogong Moth (*Agrotis infusa*) in Australia (Warrant *et al.* 2016). Lowland colonies of these moths appear to have been extirpated, but a few colonies may still occur in high elevation caves on Mauna Loa on Hawai‘i (Ziegler *et al.* 2016, Howarth & Stone 2020). Additional colonies of these moths were documented in the literature from moth wing fragments in caves. These cave deposits suggest that a diverse assemblage of cave-roosting moths once existed in Hawai‘i. This assemblage probably included many additional species of *Peridroma* and possibly some *Agrotis* species. These roosts were exploited by the native bird, the ‘apapane (*Himatione sanguinea*), which nested in the entrance and twilight zones of occupied caves (Van Riper 1973, Howarth & Stone 2020). The remarkable phenomenon of large communal colonies of moths is disappearing along with the food resource and unusual nesting behavior of the ‘apapane. The cause of this demise is unknown, but a main culprit may be the black rat (*Rattus rattus*), which readily enters caves and would find roosting moths easy prey (Howarth & Stone 2020). *Peridroma* and *Agrotis* were also targets of parasites and predators purposefully introduced for biological control of related pest species (Gagne & Howarth 1985).

Three native species are strongly associated with caves and live and reproduce underground. *Pseudoschrankia nohoana* displays few morphological adaptations to the cave environment. Its biology remains poorly known. It is widespread in caves on Hawai‘i Island with adults found most often in the twilight zone. Its presumed larva is attracted to and feeds on decomposing plant material in deep zone environments. *Orthomecyna* sp. is so far known from a few caves between 1,500 and 2,000 m elevation on the southern slope

of Mauna Loa. Its larvae feed on fleshy etiolated root flushes, and represent only the second report of larval biology for any of the 15 endemic species of *Orthomecyna*. The only previous record is Swezey's rearing of a single larva of *O. mesochasma* found among roots of sugarcane on the island of Kaua'i (Swezey 1924, Zimmerman 1958b, p 295).

The most interesting Hawaiian species is *Schrankia howarthi*. It is one of only two known lepidopterans morphologically and behaviorally adapted to live in the deep cave environment. The other cave-adapted species is *Tinea microphthalma* Robinson, 1980 from the Philippines. Surprisingly, *Schrankia howarthi* is polymorphic with eyeless, depigmented weakly volant forms largely restricted to the deep zone, but also has an eyed, flighted form occurring in the entrance and twilight zones. The two forms hybridize where their habitats overlap, creating a kaleidoscope of intermediate forms. Also, unexpectedly, the cave-adapted morph occurs on both Hawai'i and Maui. DNA analysis revealed that the cave-adapted population on Maui originated from flighted individuals from adjacent areas on Hawai'i Island (Medeiros *et al.* 2009).

On the active volcanoes, new lava flows create new cave habitats while simultaneously destroying older habitats. Thus, cave ecosystems are dynamic with the fauna playing leapfrog from older to younger flows. New caves are colonized sequentially as the physical and biotic environment develops. The order in which species arrive is both random and non-random; that is, some generalists and predators can colonize rapidly soon after the habitat cools; while others can only establish after the habitat matures. In this way, lava tubes and their ecosystems of different ages provide model systems for the study of community development and evolutionary ecology (e.g., Medeiros *et al*. 2009, Wessel *et al.* 2013). Within *Schrankia*, the troglophilic morph can colonize caves by overland dispersal as soon as roots become available, often within a few decades after the lava flow cools. However, the cave-adapted morph arrives later. In 1971, when surveys began in Kaumana Cave, which is within the 1881 lava flow from Mauna Loa at 300 m elevation, the troglophilic morph of *S. howarthi* and *S. altivolans* were common in the cave, even in the deep zone. Sometime in the late 1980s to early 1990s (i.e., circa 110 years after the cave formed), the troglomorphic morph appeared, and subsequently *S. altivolans* became rare and the troglophilic morph became more restricted to the twilight and entrance zones. It is unknown whether the Kaumana Cave morph evolved *in situ* from the polymorphic troglophilic form, or arrived via subterranean dispersal, but both scenarios are possible and not mutually exclusive (Medeiros *et al*. 2009). The majority of root biomass in young pahoehoe occurs in the intermediate-size voids that permeate the flows. This hidden resource would be largely unavailable to the troglophilic form but represents the principle habitat for the cave-adapted morph (Howarth *et al*. 2019).

Hawaiian cave moths and their associated plants and animals are vulnerable to a variety of anthropogenic threats (Stone and Howarth 2007). Disturbance of the surface of inhabited flows destroys the life-giving roots as well as blocks food and water from entering voids and caves. Areas near agriculture or urban development can be affected by pollutants in runoff and from pesticide use. Fortunately, major government agencies and conservation organizations have established protective management policies for caves and their biotic and cultural resources. These entities include the U.S. National Park Service, U.S. Fish and Wildlife Service, Hawai'i Natural Area Reserves System, and The Nature Conservancy.

A more pervasive and insidious threat is posed by invasive alien species, which can invade across property boundaries. Several non-native species have invaded caves. The

impact of the black rat was discussed above and in Howarth & Stone (2020). Fortunately, many invasive animals (e.g., *Rattus rattus* and the American cockroach, *Periplaneta americana* L.) appear to be limited to larger, more accessible cave passages, a circumstance that affects some cave species as well as research programs, but these invaders may have less effect in the more isolated smaller voids (Howarth 1981). A few species appear to be able to colonize large sections of the underground habitat and may be reducing populations of cave moths. The latter include the predatory nemertine worm, *Argonemertes dendyi* (Dakin, 1915) (Howarth & Moore 1984) and several small web-building spiders. Some alien biological control agents purposefully introduced to control pest species have expanded their host range to attack native species (Howarth 1993). Their role in the reduction of cave-roosting moths was described above. The impacts of purposefully introduced microorganisms for biocontrol is not well researched, but theoretically, their effect on the cave fauna could be severe. These biological pesticides, which include strains of bacteria, fungi, and nematodes, are soil organisms reared to attack pest species. They survive well in damp, dark habitats such as caves. However, their potential impacts have not been studied in part due to the difficulty in correctly identifying the pathogen in novel hosts. For example, *Schrankia howarthi* pupae are often attacked by an unknown fungus. Cave populations occasionally experience severe epizootics that greatly reduce moth populations. The "ghosts" from these epizootics are represented by numerous moth cocoons and some dead moths covered with fungal fruiting bodies. Whether these outbreaks are the result of natural population cycles or are caused by a novel alien pathogen is unknown. Future research in this area would be worthwhile to identify the pathogen(s) and determine the cause of resultant moth declines.

The lepidopteran fauna of caves is often ignored in biological surveys and remains poorly known, largely because of the difficulties of collecting and preparing specimens suitable for study and identification. The advent of molecular techniques for identification will ameliorate this problem. Additional species of Lepidoptera will be discovered in caves both in Hawai‘i and elsewhere. The 16 species of native moths that are recorded herein and that are associated with cave habitats demonstrate that the lepidopteran fauna of caves can be exceptionally diverse and should be recognized as a significant component of cave ecosystems. Some species may be keystone species in cave ecosystems as consumers and as prey for other species. For example, moths that roost in caves import abundant food resources into the caves; scavenging moths such as tineid moths on guano (Robinson 1980) can be important in recycling organic material. Lepidoptera should be included in future biological surveys of caves.

BIOGRAPHY OF FRED STONE

Frederick Doren Stone, 79, of Kurtistown, Hawai‘i, passed away May 29, 2018 from complications of a serious caving accident that left him partially paralyzed. Fred (Fig. 3) was born 24 July 1938 on the family dairy farm in Freetown, New York. He earned a B.S. in agricultural engineering, an M.S. degree in entomology from Cornell University, and a doctorate in biogeography from the University of Hawai‘i. He kept his love for farming throughout his life and career. From 1964 to 1970, he served as an agricultural adviser in Vietnam with the International Voluntary Service and subsequently with the Thai Border Police in Thailand. After returning to the U.S.A., he taught agricultural science, organic farming and permaculture at SUNY Oswego, NY, Evergreen State College in Olympia,

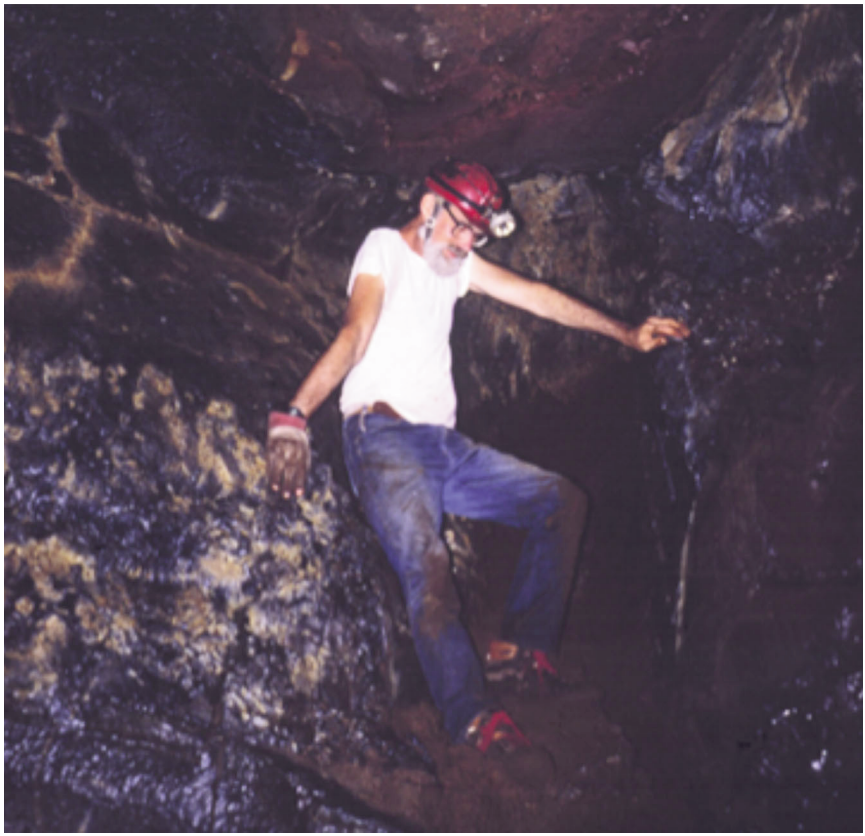

Figure 3. Fred Stone in a piping cave (Ziegler *et al.,* 2016) in the montane rainforest of East Moloka‘i. Photograph taken in January 1983 by FGH.

Washington, and environmental science at the University of Hawai‘i, Hilo. Fred developed a new educational unit at Hawai‘i Community College in Hilo, the Tropical Forest Ecosystem and Agroforestry Management (TEAM) and was its director for many years. The TEAM program inspired and trained students to competently manage native Hawaiian forest ecosystems, grow native plants, establish sustainable agroforestry operations, as well as create and use environmental and geospatial databases.

But Fred’s passion was cave exploration and cave science, and he went caving at every opportunity beginning as a student at Cornell and continuing until his accident in 2012. Stone and Howarth began caving together in New York in 1961 and formed a lifelong partnership exploring caves in the eastern U.S.A., Hawai‘i, Southeast Asia, and Australia. During their time at Cornell, Fred discovered previously unknown passages in McFails Cave in Schoharie County, New York, which made the cave the longest and most significant cave in the northeast. He then led a successful effort to raise funds to purchase and donate the cave to the National Speleological Society (NSS). The donation initiated

an interactive cave management model now used by the NSS and numerous land management agencies (Stone 2007).

Fred enjoyed teaching and frequently took his students on field trips into caves to inspire them in natural history and resource protection. He also assisted visiting scientists on their research in caves especially on Hawai'i Island where he lived from 1985 onwards. He published more than 25 articles on cave biology, many co-authored with collaborators (e.g., Northrup *et al.* 2011, Wessel *et al.* 2013). He had two long-term projects: the diversity and evolution of nocticolid cockroaches of SE Asia and Australia (Stone 1988) and *Caconemobius* crickets in Hawai'i.

Fred also worked diligently on biodiversity conservation and led many biological surveys of caves and threatened habitats in Hawai'i, Thailand, and Australia (Howarth & Stone 1993, Stone & Howarth 2007). The protocol for these surveys evolved into a more efficient and comprehensive strategy wherein all would enter and explore a cave together until the party reached a suitable sampling site. Howarth would lead the survey at the site while Stone and others explored further into the cave looking for potentially rich biological sites. When found, Stone would report back, and the survey group would move to sample the new site while the exploration group searched for the next new site.

Stone willingly provided expert witness testimony on projects affecting biodiversity including the contested case regarding industrial development of Mauna Kea's vulnerable biologic ecosystems. A life-long farmer, Stone applied his childhood farm experience to his farm in Hawai'i where he developed a Cordyline (ti leaf) nursery and where he bred novel purple cultivars.

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New plant records for the Hawaiian Islands 2015–2019

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Here we document seven new state records, eight new naturalized records, six new island records, and three species spreading adventively. A total of 18 plant families are discussed.

Information regarding the formerly known distribution of flowering plants is based on the *Manual of the Flowering Plants of Hawai'i* (Wagner *et al.* 1999) and information subsequently published in the *Records of the Hawaii Biological Survey*. All supporting voucher specimens are deposited at Bernice Pauahi Bishop Museum's *Herbarium Pacificum* (BISH), Honolulu, Hawai'i.

Acanthaceae

Justicia gendarussa Burm.f. **New state record**

Justicia gendarussa, a species native to Southeast Asia and cultivated widely throughout Asia for its use as a medicinal species for the treatment of various ailments and as a birth control method for men (Winn 2011), can be found in streambeds and roadsides in its native range. It is often naturalized where grown, to the extent that its true native range is unknown (Anonymous 2005). Several individuals of this species were found near a local swimming hole. The full description of this species from *Flora of China Online* (Hu & Daniel 2011) is as follows:

> "Subshrubs 0.7–1.5 cm tall, much branched. Stems subterete, swollen at nodes, glabrous. Petiole 3–10 mm; leaf blade narrowly lanceolate, 6–10 × 1–1.5 cm, glabrous, secondary veins 5–8 on each side of midvein, base cuneate to attenuate, margin subsinuate, apex acute to shortly acuminate. Spikes terminal or axillary, 3–12 cm, interrupted, usually in a leafy panicle; peduncle 0.5–1.5 cm; bracts triangular, 2–6 × 1–2.5 mm, basal ones longer than calyx then gradually smaller with apical most ones shorter than calyx, margin ciliate, apex acute; bracteoles elliptic to linear-lanceolate, ca. 3 × 1 mm, margin ciliate, apex acute. Calyx ca. 5 mm, 5-lobed; lobes linear-lanceolate, 3–4 × ca. 0.5 mm, subequal, apex acuminate. Corolla creamy white, 1.2–1.5 cm; tube basally cylindric and ca. 2 mm wide for 8–9 mm; lower lip violet dotted basally, cuneate-obovate, 6–10 mm broad, 3-lobed, lobes oblanceolate and 3–5 × ca. 3.5 mm; upper lip violet blotched, triangular, ca. 7 × 3.5 mm, 2-cleft. Stamens exserted; filaments 3–6 mm, glabrous; anther thecae oblong, ca. 1.2 mm, superposed, lower one spurred at base, upper one muticous. Ovary glabrous; style ca. 1 cm, glabrous; stigma capitate, shortly 2-lobed. Capsule clavate, ca. 1.2 cm. Fl. Jan–Apr. 2n = 28, 30."

Material examined. **MAUI**: Ke‘anae, Ching’s Pond, several shrublike plants ca 2 m tall, naturalized in wet lowland streambed amongst boulders with *Ardisia elliptica* and *Polygala paniculata*, 27 Oct 2014, *F. Starr & K. Starr 141027-02*.

Amaranthaceae

Amaranthus polygonoides L. **New state record**

This species was previously uncollected in the state of Hawai‘i, but now has been found in several roadside locations on O‘ahu. In its native range in the mainland U.S., it can be found in disturbed habitats and coastal areas (Flora of North America Editorial Committee 1997). It has been introduced to Europe and Asia, where it has been described as a “casual” alien (GBIF Secretariat 2019). It is likely, given the circumstances in which this species has been found on O‘ahu, that it is being spread on mowing equipment. The full description from *Flora of North America Online* (Mosyakin & Robertson 2003) is as follows:

> “Plants annual, glabrescent proximally, pubescent distally, becoming glabrous at maturity. Stems erect-ascending to prostrate, branched mostly at base and in proximal 1/2, 0.1–0.5 m. Leaves: petiole ± equaling blade; blade ovate, obovate-rhombic to narrowly ovate, sometimes lanceolate, 1.5–3(–4) × 0.5–1.5(–2) cm, base cuneate, margins entire to undulate-erose, apex rounded, obtuse, or emarginate, mucronate. Inflorescences axillary, congested clusters. Bracts of pistillate flowers lanceolate or linear, 1–1.5 mm, 1/2 as long as tepals. Pistillate flowers: tepals 5, connate in proximal 1/3 (entirely distinct in all other species), with 3 prominent veins abaxially, spatulate or somewhat clawed, equal or subequal, 2–3 mm, apex rounded or retuse, mucronate; style branches somewhat spreading; stigmas 3. Staminate flowers intermixed with pistillate; tepals (4–)5; stamens 2–3. Utricles cylindric or narrowly turbinate, 2–2.5 mm, ± equaling tepals, smooth proximally or roughened toward tips, indehiscent or tardily dehiscent. Seeds dark reddish brown to black, lenticular, 0.8–1 mm diam., shiny.”

Material examined. **O‘AHU**: Waikele, H-1 westbound off-ramp, dry to mesic disturbed roadside, herbs ca 0.33 m tall, ca 100 plants in a small patch, *D. Frohlich & A. Lau 20181201*; Wai‘anae HDOT baseyard, low-growing herbs in a mowed field growing with roadside ruderal vegetation, occasional on property, not common, 21 Sep 2019, *A. Lau & D. Frohlich 2019092101.*

Asteraceae

Hedypnois rhagadioloides (L.) F.W. Schmidt **New state record**

This species, which is native to the Mediterranean, is naturalized in California and Texas on the U.S. mainland. This thorny herb has proven to be difficult to control at Schofield Barracks on O‘ahu, where thousands of individuals were found naturalized in several locations. The full description of this species comes from *Flora of North America Online* (Strother 2006):

> “Annuals, (5–)10–60+ cm; taprooted. Stems usually 1, erect, branched distally, ± hispid to setose (hair tips often forked). Leaves basal and cauline; basal ± petiolate, distal sessile; blades lanceolate, linear, oblanceolate, oblong, or ovate, margins entire or dentate to pinnately lobed (faces ± hispid). Heads borne singly or in loose, corymbiform arrays. Peduncles ± inflated distally, not bracteate. Calyculi of 3–10+, deltate to lanceolate or lance-linear bractlets. Involucres campanulate to cylindric, 3–12 mm diam. (larger, ± globose in fruit). Phyllaries 5–13+ in 1 series, linear-navicular (± keeled, each ± enfolding subtended ovary or cypsela), subequal, margins little, if at all, scarious, apices acuminate.

> Receptacles flat, ± pitted, glabrous, epaleate. Florets 8–30+; corollas yellow (often reddish proximally, greenish abaxially). Cypselae dark brown to black, cylindric to fusiform (usually ± arcuate), not beaked, ribs 12–15, faces ± scabrous or barbed; pappi persistent, whitish; on outer cypselae often coroniform (distinct or connate, erose to fimbriate scales); on inner cypselae 0–5+, cuneate to lanceolate or subulate outer scales plus 5+, lance-aristate to subulate-aristate, inner scales. x = 9."

Material examined. **O'AHU**: Schofield Barracks, Kolekole ranges, MAF landing zone, sprawling herb in disturbed open area, naturalized, thousands of plants present, 25 May 2013, *J. Beachy & J. Gustine-Lee US Army 313*; Schofield Barracks South Range, at MOUT training facility, sparingly naturalized in non-native dominated habitat, 16 Feb 2015, *J. Beachy, K. Cloward, C. Osaki & E. Long US Army 373*; Schofield Barracks, Kolekole ranges, MAF landing zone, multiple naturalized populations in the area, 23 Mar 2015, *J. Beachy & J. Hawkins US Army 377*.

Elaeocarpaceae

Elaeocarpus argenteus Merr. **New state record**

This species is not known to be cultivated, nor has it been collected as a weed, outside its native range of the Philippines. Its introduction history to Hawai'i is unclear. It is scattered and rare in native-dominated forest near the summit ridge of the central Ko'olau Mountains. Some individuals found in the area have been controlled, and others remain. Reports from local botanists indicate there may be a more established population in Punalu'u Valley. It is possible the species was intentionally introduced to that valley at some point. This species can be distinguished from other *Elaeocarpus* known in Hawai'i by the following combination of characters: branchlets glabrous; petiole 1.5–2 cm long, swollen at base and at apex; leaf blades elliptic-oblong, leathery, and glabrous, with glands (or domatia) on underside at junctions of the midvein and secondary veins, the margins crenate, apex acuminate; racemes 5–7 cm long, peduncle densely pubescent; flowers bisexual, the buds ellipsoid with an acute apex; petals laciniate. The full description of this species from *Flora of China Online* (Tang & Phengklai 2007) is as follows:

> "Trees evergreen. Branchlets brown, terete, glabrous. Petiole 1.5–2 cm, glabrous, slightly swollen at each end; leaf blade elliptic-oblong, usually tapered to base, 6.5–8 × 2–2.5 cm, leathery, glabrous, lateral veins 5 or 6 per side, midvein raised on both surfaces, axils mostly prominently glandular abaxially, base obtuse or acute, margin shallowly sparsely crenate, apex acuminate. Raceme 5–7 cm; peduncle densely pubescent. Pedicel 5–6(–8) mm, densely appressed-pubescent. Flowers bisexual; buds ellipsoid, ca. 4 mm, apex acute. Sepals 5, lanceolate, abaxially densely minutely gray pubescent, adaxially keeled. Petals 5, oblong-obovate, ca. 4 mm, abaxially silvery sericeous, adaxially white villous in lower part and along margin, upper 1/3 laciniate; segments 12. Stamens ca. 28; filaments ca. 1 mm, villous; anthers linear, ca. 2 mm, minutely puberulent, not awned but pubescent at apices. Disk 5-lobed, villous. Ovary villous, 2-loculed; style tomentose on lower 1/2. Drupe ovoid, ca. 8 × 6 cm; exocarp obscure, glabrous; endocarp inconspicuously verrucose. Fl. and fr. unknown."

Material examined. **O'AHU**: Central Ko'olaus, upper Kaluanui, single small tree in native-dominated wet forest., though others noted in central Ko'olau summit area, UTM 612183, 2384083, 12 Mar 2015, *L. Reynolds & R. Pender 2015031201*; Ko'olau Mountains, upper Pe'ahināi'a, near summit, single tree with white bark, ca 5 m tall, 8–9 cm diam trunk, very young trees of same description in Pe'ahināi'a observed in the past, 7 Dec 2005, *J. Beachy US Army 29*.

Fabaceae

Albizia procera (Roxb.) Benth. **New naturalized record**

Albizia procera, a species native to China and Southeast Asia, has been found naturalized in several locations in central O‘ahu. While there are examples of this tree that are clearly planted in the landscaping at Wheeler Army Airfield, several medium-sized to small trees on Wheeler were observed in places that do not look like deliberate plantings. The full description of this species comes from *Flora of China Online* (Delin & Nielsen 2010):

> “Trees, deciduous, to 15 m tall. Branchlets slightly pubescent or subglabrous. Leaf petiole with an oblong gland ca. 1 cm above base; pinnae 3–5 pairs, 15–20 cm; petiolules ca. 2 mm; leaflets 6–12 pairs, ovate to subrhombic, 3–4.5 × 1.2–2.2 cm, subleathery, sparsely appressed pubescent, main vein closer to lower side, base oblique, apex obtuse or emarginate. Heads ca. 20-flowered, arranged in axillary or terminal panicles. Flowers uniform, sessile. Calyx 2–3 mm, glabrous. Corolla yellow-white, ca. 6 mm; lobes lanceolate, ca. 2.5 mm, apex pubescent. Staminal tube longer than corolla tube. Ovary glabrous, subsessile. Legume ligulate, flat, 10–15 × 1.5–2.5 cm, glabrous. Seeds 8–12, obovoid-elliptic; pleurogram obovate-elliptic. Flowers May–Sep, fruits Sep–Feb of following year.

Material examined. **O‘AHU**: Waipi‘o, along Kamehameha Hwy just south of Mililani, near south end of Kīpapa Gulch, dry/mesic roadcut, upright tree with sparse canopy 10–12 m tall, scattered on roadcut, more trees in area, UTM 602253, 2570026, 06 Jan 2017, *A. Lau 01*; perimeter of Wheeler Army Airfield, along Kunia Road, growing with *Spathodea campanulata*, planted *Carex wahuensis*, tree 30 ft [9 m] tall, ca 5 plants, 850 ft [260 m], UTM 599428, 2376407, 16 Jan 2019, *K. Kawelo US Army 505.*

Calliandra surinamensis Benth. **New island record**

This record represents the first collection of this species as naturalized on Kaua‘i, having been collected in 1987 naturalizing in a fencerow and into a pasture in Kalaheo. It was first collected as naturalized on West Maui in 2009 (Starr & Starr 2011).

Material examined. **KAUA‘I**: Kōloa Distr., Kalaheo, along Waha Road 0.5 mi [0.8 km] east of intersection with Papalina Road, small tree 3 m tall, naturalized locally in fence row and adjacent pasture, 600 ft [185 m], 1 May 1987, *D. Lorence & T. Flynn 5202*.

Leucaena* ×*spontanea C.E. Hughes & S.A. Harris **New island record**

Leucaena ×*spontanea*, a hybrid of *L. leucocephala* and *L. diversifolia*, was found sparingly naturalized in an O‘ahu botanical garden, in proximity to its parent species. It was previously recorded as naturalized on East Maui (Oppenheimer 2004). This species is so named in reference to its spontaneous occurrence when the two parent species are brought together in cultivation. The complete description of this hybrid is from Hughes (2010):

> “Small to medium-sized tree, 5–15(–20) m tall, bole diameter 30–40 cm, with a short bole, heavy branching, and a wide, open, spreading crown. Bark mid-grey-brown with shallow rusty orange-brown vertical fissures, inner bark green. Shoots terete, mid-orange brown, glabrous or sparsely puberulent. Leaves (19–)24–27(–30) cm long, (10–)11–14 cm wide; petioles (including pulvinus) (30–)32–36(–38) mm long, with a single green or reddish green, sessile, elliptic or rounded, cupulate nectary, 2.8–3.5 × 2–2.5 mm, often slightly wider at distal end than at the base, at the distal end on adaxial side of petiole; rachis 14–21 cm long, with 1 or 2 nectaries, 2.6 × 1.4 mm, elliptic, discoid, or shallowly crateriform, at the distal end, apex of rachis extending beyond the terminal pinnae as a slender pointed glabrous mucro 2.5–4 mm long, curling when dry; pinnae

(10–)11–16(–18) pairs; pinnular rachis 6.5–9 cm long, angled, sparsely puberulent, with 1 or 2(–3) sessile discoid elliptic nectaries, 0.3 × 0.7 mm, at base of terminal pairs of leaflets; leaflets (22–)26–36(–48) pairs per pinna, (6.2–)8–10(–11.9) mm long, 1.2–2(–2.3) mm wide, nearly sessile, asymmetric, linear, acute or acuminate apically, rounded and strongly asymmetric basally, glabrous except ciliate at margins, asymmetric midrib and 1 or 2 secondary veins visible on dried leaflets. Capitula (17–)20–24(–28) mm in diameter at anthesis, in fascicles of (1–)2–5 in leaf axils on actively growing shoots, the leaves developing with the capitula, each capitulum with 130–160 flowers; peduncles 24–33 mm long, angled, densely or sparsely pubescent with an involucre of bracts at the distal end. Flowers subtended by peltate bracts, 2.5–3 mm long, 0.8 mm in diameter; calyx 3–3.3 mm long, hairy on distal half and ciliate on lobe margins, pale whitish green; petals 4.7–5.4 mm long, free, hairy on distal half and ciliate on margin, pale whitish green; filaments 7.5–9.5(–10) mm long, white or pale pink; anthers hairy, white or pale pink, apiculum absent; ovary 2.5–2.8 mm long, covered in white hairs at distal end, pale greenish white, with 18–24 ovules, style 12–13 mm long, white or pale pink, with a terminal tubular stigma, exserted strongly beyond the anthers. Pods (8–)10–15(–18) cm long, (12–)15–20(–22) mm wide, linear-oblong, the apex rounded with a short pointed beak, the base cuneate, 14–20-seeded, valves chartaceous or membranous, mid-green when unripe, turning mid-brown, glabrous, opening along both sutures, endocarp not partitioned between seeds. Seeds 6.5–7 mm long, 2.9–3.5 mm wide, compressed, oblong, dark reddish chest nut-brown, glossy, pleurogram visible, U-shaped with 95% arm extension."

Material examined. **O'AHU**: Ho'omaluhia Botanical Garden, edge of garden grounds, mesic lowland disturbed site, sparingly naturalized at this site, growing with both *Leucaena diversifolia* and *L. leucocephala*, 08 Dec 2015, *A. Lau 2015120801*.

Platymiscium stipulare Benth. **New naturalized record**

Previously found as a small adventive population in a suburban setting, this species has now been collected on O'ahu spreading into a forest reserve in Nānākuli.

Material examined. **O'AHU**: Nānākuli Valley, terminus of ranch road into forest reserve, dry to mesic lowland forest reserve, scattered about, young and older trees present, UTM 2366896, 592106, 1 Apr 2016, *T. Takahama 20160401A*.

Tephrosia pumila (Lam.) Pers. **New naturalized record**

This species, which is widespread throughout tropical regions, was found scattered throughout a weedy roadside location near Kahului Airport on the island of Maui. The full description comes from *Flora of West Pakistan* (Stewart 1982):

"Annual or short lived perennial, branches procumbent, stem pilose. Leaf imparipinnate, petiole c. 3–10 mm long, rachis up to 4.5 cm long; leaflets 7–13, c. 4-20 mm long, up to 8 mm wide, oblong or oblanceolate truncate to retuse, glabrous or pubescent above, pilose below; stipules up to 4 mm long. Inflorescence terminal or leaf-opposed, a 1–3-flowered raceme. Bract 2–3 mm long. Pedicel 2.5–4 mm long. Calyx hispid, tube c. 1.5 mm long, teeth 2.5–3.5 mm long. Corolla white, pale-pink or purplish. Vexillum c. 6–10 mm long. Fruit 3.5–4 cm long, c. 4 mm broad, pubescent, curved towards the tip, 8–14-seeded."

Material examined. **MAUI**: Kahului Airport, growing in a gravel pile, low prostrate mats 60–80 cm diam, 30 May 2012, *R. Hobdy 4340*; Kahului Airport, on edge of rental car storage lot and *kiawe* shrubland, scattered along margin of *kiawe* thicket and grassy parking area, lowland coastal scrub with *Prosopis pallida, Boerhavia coccinea, Cenchrus ciliaris*, 20.509839 N, -156.443906 W, 21 Nov 2017, *K. Starr & F. Starr 171121-01; loc. cit.,* 26 Jan 2018, *F. Starr & K. Starr 180126-01*.

Vigna luteola (Jacq.) Benth. **New island record**

This species, which has previously been collected as naturalized on the islands of Kauaʻi (Frohlich & Lau 2012), Oʻahu (Staples *et al.* 2003), and West Maui (Oppenheimer 2019), was found in a roadside location on the island of Hawaiʻi, vining up several trees and along the ground.

Material examined. **HAWAIʻI**: HDOT staging area vining up a nearby tree, growing with *Urochloa maxima, Bidens pilosa*, 7 × 7 m patch, three other patches in this area, another farther north towards Ikaika St., UTM 284912, 2174021, 10 Jan 2019, *A. Lau & D. Frohlich 2019011001*.

Gentianaceae

Chelonanthus acutangulus Slooten **New state record**

This species, which is native to Brazil, Venezuela, Trinidad, and the Guianas, was found on Oʻahu growing out of erosion matting along an Army access road and in an LZ on the same installation. The introduction pathway for this species remains unclear. Over 200 plants total were found and treated with herbicide in these two areas. The full description of this species is from *Flora of the Guianas Online* (Mota de Oliveira 2014; *as C. alatus*):

> "Herb to subshrub, up to 2.5 m high, unbranched to sparsely branched. Stems and branches up to 1.1 cm in diam., strongly quadrangular, 4-angled to 4-winged, wings 0.1–1.3 mm wide; internodes 0.5–30.3(–47.3) cm long. Leaves sessile, cauline, evenly distributed along stem; blade membranaceous, elliptic, 2.9–23.2 × 1.2–8(–12) cm, margin not thickened, flat, apex acute to acuminate, base attenuate, obtuse to truncate. Inflorescence 3–100-flowered; bracts ovate with obtuse (acute) apex, 0.8–9.4 mm long; pedicel 4–9 mm long. Flowers erect to horizontal; calyx green, 4–8 × 3–6 mm, lobes ovate, 2–6 × 2–4 mm, margin membranaceous, apex obtuse; corolla white, cream, with dark green spot on apex of each corolla lobe, funnel-shaped to campanulate, 20–50 mm long, 8–21 mm wide at mouth, lobes ovate, 3–11 × 4–13 mm, apex obtuse or acuminate; stamens exserted or not, filaments 14–40 mm long, straight, or curved downward close to anther, anthers white to pale green, oblong, 2–3.8 mm long, straight to slightly curved; pollen exine with muri fragmented into elongated to knob-like processes that are thickened along equatorial zone; pistil 24–34 mm long, ovary 4.4–5.6 × 2.1–2.6 mm, style 14–23 mm long, stigma lobe elliptic to obovate, 2.8–4.4 × 1.1–2.3 mm. Fruit nodding, brown, 8–23 × 3–10 mm; seeds brown, 0.1–0.4 mm in diam."

Material examined. **Oʻahu**: Kawailoa, Drum Road, herb up to 1 m tall, sparingly naturalized population of ca 15 plants, growing out of erosion control matting, 9 Mar 2016, *J. Hawkins & J. Rellamas US Army 428*; Kawailoa, Drum Road, after LZ Puʻu Kapu near mile marker 10, open canopy on hot, dry, 45-degree slope, growing with *Spathoglottis plicata, Pterolepis glomerata, Metrosideros polymorpha, Nephrolepis brownii, Clidemia hirta, Bidens alba,* 170 plants (incl. seedlings) in 2 areas within black mesh erosion control matting, all treated with herbicide, UTM 2387579, 601753, 5 May 2016, *J. Hawkins & J. Rellamas US Army 443.*

Juncaceae

Juncus acuminatus Michx. **New island record**

This species has previously been documented from the islands of Maui and Hawaiʻi (Wagner *et al.* 1999), and is now known to occur on Oʻahu. It was found growing in pooled water on a streamside boulder in full sun.

Material examined. **Oʻahu**: Waimea Valley, along Kamananui Stream, small naturalized population in a lowland riparian area, growing in puddles on large boulder, UTM 599169, 2392103, 03 Jun 2013, *A. Lau & D. Frohlich 2013060301*.

Lamiaceae

Callicarpa macrophylla Raeusch. **New naturalized record**

This species is not common in cultivation in Hawai‘i but has been documented in cultivation since 1928. It is native to tropical and subtropical Asia, where it grows in a variety of habitats, including disturbed areas as well as mixed forests. It does not appear to be documented as naturalized anywhere else. A small population was observed along the Ko‘olau summit in native-dominated forest. It can be distinguished from other *Callicarpa* in Hawai‘i by its lanceolate-elliptic leaves that are pointed at both ends, more open inflorescence heads that are 1–3 inches [2.5–7.5 cm) in diameter, and white fruits (Staples & Herbst 2005).

Material examined. **O‘AHU**: Waiawa, near summit ridge, wet native-dominated forest, small tree to 3 m height, small naturalized population, ca 5 plants of various sizes present, UTM 615097, 2374408, 22 Apr 2015, *M. Berger s.n.* (BISH 763743).

Lauraceae

Neolitsea cassia (L.) Kosterm. **New naturalized record**

This species was previously published as showing signs of naturalization on O‘ahu (Lau and Frohlich 2013), where a single naturalized tree was found in secondary forest on the Likeke Trail above Ho‘omaluhia Botanical Garden. A naturalized population is documented here from secondary forest surrounding the garden, where it is an occasional to locally common element of the vegetation, primarily in shady, non-native dominated habitat. It is a small tree distinguishable from other taxa in Lauraceae in Hawai‘i by its alternate leaves with two sub-basal lateral veins, which do not have a cinnamon-like scent when crushed, the flowers in umbels, sessile on very short branchlets at the internodes. Keys and a full description can be found in *Flora of Ceylon* (Dassanayake *et al.* 1995).

Material examined. **O‘AHU**: Ho‘omaluhia Botanical Garden, near Kahua Kuou section, small tree to ca 5 m, occasional to common in non-native secondary vegetation surrounding cultivated areas of garden, occasional in areas *mauka* of garden grounds, 2 Jun 2015, *A. Lau 2015060201*.

Moraceae

Ficus religiosa L. **New island record**

This species has previously been documented as naturalized on the islands of Maui and Hawai‘i (Oppenheimer & Bustamente 2014; Parker & Parsons 2012), and O‘ahu (Frohlich & Lau 2008), although the original O‘ahu record is considered adventive (Wagner *et al.* 2012). Since it was first found, it has become increasingly common and established as naturalized on the island, particularly in urban areas throughout Honolulu. Some plants are repeatedly cut back but resprout vigorously and have reached maturity under these circumstances.

Material examined. **O‘AHU**: Honolulu, along H-1 freeway, at Pali exit (*‘ewa* bound), dry lowlands in urban setting, 5 m tall, established in and widening seam in concrete wall next to freeway, figs at various stages of development, 02 Dec 2014, *A. Lau 2014120201*.

Piperaceae

Piper divaricatum G. Mey. **New naturalized record**

Native to tropical South America, this *Piper* species does not appear to be widely introduced to regions outside of its native range. It has been introduced to at least two botanical gardens on O‘ahu and was found naturalizing in one on the windward side of the

island. It is capable of forming thickets in dense shade. It can be distinguished from other species of *Piper* in Hawai‘i by its shrub habit, subcoriaceous leaves with pinnate venation, young stems green with white spots, and swollen nodes. A key and full description is available in *Bulletin of the British Museum* (Tebbs 1990).

Material examined. **O‘AHU**: Ho‘omaluhia Botanical Garden, near Kahua Kuou section, sparsely branched shrub 2 m tall, growing in dense shade at edge of *hau* thicket, spreading from plantings in Tropical American section, capable of forming dense thickets, UTM 623736, 2365214, 14 Apr 2015, *A. Lau 2015041405*.

Poaceae

Paspalum arundinaceum Poir. **New island record**

This species has been previously documented on Maui (Snow & Davidse 2011), and is now known to occur on O‘ahu as well. The population occurs over at least an acre of pastureland. Reports indicate that it can create thickets of vegetation that can cut skin, and may be unpalatable to cattle.

Material examined. **O‘AHU**: Ka‘a‘awa Valley, Kualoa Ranch, NW slope of valley in a cattle pasture, lowland disturbed rangeland, ca 1.5 m tall, occupying at least an acre, 22 Oct 2015, *P. Conant s.n.* (BISH 765243).

Pteridaceae

Adiantum trapeziforme L. **New naturalized record**

This tropical American fern species, which is moderately popular in cultivation, was found growing along a popular trail in central O‘ahu. This species can be distinguished from other *Adiantum* in Hawai‘i by its twice-pinnate, mostly trapezoid-shaped, unequal-sided leaflets 1–2 inches [2.5–5 cm] long, on slender, short, jointed stalks. The color of the stalks ends abruptly at the leaflet blades (Staples & Herbst 2005).

Material examined. **O‘AHU**: Kalauao Falls Trail, mesic non-native forest, erect to arching terrestrial fern to ca 1 m tall, rhizomatous, ca 5 plants in the area, naturalized, UTM 614507, 2367346, 29 Jan 2016, *K. Kawelo & J. Rohrer US Army 408.*

Salicaceae

Flacourtia zippelii Slooten **New state record**

This species, which is native to Papua New Guinea, was found widely scattered throughout a botanical garden on the windward side of O‘ahu. A parent plant had been accessioned to the garden and was still present at the time of collection. Individuals of all size classes were noted. A full description of this species can be found in *Trees of Papua New Guinea* (Conn & Damas 2019). An abridged description follows:

> “Large canopy tree (up to c. 30 m high) or small sub-canopy tree (10–20 m high); bole cylindrical (up to c. 25 cm diam.); bark grey or brown, smooth; bark exudate (sap) absent; terminal buds not enclosed by leaves…Leaves… simple, (7.0–)12.0–21.0 cm, (30.0–)50.0–70.0(–90.0) cm, symmetric (to very slightly asymmetric), entire or coarsely crenate, acuminate, venation pinnate, secondary veins open, prominent, leaves lower surface dark green (sub-glossy), upper surface green, indumentum (hairs) absent. Inflorescence axillary, flowers on an unbranched axis, cones absent; flowers unisexual, with male and female flowers on the same plant, stalked; flowers 2.0–3.0 mm long, up to 10 mm diameter; perianth present, with all sepals and/or petals (tepals) similar or petals absent, inner perianth pale yellow, green, or cream-coloured (sepals); 4–5, free or some or partly joined (slightly joined at base); stamens 15 (c.), ovary superior, carpels joined

(when more than one), locules 4–5; styles free, 4(usually persistent in fruit)–5. Infructescence arranged on unbranched axis, fruit 15.0–20.0 mm long, red, non-fleshy to fleshy drupe; seeds (1–)2(–4), to about 5 mm long (5–8 mm long), not winged, broad (as wide as long), seed 1–10 mm diam. (c. 6 mm diam.)."

Material examined. **O'AHU**: Ho'omaluhia Botanical Garden, just *mauka* of Kahua Kuou section, tree to 5 m tall, naturalized population including trees ca 18 m tall, juvenile plants rare and well scattered in garden, 19 May 2015, *A. Lau 2015051901*.

Urticaceae

Pilea spruceana Wedd. **New state record**

This species is a sparsely villous, low-growing herb with oblong to ovate-oblong, ciliate leaves 2–8 cm long and 1.5–4 cm wide, purple-tinged below and dark green above with silver stripes along the central vein, and crenate-serrate, sparingly ciliate margins. Leaves are strigillose above, villous beneath, with punctiform and fusiform cystoliths (more punctiform at the margins). Plants are monoecious or dioecious, with pistillate flowers in short-peduncled cymes (Killip 1937). Hundreds of individuals were found spread along a more than 60-meter stretch of streambed in east Maui; the nearest residence was over 300 feet away [90 m] from the collection.

Material examined. **MAUI**: Nāhiku, growing along seasonal streambank with *Mangifera indica*, *hau, Miconia calvescens*, herbaceous plant ca 4–6 in [10–15 cm] tall, no flowers or fruit seen, hundreds of individuals along >200 ft [120 m] stretch of stream, UTM 2305596, 802548, 20 Jun 2019, *D. Frohlich & A. Lau 2019062001*.

Violaceae

Viola hederacea Labill. **New naturalized record**

Known also by the common name Australian violet, this low-growing herb is occasional in cultivation in Hawai'i, having been first documented here in 1977. It is grown elsewhere outside its native range, and has become naturalized in at least China (Chen *et al.* 2007). It can be distinguished from other species of *Viola* in Hawai'i by a stoloniferous habit, the plants essentially stemless with leaves in rosettes, the leaves kidney-shaped with rounded apices. A key and full description can be found in *A Tropical Garden Flora* (Staples & Herbst 2005). It was found along a dirt road through mesic secondary forest in in the vicinity of home sites. When not flowering, its vegetative resemblance to other common weeds in Hawai'i (such as *Centella asiatica*) may limit the degree to which this species is noticed and documented as naturalized by field botanists.

Material examined. **O'AHU**: Pālehua, side road leading to single cabin, mesic secondary forest, growing in partial shade in non-native dominated secondary forest, naturalized patch of ca 100 plants, 28 Jul 2015, *K. Kawelo US Army 397*.

TAXA SHOWING SIGNS OF NATURALIZATION

Asteraceae

Carthamus tinctorius L.

This species, known by the common name safflower, is cultivated as a source of vegetable oil, dye, as an ornamental, and as birdseed. Given its location in a public park, it is likely to have been brought in for birdseed, as the species is a common component in birdseed mixes. It is believed to have originated in the Mediterranean, but today it is only found in cultivation and escapes where grown (Keil 2006). Two mature plants with many small

seedlings were found in this area; a separate immature plant was noted elsewhere in the park in a coral fill pile.

Material examined. **O‘AHU**: Ala Moana Beach Park, Magic Island, near lifeguard stand, herb to 0.5 m tall, leaves spiny along margins, flower heads thistle-like, petal/corolla lobes yellow, aging to orange, dry coastal area near cultivated setting, open canopy, growing with *Melilotus indicus* and *Medicago*, 17 Mar 2017, *D. Frohlich & A. Lau 2017031701*.

Convolvulaceae

Ipomoea corymbosa (L.) Roth ex Roem. & Schult.

This species was found sprawling over a *Leucaena leucocephala* shrub along a major highway in Anahola, Kaua‘i. Although there are a few houses in the area, this vine was not obviously planted or tended. This species commonly naturalizes where it is grown. The full description of this species from *Kew Bulletin* (Wood *et al.* 2015) is as follows:

> “Liana climbing to about 7 m over shrubs and small trees; stems woody, usually glabrous. Leaves petiolate, 4–10 × 3–9 cm, ovate, cordate with rounded auricles, narrowed to an obtuse, shortly mucronate apex, glabrous or (rarely) pubescent, abaxially paler; petioles 2–5 cm. Inflorescence of lax compound cymes terminal on the main stem and on lateral branchlets 5–20 cm long; secondary peduncles 1–5 cm, bracteoles c. 2 mm, scale-like; pedicels 7–17 mm, sepals slightly unequal, oblong, obtuse, nearly completely scarious, glabrous, outer 10–11 mm, inner 11–14 mm; corolla 2.5–3 cm, campanulate, cream with dark center and yellow midpetalline bands, glabrous, limb c. 1.5–2 cm diam. Capsule narrowly ovoid, 11–14 × 3–4 mm, glabrous, style persistent, seeds 1–2, 4–5 mm diam., subglobose, tomentose.”

Material examined. **KAUA‘I**: Kūhiō Road near intersection with Hui Road, Anahola area, growing with *Leucaena leucocephala, Megathyrsus maximus, Lantana camara*, vine forming small patch (5 × 5 m) overhanging roadside vegetation, 15 Mar 2019, *A. Lau & D. Frohlich 2019031501*.

Primulaceae

Ardisia solanacea (Poir.) Roxb.

This species, one of several *Ardisia* species either naturalized or spreading adventively in Hawai‘i, was found spreading 10 meters away from the parent plant in a botanical garden in central O‘ahu. The full description of this species comes from *Flora of China* (Chen & Pipoly 2010):

> “Shrubs or trees to 6 m tall, glabrous. Branchlets prominently angular, 5–7 mm in diam. Petiole canaliculate, 1–2 cm; leaf blade elliptic or oblanceolate, 12–20 × 4–7 cm, papery, conspicuously black punctate and punctate-lineate abaxially, not prominently punctate adaxially, base cuneate or narrowly decurrent on petiole, margin subrevolute, entire, apex acute; lateral veins ca. 20 on each side of midrib, raised on both surfaces, marginal vein absent. Inflorescences at bases of new shoots, paniculate with racemose or rarely corymbose branches, 3–8 cm. Flowers leathery, pink, ca. 1 cm. Sepals broadly ovate to reniform, ca. 3 mm, densely black punctate, base subauriculate, margin subentire or crenulate, ciliate, scarious, apex rounded. Petals nearly free; lobes broadly ovate, ca. 9 mm, punctate, margin entire, hyaline, apex obtuse or acute. Stamens subequalling petals; filaments ca. 1/4 anther length; anthers linear-lanceolate, densely punctate dorsally, longitudinally dehiscent, apex acute. Pistil subequalling petals; ovary globose, densely punctate; ovules numerous, multiseriate. Fruit purplish red or blackish, oblate, 7–9 mm in diam., densely black punctate. Fl. Feb–Mar, fr. Aug–Nov. 2n = 46.”

Material examined. **O‘AHU**: Wahiawā Botanical Garden, *Ficus* overstory with mixed botanical garden species, growing in dappled shade, flowers hot pink, cupped upward, leathery, fruits immature, 5 plants growing 10 m away from parent plant, 16 Jul 2012, *A. Lau & D. Frohlich 2012071602*.

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New Hawaiian plant records from *Herbarium Pacificum* for 2019

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Reducing the backlog of unprocessed historical collections in Bishop Museum's *Herbarium Pacificum*, combined with a sweep through the Hawaiian vascular plant database, has revealed a number of new plant records for the Hawaiian Islands. Among these are four new state records (naturalized taxa previously unrecorded in Hawai'i), four new naturalized records (naturalized taxa previously known only in cultivation in Hawai'i), numerous new island records (naturalized taxa now reported on a new island), and one cultivated species showing signs of adventive naturalization. Among the 51 taxa included in this paper, all are introduced except for 4 native taxa (*Cyperus hillebrandii* var. *hillebrandii, Microlepia strigosa* var. *mauiensis, Peperomia cookiana, Panicum fauriei* var. *carteri*). All identifications of taxa included in this paper were made by staff of Bishop Museum's Department of Natural Sciences/Botany, except where noted in the acknowledgments, and all supporting voucher specimens are on deposit at *Herbarium Pacificum* (BISH), except as otherwise noted.

Readers of the *Records of the Hawaii Biological Survey* should note that *Herbarium Pacificum* subscribes to the taxonomic constructs recommended by the Angiosperm Phylogeny Group (1998, 2003, 2009, 2016) and Pteridophyte Phylogeny Group (2016). As such, some genera are placed in families that may be unfamiliar to those who are intimately familiar with Wagner *et al.* (1990, 1999) and Palmer (2003) (*e.g., Atriplex* in Amaranthaceae, not Chenopodiaceae; *Lemna* in Araceae, not Lemnaceae; *Cuscuta* in Convolvulaceae, not Cuscutaceae; *Azolla* in Salviniaceae, not Azollaceae). A review of recent taxonomic and nomenclatural changes affecting naturalized taxa in Hawai'i can be found in Imada (2019; see Appendix A for updated synonymy listing); also included is an alphabetical listing of all families and genera of naturalized taxa in Hawai'i, dating back to Wagner *et al.* (1990) and Palmer (2003), along with their current dispositions.

Acanthaceae

Justicia secunda Vahl **New state record**

Justicia is a large genus of ca. 700 species (Mabberley 2017) mostly distributed throughout tropical regions of the world. It is separable from many other cultivated acanth genera in Hawai'i by its distinctly 2-lipped (as opposed to more openly spreading) corollas with 2 fertile stamens. Up to now, four species of *Justicia* have been documented as naturalizing in the Hawaiian Islands: *J. betonica* L. (white shrimp plant), *J. carnea* Lindl. (flamingo flower), *J. spicigera* Schltdl. (see Imada 2019 for details), and, most recently, *J. gendarussa* Burm. f. (Frohlich & Lau 2020). A new naturalizing species of *Justicia* was

1. Contribution No. 2020-005 to the Hawaii Biological Survey.

first observed and collected in 2018 by Talbert Takahama, biologist with the Hawai‘i State Department of Land and Natural Resources–Division of Fish and Wildlife, along Poamoho Stream in central O‘ahu. Exploring the streambank between 1,000 and 1,200 feet (305–365 m) elevation, he observed that the plant was the predominant understory species, in association with an alien overstory of *Psidium cattleyanum*, *Ardisia elliptica*, *Citharexylum caudatum*, *Eucalyptus* spp., and *Falcataria moluccana*. Field photos were sent to Tom Daniel (California Academy of Sciences), who thought they matched *J. secunda* Vahl, a species whose native range includes the West Indies, Panama, and Colombia (Durkee 1978). Subsequent study of the *Justicia* key and description in the Acanthaceae treatment of the *Flora of Panama* (Durkee 1978) by *Herbarium Pacificum* staff confirmed its identification. The following plant characters are extracted from Durkee's description:

> "Herb to ca. 2 m tall. Leaves ovate to lanceolate, to 16.5 cm long and 6.5 cm wide, apically acuminate, basally acute or obtuse, the cystoliths numerous and prominent to ca. 2 mm long, the margins entire to crenulate; petioles to 3 cm long. Inflorescences thyrsoid to paniculate, mostly terminal, 5–15 cm long, 7 cm broad; rachis with the peduncle and the pedicel pilose; bracts linear to subulate, to ca. 6 mm long and 0.5 mm wide, keeled, ciliolate. Flowers with the calyx 5-merous, the segments elliptic oblong, equal, to 9 mm long, 2 mm wide, apex acuminate; corolla red or purplish red, bilabiate, 2.5–4.3 cm long, the tube short, ca. 1 cm long, 3 mm wide at base, 5 mm wide at the throat, the upper lip to 32 mm long and 8 mm wide with two small 1 mm wide, acute lobes at the apex, the lower lip slightly longer, to 35 mm long and 6.5 mm wide with 3 small, ca. 2 mm long, semiorbicular lobes at the apex, the middle lobe 2 mm wide, the lateral lobes 1.5 mm wide; stamens extending about as far as the upper lip and mostly within it, the anthers usually exposed at maturity, the cells subparallel, attached unequally by a connective 0.5–0.75 mm wide, filaments glabrous, flattened; style held within the upper lip, extending just beyond the stamens, increasingly puberulous toward the tip, the stigma subcapitate. Capsule clavate, ca. 1 cm long, 5 mm wide, the apex acute."

Justicia secunda apparently has no prior recorded history of cultivation in Hawai‘i, and its weediness in other countries is undocumented. Three of the already-naturalized *Justicia* species (*J. betonica, J. carnea, J spicigera*) have received high-risk scores for invasiveness potential in Hawai‘i (Hawaii-Pacific Weed Risk Assessment 2009b). The leaves are used in folkloric medicine for anemia, wound-healing, and abdominal pain in tropical countries ranging from Barbados (where it is called blood root) to Venezuela (called sanguinaria) and Nigeria, Congo and Côte-de-Ivoire in Africa, and laboratory studies have confirmed its anti-inflammatory, antinociceptive (blocking the sensation of pain), and antioxidant properties (Onoja *et al.* 2017). The following is a key to the five species of *Justicia* now documented as naturalized in the state (derived from Leonard 1958; Durkee 1978, 1986; Staples & Herbst 2005; Hu & Daniel 2011).

1. Infl bracts conspicuous, white netted with green veins … *J. betonica*
1. Infl bracts green or inconspicuous (2).
2(1). Leaves narrowly lanceolate, 6–10 cm long, 1–1.5 cm wide; flowers creamy white … *J. gendarussa*
2. Leaves ovate to oblong or lanceolate, but not narrowly lanceolate, up to 25 cm long, 9 cm wide; flowers red, purplish red, pink, or orange (3).

3(2). Inflorescence a dense terminal panicle; flowers pink (sometimes rose or white) … *J. carnea*
3. Inflorescence more open, a thyrse, panicle, or raceme, terminal or axillary; flowers red to purplish red or orange (4).
4(3). Flowers orange; leaf bases decurrent along petiole … *J. spicigera*
4. Flowers red to purplish red; leaf bases acute to obtuse, petiole distinct ... *J. secunda*

Material examined. **O'AHU**: Poamoho Stream north of Whitmore Village, sometimes dominant along stream trail in alien forest, Lat 21.52645661, Long -158.00334133, 1,050 ft [320 m], 18 Dec 2018, *T. Takahama s.n.* (BISH 775085).

Ruellia squarrosa (Fenzl) Cufod. **New naturalized record**

A genus of ca. 350 species, *Ruellia* naturally occurs in the tropics and temperate North America and includes a number of cultivated ornamental species (Mabberley 2017); six of them are treated in *A Tropical Garden Flora* (Staples & Herbst 2005), and three of the six—*R. brevifolia, R. brittoniana, R. devosiana*—were previously documented as escaping from cultivation and naturalizing (Imada 2019). Now a fourth species—*R. squarrosa*, fringe-leaf ruellia—has been documented as naturalizing, likely an escape from cultivation on O'ahu, where it was noted as a common groundcover on the banks of a windward O'ahu stream channel growing with *Sphagneticola trilobata*, *Hiptage benghalensis*, and *Pilea microphylla*. The species has been profiled as displaying high risk characters for invasiveness (Hawaii-Pacific Weed Risk Assessment 2009c), and this native of Veracruz, Mexico has been documented as naturalizing in Reunion Island, Australia, and Okinawa. Its ecological preferences in Sydney, Australia, along shaded creekside areas (Hawaii-Pacific Weed Risk Assessment 2009c), mirror those at the O'ahu collection site. Besides producing numerous seeds (each capsule contains 12 seeds), the species is easily propagated by cuttings or division of clumps (Staples & Herbst 2005). *Ruellia squarrosa* has been cultivated in Hawai'i at least since 1960, when it was collected in Honolulu's Foster Botanical Garden (*C. Potter s.n.,* BISH 20089). The species is an herb 3–4.5 dm tall, softly hairy on all parts; leaf blades opposite, lanceolate, 3–8 cm long; and flowers solitary, axillary, purple or bluish purple, ca. 6 cm long (Staples & Herbst 2005). The following is a key to the six species of *Ruellia* now documented as naturalized in the state.

1. Leaves green, whitish along veins on upper side, ± purplish on underside ... *R. devosiana*
1. Leaves uniformly green on both sides (2).
2(1). Erect herb; flowers in terminal, cymose panicles (3).
2. Prostrate herb or low groundcover; flowers solitary in leaf axils (5).
3(2). Flowers in spikes; bracts imbricate ... *R. blechum*
3. Flowers in panicles, or solitary; bracts not imbricate (4).
4(3). Flowers lavender; leaves narrowly linear-lanceolate ... *R. brittoniana*
4. Flowers red; leaves ovate ... *R. brevifolia*
5(2). Prostrate herb, often rooting at nodes; floral bracts 15–23 mm long; flowers 2.4–3.2 cm long, corolla violet blue to nearly white ... *R. prostrata*
5. Low groundcover up to 4.5 cm tall; floral bracts 8 mm long; flowers 5.5 cm long, corolla purple or bluish purple ... *R. squarrosa*

Material examined. **O'AHU**: Kāne'ohe, Kea'ahala Stream, just below Wailele Bridge overpass, common trailing herb on damp, rocky streamside banks under heavy canopy of *Ficus microphylla, Syzygium cumini, Schefflera actinophylla,* ca 50 ft [15 m], 12 Jun 2001, *C. Imada, R. Englund & D. Preston 2001-48*.

Amaranthaceae

Amaranthus spinosus L. **New island record**

This widespread, troublesome weed was recorded in Wagner *et al.* (1990, 1999: 188–189) as naturalized on Kure Atoll and all of the main Hawaiian Islands except Niʻihau and Lānaʻi, and subsequently recorded from Midway Atoll (Starr *et al.* 2002: 17) and Lānaʻi (Oppenheimer 2003:5). On Lehua, a tuff cone remnant off the coast of Niʻihau, 70 naturalizing mature and 10 immature plants were pulled and bagged. Spiny amaranth has been characterized as being one of the 18 most serious agricultural weeds in the world (Holm *et al.* 1977).

Material examined. **LEHUA**: East of weatherport on ridge above restoration plantings, sparse non-native scrubland with *Pluchea indica* dominant in gulches and open areas of lithified ash with non-native grasses, 41 m, 22 Feb 2007, *N. Tangalin 1657*.

Atriplex muelleri Benth. **New state records**

Atriplex is a genus of ca. 300 species mostly found in temperate and subtropical parts of the world (Mabberley 2017). Many species are halophytic, as its common name saltbush suggests. It can be mistaken for species of *Chenopodium*, except that *Atriplex* has usually unisexual flowers, and the female flowers are subtended by two distinctive fleshy or hardened bracts at maturity, while in *Chenopodium* the flowers are usually perfect and devoid of subtending bracts. Wagner *et al.* (1990) treated four naturalized species (*A. eardleyae*, *A. lentiformis*, *A. semibaccata*, *A. suberecta*). Subsequently, *A. maximowicziana* (Wagner *et al.* 1997: 55) and *A. canescens* (Staples *et al.* 2003: 10) were both added as new records, both restricted to the island of Hawaiʻi. Now a seventh naturalized species, *A. muelleri*, has been documented on Oʻahu and Maui. In Wagner *et al.* (1990: 535), *A. muelleri* was treated as a name misapplied to *A. suberecta*. The species are similar, differing by characters of the fruiting bracts (teeth large, deltate in *suberecta*; short, rounded in *muelleri*) and leaf apices (rounded in *suberecta*, truncate in *muelleri*). In Australia, where both species are native, they are differentiated primarily by these key characters (Wilson 1984; Jacobs 1990). Confirmation of identification was received by botanists at the Western Australian Herbarium (M. Hislop) and University of Adelaide (J. McDonald). To the first author, the plump bracteoles resemble tiny Chinese dim sum potstickers. Hawaiian material is described as a sprawling or semi-erect subshrub, and was sometimes collected in coastal salty substrates, sometimes in inland waste areas. The following key separates the naturalized *Atriplex* species in Hawaiʻi.

1. Perennial shrubs, stems ascending or sprawling, 8–30 dm long (2).
1. Annual or perennial herbs, stems ascending or prostrate, 2–15 dm long (3).
2(1). Pistillate flowers in dense terminal panicles; fruiting bracts orbicular-ovate; leaves oblong to ovate-deltate, 1.5–4 cm long, 5–25 mm wide ... *A. lentiformis*
2. Pistillate flowers in reduced terminal panicles; fruiting bracts forming 4 wings; leaves linear to oblanceolate, 0.8–5 cm long, 3–8 mm wide ... *A. canescens*
3(1). Stems prostrate; fruiting bracts fleshy, reddish-tinged to red ... *A. semibaccata*
3. Stems procumbent to ascending; fruiting bracts not as above (4).
4(3). Fruiting bracts fan-shaped ... *A. eardleyae*
4. Fruiting bracts rhombic (5).
5(4). Inflorescences in terminal spikes ... *A. maximowicziana*
5. Inflorescences in axillary clusters (6).

6(5). Bracteoles swollen, rounded, apex obtuse with all teeth ± equal in length; leaf apex obtuse ... *A. muelleri*
6. Bracteoles compressed, rhomboid to deltoid, apex acute with one tooth more prominent; leaf apex acute to obtuse ... *A. suberecta*

Material examined. **O'AHU**: Wai'anae Mts., upper Makakilo, adjacent to subdivision at end of Pueonani St., common curbside weed, 700 ft [215 m], 09 Mar 2004, *C. Imada & L.M. Crago 2004-25*; Waipahu, Pouhala Marsh, above water mark and salt line in drier red soil, in full sun, 24 Jan 2005, *L.M. Crago & T. Erickson 2005-027*; Wheeler Army Airfield, growing in soil pile containing several plants not frequently found on base, 5 plants seen, seedlings present, 820 ft [250 m], 13 Feb 2017, *J. Beachy & J. Gustine-Lee USARMY 461*. **MAUI**: Kanahā, naturalized small shrub in sand on beach east of treatment plant and west of drainage, sea level, 25 Mar 2000, *F. Starr & K. Martz 000325-1.*

Araceae

Lemna obscura (Austin) Daubs **New island record**

Species of *Lemna*, duckweed, are among the world's smallest flowering plants, making them difficult to identify. They are also among the fastest-multiplying of vascular plants, due to their ready ability to propagate vegetatively by budding, and can completely cover slow-moving bodies of water in short order (Staples & Herbst 2005). Wagner *et al.* (1990: 1457–58) treated a single species in Hawai'i, *L. perpusilla* Torr., which was regarded as possibly naturalized or indigenous, due to the ease with which it may have been transported naturally to the Islands via migrating water birds. Wagner *et al.* (1997: 58) later corrected the identity of the known *Lemna* species to *L. aequinoctialis* Welw., based on taxonomic work by Landolt (1986), and also documented a new state record for *L. obscura* on O'ahu and Hawai'i. At that time, it was reported that the new Hawaiian records represented the only known distribution of *L. obscura* outside of its native range in southeastern North America (Wagner *et al.* 1997). Landolt (2000) extends the natural range of the species to central Mexico, Colombia, and Ecuador, and provides key characters for distinguishing the taxa: *L. aequinoctialis* with root sheath winged at the base, root tip usually sharp pointed, roots to 3(–3.5) cm long, and fronds without a reddish color or spots of anthocyanin; *L. obscura* with root sheath not winged, root tip mostly rounded, roots often longer than 3 cm, and fronds often with a reddish tinge or spots of anthocyanin. A naturally occurring collection on Kaua'i now extends its Hawaiian distribution.

Material examined. **KAUA'I**: Līhu'e Distr., near mouth of Wailua River, west side of Hwy 56 (south side of river) at extreme west end of Smith's Tropical Paradise Botanical Garden, homogeneous populations in ponds of *Hibiscus tiliaceus* marsh, 6 m, 20 Aug 1999, *W.P. Armstrong & E.M. Collins 1338.*

Pistia stratiotes L. **New island record**

Previously documented as naturalized on Kaua'i, O'ahu, Moloka'i, and Maui (Wagner *et al.* 1990, 1999: 1359), this highly invasive weed of waterways has also been documented on the Big Island.

Material examined. **HAWAI'I**: Ka'ū , in a pond behind Punalu'u Beach, covering entire pond, along with patches of water hyacinth and water lilies, sea level, 04 May 2006, *B.H. Gagne 3154*.

Asteraceae

Emilia sonchifolia (L.) DC.
var. ***javanica*** (Burm. f.) Mattf. **New island records**

Previously recorded as naturalized from Kauaʻi and Oʻahu (Wagner *et al.* 1990, 1999: 312), East Maui (Wagner *et al.* 1997: 52), and Lānaʻi (Oppenheimer 2008: 24), recently identified decades-old specimens from 1948 (Molokaʻi) and 1979 (Hawaiʻi) extend the known Hawaiian range for *E. sonchifolia* var. *javanica*.

Material examined. **MOLOKAʻI**: Kualapuʻu, common in ravine sides, roadsides, etc., in pineapple field, 21 Feb 1948, *F.R. Fosberg 29545*. **HAWAIʻI**: Puna District, Halepuaʻa Forest Reserve, experimental tree planting area, 100 ft [30 m], 15 Aug 1979, *ESP Field Crew s.n.* (BISH 656177, 656178).

Gamochaeta purpurea (L.) Cabrera **New island record**

Originally recorded as naturalized (as *Gnaphalium purpureum*) on all of the main Hawaiian Islands except for Niʻihau (Wagner *et al.* 1990, 1999: 321), Wagner *et al.* (1997: 54) reported that the genus had been transferred to *Gamochaeta*. Alford (2012) updated the taxonomy for Hawaiian plants, and reported that there were four additional naturalized species of *Gamochaeta* in the islands. In the shuffle of specimens, all *G. purpurea* vouchers from Lehua, Kauaʻi, Lānaʻi, and Kahoʻolawe were renamed, and the known distribution of *G. purpurea* was reduced to Oʻahu, Molokaʻi, Maui, and Hawaiʻi. The following voucher confirms that the species does occur on Kauaʻi.

Material examined. **KAUAʻI**: Nāpali coast, Nualolo Kai, on weedy talus slopes toward back wall of valley, 15 m, 30 Apr 2010, *N. Tangalin 2295.*

Tridax procumbens L. **New island record**

Coat buttons is a common weed of low elevation, dry, disturbed habitats, which Wagner *et al.* (1990, 1999: 370) recorded from Midway Atoll and all of the main Hawaiian Islands except for Niʻihau. It has now been documented from nearby Lehua islet.

Material examined. **LEHUA**: Western crescent arm, growing on islet crest on open, dry, windswept, sparsely vegetated habitat on lithified ash, 107 m, 28 Oct 2008, *N. Tangalin, J. Carbone, C. Trauernicht, & E. Griffin-Noyes 1823*.

Basellaceae

Basella alba L. **New island records**

Previously documented as naturalized only on Oʻahu (Nagata 1995: 11) and Midway Atoll (Wagner *et al.* 2012: 17), vouchers dating back to the 1990s of this cultivated twiner, called Malabar nightshade or Ceylon spinach, from Kauaʻi and Hawaiʻi, suggest that it is naturalized on those islands as well.

Material examined. **KAUAʻI**: North shore of Hanamāʻulu Bay, on banks above high water line, well naturalized, 22 May 1991, *L. Hume & R. Levine 515*. **HAWAIʻI**: ʻUpolu Point, population of approximately 25 on strand, ca 30–46 m, Oct 1997, *V. Caraway 152*.

Brassicaceae

Lepidium didymum L. **New island record**

Reported from all the main islands as well as Midway and Pearl & Hermes Atolls of Papahānaumokuākea (Wagner *et al.* 1990, 1999: 403), the range of swinecress was extended to Laysan (Staples *et al.* 2003: 9), and now Kure Atoll, based on this 1979 collection. Formerly known in the literature as *Coronopus didymus* (L.) Sm., the genus was sunk into *Lepidium* based on molecular evidence (Al-Shehbaz *et al.* 2002).

Material examined. **KURE ATOLL**: Green Island, around LORAN buildings and roadsides in that area, 04 Jan 1979, *D.R. Herbst, C.H. Lamoureux & C. Corn 6252*.

Cactaceae

Selenicereus setaceus (Salm-Dyck ex DC.) A. Berger ex Werderm. **New naturalized record**

Collections of this climbing cactus, made 20 years or more ago in Kōloa District on Kauaʻi, are still extant (D. Lorence, pers. comm., March 2020) and are now formally included in the Hawaiian naturalized plant ensemble. *Selenicereus setaceus* occurs in the same part of Kauaʻi in which other cacti have been reported as naturalizing, among them *Acanthocereus tetragonus, Harrisia bonplandii,* and *Selenicereus macdonaldiae* (all reported in Lorence *et al.* 1995), as well as *Cereus uruguayanus* and *Harrisia martinii* (reported in Wagner *et al.* 1990, which notes that many cacti species in that area were reportedly introduced by the Moir family). [Note: The *Selenicereus macdonaldiae* record was originally misidentified as *S. grandiflorus* (L.) Britton & Rose, a change reported in Herbst & Wagner 1999: 16]

Species of *Selenicereus* and *Hylocereus* (such as the well-known night-blooming cereus, *H. undatus* (Haw.) Britton & Rose) are very similar with their climbing, scrambling habit and spectacular, usually white, night-blooming flowers. In fact, recent phylogenetic work by Korotkova *et al.* (2017) found that *Hylocereus* was a monophyletic genus but was nested within a grade formed by species of *Selenicereus*. Strong evidence pointed to the two genera sharing a common origin, necessitating a merger of the genera. D.R. Hunt (2017) formally proposed synonymization of *Hylocereus* under *Selenicereus* and the necessary new combinations were made by Hunt (2017) and Korotkova *et al.* (2017). For Hawaiian material, this means that there are now four species of naturalized *Selenicereus—S. pteranthus* (Link ex A. Dietr.) Britton & Rose forma *macdonaldeae* (Hook) Ralf Bauer [Syn. *Hylocereus macdonaldiae* (Hook.) Britton & Rose]; *S. setaceus* (as treated here); *S.* cf. *trigonus* (Haw.) S. Arias & N. Korotkova [Syn. *Hylocereus trigonus* (Haw.) Safford]; and *S. undatus* (Haw.) D.R. Hunt [Syn. *Hylocereus undatus* (Haw.) Britton & Rose]. [Note: the new record for *Hylocereus costaricensis*, based on *Flynn 3571* (Lorence *et al.* 1995: 28) was redetermined by B. Leuenberger (Berlin-Dahlem) as *H.* cf. *trigonus* in 2000]. A diagnostic description of *Selenicereus setaceus* is provided in *The European Garden Flora* (Hunt 1989): "Stems usually 3-, sometimes 4–5-angled, 2–4 (rarely to 8) cm in diameter. Areoles 2–3 cm apart, with 1–2 conical brown spines 1–2 mm long. Flowers 25–30 cm long; pericarpel with felted and spiny areoles, tube with scales naked in their axils. Fruit ovoid, tuberculate and bristly, red. Brazil to N Argentina."

Material examined. **KAUAʻI**: Kōloa District, Poʻipū area, along Poʻipū Rd., between turnoffs to Sheraton Kauaʻi Hotel (Kapili Rd.) and Poʻipū Beach, dry secondary shrubland, ca 10 m, 23 Apr 1995, *D.H. Lorence 7664*; Kōloa District, Poʻipū area, along Poʻipū Rd. just north of Sheraton Hotel, secondary shrubland, ca 10–15 m, 15 May 2000, *D.H. Lorence 8671*.

Convolvulaceae

Cuscuta campestris Yunck. **New island record**

Recorded as naturalized on Oʻahu and Hawaiʻi (Wagner *et al.* 1990, 1999: 582), Lānaʻi (Oppenheimer 2011: 7), East Maui (Starr *et al.* 2004: 22), and West Maui (Oppenheimer 2003: 10), this parasitic groundcover is now confirmed as naturalized on Kauaʻi. Native

and widespread in North America, this species is also considered to be the most widespread *Cuscuta* weed species, now recorded in Africa, Asia, Australia, Europe, and South America (Costea *et al.* 2006).

Material examined. **KAUA‘I**: Kawaihau Distr., Princeville, Church of the Pacific parking lot, localized on bed of wedelia groundcover, 114 m, 13 Jun 2013, *D.H. Lorence & K. Blackmer 10397;* Kōloa Distr., Kalāheo, upper Pu‘uwai Rd. near junction with Pu‘ulima Road, across from county water tank, parasitic on *Sphagneticola*, 341 m, 15 Nov 2013, *T. Flynn 7696*.

Cuscuta pentagona Engelm. **New state records**

Cuscuta is a parasitic genus of ca. 200 species of leafless annual herbs with worldwide distribution. Some species (*e.g., C. campestris*, treated above) are recognized pests of agriculture (CABI 2020c). In Hawai‘i, Wagner *et al.* (1990: 582) treated one endemic species (*C. sandwichiana*) and one widespread weed native to North America (*C. campestris*, western field dodder). As documented above, *C. campestris* is now known from all of the main islands except for Ni‘ihau, Moloka‘i, and Kaho‘olawe. In February 2007, Dan Austin (author of the Convolvulaceae treatment in *Manual of the Flowering Plants of Hawai‘i*), annotated several vouchers from O‘ahu, West Maui, and Hawai‘i as *C. pentagona*, all previously called *C. campestris*. In light of the fact that *Cuscuta* identification is made notoriously difficult by the need to distinguish small differences between minute flowers on already dried voucher specimens, it is understandable that misidentifications would occur. Costea *et al.* (2006) noted that *C. pentagona*, with the same North American native range as *C. campestris*, was not as common and had not yet been reported from outside of North America. Identification of fresh flowering material might make clearer whether *C. pentagona* is more prevalent than thought in the Islands.

The following updated key to *Cuscuta* in Hawai‘i is modified from Wagner *et al.* (1990), Costea *et al.* (2006), and Spaulding (2013).

1. Stems yellow to yellowish orange; flowers 3–4(–5) mm long; petals erect to slightly spreading; scales below stamens absent or reduced and forked or triangular; seeds ca. 2 mm long ... *C. sandwichiana*
1. Stems pale yellow; flowers 1.5–3 mm long; petals spreading; scales below stamens conspicuous, oblong-ovate to spathulate, the margins fringed; seeds ca. 1 mm long (2).
2(1). Calyx lobes strongly overlapping at base, forming 4–5 strong angles at sinuses of mature flowers; corolla lobes lance-acuminate; mature flowers ca. 1.5–2 mm long ... *C. pentagona*
2. Calyx lobes not strongly overlapping at base of mature flowers, not distinctly 5-angled; corolla lobes deltoid-ovate; mature flowers ca. 2–3 mm long ... *C. campestris*

Material examined. **O‘AHU**: Honolulu, Wa‘ahila Ridge, St. Louis Heights, private residence on Frank Street, climbing on cultivated *Vitex* hedge, 120 ft [35 m], 10 Feb 1975, *K.M. Nagata 1244;* Lanikai, in vacant lot near intersection of Mokulua and Mokumanu Streets, growing over *Asystasia* and grasses, 06 Nov 1985, *J. Jacobson & S. Jacobson s.n.* (BISH 502244). **MAUI**: West Maui, Wailuku Distr., Wailuku, growing roadside on *Asystasia gangetica*, 180 ft [55 m], 17 May 2001, *H. Oppenheimer H50115*. **HAWAI‘I**: Saddle Road between Hilo and Kona, roadside, 22 Feb 1955, *W.H. Welch 16704.*

Crassulaceae

Kalanchoe rotundifolia (Haw.) Haw. **New island record**

Recently documented from East Maui as a new escape from cultivation (Starr & Starr 2016: 14), an older collection from O‘ahu documents that it is escaping there as well.

Material examined. **O‘AHU**: Kīpapa Gulch, off Kamehameha Hwy., numerous plants found growing along roadside over asphalt, 400 ft [120 m], 11 Oct 2007, *R. Chang HDOA 1*.

Cyperaceae

Cyperus difformis L. **New island record**

This obligate wetland sedge was previously documented by Wagner *et al.* (1990, 1999: 1395) as naturalized on Kaua‘i and O‘ahu, and subsequently collected on West Maui (Starr *et al.* 2002: 19) and East Maui (Starr *et al.* 2006: 35). The following voucher documents its presence in the Kohala District of the Big Island.

Material examined. **HAWAI‘I**: Morgan Toledo taro farm, Waipi‘o Valley, growing on banks of taro lo‘i, just at water’s edge, 19 Mar 2005, *L.M. Crago, C. Imada, T. Erickson & C. Puttock 2005-093.*

Cyperus hillebrandii Boeckeler

var. ***hillebrandii*** **New island record**

Recorded as endemic on O‘ahu, Lāna‘i, East Maui, and Hawai‘i (Wagner *et al.* 1990, 1999: 1418, as *Mariscus hillebrandii* subsp. *hillebrandii*), this overlooked voucher confirms the presence of *Cyperus hillebrandii* var. *hillebrandii* throughout the higher islands of Maui Nui.

Material examined. **MOLOKA‘I**: Kapa‘akea Ridge, on ridge near forest reserve boundary, 10 Aug 1989, *R.W. Hobdy 3068.*

Cyperus stoloniferus Retz. **New state records**

This new state record was identified in a serendipitous way that points to the continued need to maintain herbarium collections. In 2014, *Herbarium Pacificum* received a sedge voucher from East Maui (*Oppenheimer & Bustamente H41416*) that was difficult to match but came closest to another East Maui collection (*Starr & Starr 000910-1*) that had been annotated in 2001 by sedge specialist Mark Strong (Smithsonian) as an aberrant form of *Cyperus rotundus*. In 2018, 17 years after his annotation, Strong was emailed jpgs of both vouchers to see if he agreed that the newer collection should also be called *C. rotundus*. Strong in turn enlisted the advice of *Cyperus* specialist Gordon Tucker, who immediately responded that, yes, he knew the species, which he called *C. stoloniferus*. He remembered it from working on the *Flora of China* treatment of *Cyperus*, and noted diagnostic characters of erect inflorescence bracts and dark purple spikelets. He noted that the species was widespread in the Pacific and East Asia. Now it is also known from the Hawaiian Islands. Besides East Maui, another voucher from the Big Island (*Duvall s.n.*) was also pulled from the *C. rotundus* folders. The following description is extracted from *Flora of China* (Dai *et al.* 2010).

> “Perennials. Rhizomes long, ± thick, ± hardened, base of shoot with ellipsoid to ovoid tubers. Culms solitary, 8–22 cm tall, 3-angled, smooth, basal sheaths usually disintegrating into fibers. Leaves usually shorter than culm to rarely longer; leaf blade medium green, 2–4 mm wide, usually folded, rarely flat. Involucral bracts 2 or 3, ± erect, leaflike, basal 2 longer than inflorescence. Inflorescence a simple anthela; rays 3 or 4, 0.5–3 cm, each with 3–8 congested spikelets. Spikelets narrowly oblong-ovoid to narrowly ovoid, 6–12 × 2–3 mm, slightly thickened, 10–18-flowered; rachilla narrowly winged. Glumes yellow to brownish yellow on both surfaces variegated with brownish blood-red but middle green, densely imbricate, broadly ovate, ca. 3 mm, papery, 5–7-veined, keel obtuse, margin broadly white hyaline, apex acute to subobtuse. Nutlet dark brown when mature, ellipsoid to subobovoid, ca. 2/3 as long as subtending glume, 3-sided.”

Bryson & Carter (2008) listed *C. stoloniferus* as a vegetative colonizer of coastal sands, with a range that includes Pakistan, India to China and northern Australia, Mauritius, and Madagascar.

Material examined. **MAUI**: East Maui, near Olinda, in pasture near Po‘okela Church, up to 50 cm tall, large patches in pasture visible due to dark glumes, 1,800 ft [550 m], 10 Sep 2000, *F. Starr & K. Martz 000910-1*; East Maui, Makawao Distr., Pi‘iholo, naturalized in lawn used as a helicopter landing zone, adjacent to Maui Invasive Species Committee baseyard, 2,100 ft [635 m], 23 Apr 2014, *H. Oppenheimer & K. Bustamente H41416*. **HAWAI‘I:** Kahuku Ranch, 1 mile [1.6 km] E of Hawaiian Ocean View Estates, pasture with ‘ōhi‘a-koa remnants, 4,500 ft [1,370 m], 30 Nov 2006, *F. Duvall s.n.* (BISH 664566).

Eleocharis geniculata (L.) Roem. & Schult. **New island record**

Wagner *et al.* (1990, 1999: 1402) documented this wetland species as naturalized on Kaua‘i, O‘ahu, and Moloka‘i; subsequently, it was reported by Oppenheimer (2003: 10) on West Maui and Imada *et al.* (2008: 12) on Lāna‘i. The following vouchers document its presence on the Big Island back to 1979.

Material examined. **HAWAI‘I**: Pi‘ihonua, Hilo Forest Reserve, site 34 OS, 4,900 ft [1,495 m], 02 Jul 1979, *K. Adee s.n*. (BISH 581614); South Hilo District, Hilo Forest Reserve, within a large bog south of the Wailuku River, 3,620 ft [1,105 m], 20 May 1981, *G. Clarke 601*; Nīnole, Ka‘ū, in muck of drying freshwater pond next to ocean, 16 May 1983, *O. Degener & I. Degener 35792.*

Fimbristylis littoralis Gaudich. **New island record**

This wetland sedge was first collected around taro patches in Hanalei Valley, Kaua‘i in 1977. Strong and Wagner (1997: 45) reported on this new state record under the name *F. miliacea* (L.) Vahl. Subsequently it was reported from the Waipi‘o Valley on the Big Island (Imada *et al.* 2000: 12) and Ke‘anae, East Maui (Oppenheimer 2003: 11). The species, now known as *F. littoralis* (see Imada 2007: 35 for details) has now been documented from O‘ahu in its obligate wetland habitat.

Material examined. **O‘AHU**: Kahuku, James Campbell National Wildlife Refuge, Ki‘i Unit, Pond C Makai, growing intermixed with *Cyperus polystachyos*, most prevalent in lee areas behind bulrush, in dry ground, but moist soil adhering to roots, several patches observed, 19 Jul 2007, *M. Silbernagle & D. DesRochers s.n.* (BISH 726217).

Dennstaedtiaceae

Microlepia strigosa (Thunb.) C. Presl

var. ***mauiensis*** (W.H. Wagner) D.D. Palmer **New island record**

Microlepia mauiensis was originally described in 1993 by W.H. Wagner, Jr. as a rare, new endemic Hawaiian fern, restricted and localized to extremely wet habitats above 1,200 m elevation on West Maui, East Maui, and Hawai‘i (Wagner Jr. 1993). Characters that helped distinguish it from the abundant, indigenous *M. strigosa* included its densely hairy fronds (vs. sparsely hairy in *strigosa*) and flexuous rachises and costae (vs. non-flexuous in *strigosa*). After study of Hawaiian *Microlepia* in the field and herbarium, it became apparent to Dan Palmer that he was seeing a continuum of intermediate forms from nearly completely glabrous to very hairy, suggesting a variable species with, as one extreme manifestation, a very hairy variety with a slightly zigzag rachis (*M. mauiensis*); for this he published the new combination *M. strigosa* var. *mauiensis* (Palmer 2002). In 2016, this taxon was Federally listed as Endangered (Pacific Islands Fish and Wildlife Office 2016), consisting of fewer than 100 known wild individuals on O‘ahu (lowland mesic forest),

Maui (montane wet forest), and Hawai‘i (montane mesic and wet forest). This record acknowledges the presence of this endangered fern on O‘ahu.

Material examined. **O‘AHU**: Wai‘anae Mts., West Makaleha Valley, *Metrosideros-Dicranopteris* forest, ca 20 plants, 03 Mar 2011, *S. Perlman, S. Ching, & J. Lau 22455.*

Fabaceae

Macroptilium lathyroides (L.) Urb. **New island record**

Wild bean or cow pea is widely naturalized in pastures and disturbed lowland areas throughout the main islands (Wagner *et al.* (1990, 1999: 683; Shannon & Wagner 1996: 13; Herbarium Pacificum Staff 1996: 4) and on Midway Atoll (Starr & Starr 2017: 5). It has now been documented from Lehua islet, adjacent to Ni‘ihau.

Material examined. **LEHUA**: Ridge between Pritchardia Gulch and Weatherport Gulch, coastal dry shrubland*,* 20 m, 07 May 2012, *N. Tangalin 3195*.

Vigna vexillata (L.) A. Rich. **New island record**

This species of *Vigna* was first collected in Lāwa‘i, Kaua‘i in 2003 (*Lorence 9071*, PTBG) and described as an herbaceous, twining vine forming a large patch along the edge of an abandoned coffee field near the entrance of National Tropical Botanical Garden, growing in weedy secondary vegetation. It was identified by J.A. Lackey (Smithsonian) in 2004 as *V. vexillata*, making it a new state record (Wagner *et al.* 2012: 43). Now it has been documented as naturalizing along the Kona coast on Hawai‘i. The species is widely distributed naturally in the tropics and subtropics, but its weedy range is undocumented. The following description is modified from Wu & Thulin (2010):

> “Perennial herbs, twining. Stems with spreading brown bristly hairs, glabrescent. Stipules ovate to ovate-lanceolate, 3–5 mm, cordate or auriculate at base, ciliate; petiole 1–11 cm; leaflets membranous, variable in shape, ovate to lanceolate, 4–9(–15) × 2–5(–8) cm, brown or gray pubescent on both surfaces, base rounded to cuneate, margin entire, sometimes slightly 3-lobed, apex acute or acuminate. Racemes axillary, 2–6-flowered, subumbellate; peduncles 5–20 cm. Bracteoles subulate, ca. 3 mm, caducous. Calyx with brown or white bristly hairs, rarely glabrescent; tube 5–7 mm; lobes linear or linear-lanceolate, 2–5 mm, upper 2 connate at base. Standard pink, purple, or partly yellow, sometimes with yellow or purple spots inside at base, 2–3.5 × 2–4 cm, emarginate; keel whitish or purplish, falcate, with beak incurved through 180°. Legumes erect, linear-terete, 4–14 cm × 2.5–4 mm, bristly. Seeds 10–18, yellowish, black, or brown to scarlet with black spots, oblong or oblong-reniform, 2–4.5 mm.”

The following key is extracted from the key to *Vigna* in the *Flora of China* (Wu & Thulin 2010) that includes the three documented naturalized species in the state (*V. hosei, V. luteola, V. vexillata*) and the most common native species (*V. marina*).

1. Corolla keel prolonged into a conspicuous beak incurved through 180° ... *V. vexillata*
1. Corolla keel without a conspicuous incurved beak (2).
2(1). Corolla 0.5–1 cm long ; legumes l–2 cm long ... *V. hosei*
2. Corolla 1.2–3 cm long; legumes 3.5–8 cm long (3).
3(2). Leaflets rounded or obtuse at apex; mature pods glabrous ... *V. marina*
3. Leaflets acute or acuminate at apex; mature pods pubescent ... *V. luteola*

Material examined. **HAWAI‘I**: Captain Cook, Amy Greenwell Botanical Garden, volunteer plant twining in the garden, 448 m, 26 Nov 2016, *E.J. Judziewicz & P. Van Dyke s.n*. (BISH 767688); *loc. cit.,* collector has noted seeing this plant at several places in Kona for several years, 03 Dec 2016, *K. Kimball s.n*. (BISH 767743, 767748).

Juncaceae

Juncus polyanthemos Buchenau **New island record**

Previously recorded as naturalized only on East Maui (Wagner *et al.* 1990, 1999: 1454; the single cited Oʻahu record was collected in a Haleʻiwa pond in cultivation with *Nymphaea* [*H. Clay s.n.,* 19 Jul 1972, BISH 78196]), *Juncus polyanthemos* is now confirmed as naturalized on Hawaiʻi Island. This obligate wetland rush can be mistaken for the more common *J. effusus*, but the latter has a solid pith (vs. interrupted in *polyanthemos*) and a perianth that is equal in length or longer than the capsule (vs. distinctly shorter than the capsule in *polyanthemos*).

Material examined. **HAWAIʻI**: South Kohala Distr., Waimea town, weed in gutter of strip mall building, growing in saturated peat, 2,675 ft [815 m], 29 Dec 1988, *P. Zika 13703;* Āhualoa, on moist, sandy soil on bank of coffee farm irrigation pond, 781 m, 24 Sep 2005, *K. Uyehara s.n.* (BISH 718799).

Malvaceae

Malvastrum americanum (L.) Torr. **New island record**

First recorded as naturalized in 1985 along the Kaiwi coast in southeastern Oʻahu (Wagner *et al.* 1990, 1999: 894), where it is fairly common in the Kaloko (Queen's Beach) area, Starr *et al.* (2008: 47) recorded it from the Moʻomomi dunes on Molokaʻi in 2005. The following specimen from South Kona on the Big Island records its presence there since at least 1986.

Material examined. **HAWAIʻI**: South Kona, Kapua Bay, below kiawe forest, 07 Oct 1986, *L. Stemmermann 7127.*

Orchidaceae

Habenaria rodeiensis Barb. Rodr. **New island record**

Wagner *et al.* (1990: 1468) noted this taxon as a single unidentified 1983 collection from a Kula, East Maui pasture (*Hobdy 1829*). The voucher was identified in 1992 by E.A. Christenson (New York Botanical Garden) as *Habenaria rodeiensis* (Herbst & Wagner 1999: 24), a ground orchid native to Brazil, Paraguay, and Peru (Batista *et al.* 2011). Subsequently, the species has been reported on West Maui in 2003 (Oppenheimer 2006:12) and Oʻahu in 2009 (Lau & Frohlich 2012: 19). The habitat data on the BISH specimens suggest that it has an affinity for open, disturbed, dry to mesic trailsides above 300 m elevation. This first record for Kauaʻi was collected in 2015, but for the first time as an epiphyte rather than a ground orchid. Very little information is readily available about this species. *A Global Compendium of Weeds* (Randall 2017: 1701) lists *H. rodeiensis* as a tropical orchid grown as an ornamental and dispersed by humans, and the five references it cites all refer to the Hawaiian collections.

Material examined. **KAUAʻI**: Līhuʻe District, banks of north fork of Wailua River, adjacent to trail that leads to Blue Hole, epiphytic in moss on branch of *Metrosideros polymorpha*, 378 m, 28 Jan 2015, *A.M. Williams, T. Flynn, & J. Shevock AMW118*.

Piperaceae

Peperomia cookiana C. DC. **New island record**

Recorded as endemic on Kauaʻi, Molokaʻi, Maui, and Hawaiʻi (Wagner *et al.* 1990, 1999: 1022), a recent collection from Mount Kaʻala on Oʻahu extends the range of this species. Closely allied to *P. blanda* (Jacq.) Kunth var. *floribunda* (Miq.) H. Huber (occurring on all main islands except Kahoʻolawe) and *P. remyi* C. DC. (all main islands except for

Ni‘ihau and Kaho‘olawe), the specimen most closely matches the key characters provided for *P. cookiana* in Wagner *et al.* (1990, 1999: 1021), and its native wet forest habitat aligns with the habitat preference of the species.

Material examined. **O‘AHU**: Wai‘anae Mts., summit of Mt. Ka‘ala, NE-facing slope in *Metrosideros* wet forest, 1,216 m, 16 Jan 2013, *S. Perlman & J. Lau 23240.*

Poaceae [Note: Grasses can be notoriously difficult to identify, and the majority of the grass taxa treated below were not keyed out in *Manual of the Flowering Plants of Hawai‘i* (Wagner *et al.* 1990). In fact, over 100 newly naturalized grass taxa have been reported for the Hawaiian Islands since the *Manual* was published (see Imada 2019). We recommend *A Key to Pacific Grasses* (Clayton & Snow 2010) as the most current source for keying out native and naturalized grasses in Hawai‘i.]

Bromus diandrus Roth **New island record**

Recorded as naturalized on Kaua‘i and Hawai‘i under the now synonymized name *Bromus rigidus* (Wagner *et al.* 1990, 1999: 1508), ripgut grass has since been recorded on East Maui (Herbarium Pacificum Staff 1999: 7, as *B. rigidus*) and Lāna‘i (Oppenheimer 2008: 32, as *B. diandrus*). Snow (2008: 38) explains the reasoning behind the name change to *B. diandrus*. The species was collected at a helicopter landing zone where the alien-dominated vegetation included *Acacia confusa* and *Schinus terebinthifolius*.

Material examined. **O‘AHU**: Wai‘anae Mts., Kea‘au LZ on ridge between ‘Ōhikilolo cabin and *Sanicula mariversa* fence, 14 Apr 2016, *N. Kai USARMY 440.*

Bromus rubens L. **New island records**

Wagner *et al.* (1990, 1999: 1507) listed this species as adventive on Moloka‘i and Hawai‘i; subsequently, Herbst & Wagner (1999: 25) confirmed its naturalized status on both islands. Here, its naturalization on Kaua‘i and West Maui are confirmed.

Material examined. **KAUA‘I**: Waimea Canyon, Kukui Trail, degraded *Grevillea*-dominant mesic forest, 782 m, 04 Jun 2009, *N. Tangalin, E. Griffin-Noyes & M. Demotta 2027.* **MAUI**: West Maui, Līhau, lowland dry shrubland, 2,600 ft [790 m], 13 Jul 1991, *P. Welton & B. Haus 1114*; *loc. cit.,* lowland dry forest, 1,400 ft [425 m], 09 Jan 1992, *P. Welton & B. Haus 1483*; West Maui, south rim of cinder cone southwest of westernmost reservoir above Lahaina, 14 Feb 2008, *W.A. Whistler s.n.* (BISH 731920).

Bromus sterilis L. **New island record**

Wagner *et al.* (1990: 1507) noted that *Bromus sterilis* was known from two collections from Big Island (Hāmākua) pastures made in 1936 and 1938, but not vouchered since; thus it was not considered part of the naturalized flora. Collections made in 2007 on Moloka‘i and Maui (Oppenheimer 2008: 32) confirmed its naturalized status in the state. An overlooked Big Island collection made by P.K. Higashino on Mauna Loa Strip Road in 1983, and identified by W.D. Clayton as *B. sterilis* in 1994, confirms its naturalized status on the island of Hawai‘i. CABI (2020a) reports that the species is native to Africa, Europe, and Asia, and is a noxious agricultural and horticultural weed in the Mediterranean region. It is weedy throughout North America, and often found in wastelands and roadsides, but also with an affinity to arable habitats where shallow cultivation is practiced. It can handle all major soil types (clays, loams, and sands; acid, neutral, and alkaline) and tolerates drought and strong winds but not salt exposure.

Material examined. **HAWAI‘I**: Mauna Loa Strip Road, Hawai‘i Volcanoes National Park, open *Metrosideros* and native shrubs and ‘a‘ā, 5,650 ft [1,720 m], 05 May 1983, *P.K. Higashino 10019*.

Bromus tectorum L. **New naturalized record**

Treated by O’Connor (1990: 1507) as adventive on East Maui since at least 1871, scattered collections of *Bromus tectorum* have been made in Haleakalā Crater between 1933 and 1969. In 2000, Gene Weller of Brigham Young University-Idaho collected numerous vouchers in Haleakalā ranging from 1,950–3,055 m elevation, confirming that it is widely distributed and naturalizing in the crater. CABI (2020b) describes this species, native mostly to central Asia and eastern Europe and called downy brome or cheatgrass, as an opportunistic, widespread, invasive annual grass. In the semi-arid to arid environments of western North America similar to central Asia where it originally evolved, *B. tectorum* dominates millions of hectares of degraded rangelands in the intermountain area between the Sierra-Cascade and Rocky Mountains. When this largely self-pollinated species is introduced to a site where it fits well genotypically, combined with its phenotypic plasticity, it can populate the site with stable duplicates of itself through self fertilization.

Material examined. **MAUI**: East Maui, Haleakalā Crater floor, near Bubble Cave, ash bed, 2,230 m, 22 Aug 1933, *F.R. Fosberg 9936*; Haleakalā Crater, west base of Hanakauhi, weed in cinders on basalt a‘ā floor, 7,000 ft [2,135 m], 01 Sep 1945, *H. St. John & A.L. Mitchell 21257*; Haleakalā, Halemau‘u Trail, weed along the trail, 7,000 ft [2,135 m], 05 Jul 1948, *R.L. Wilbur & G.L. Webster 1009*; Haleakalā National Park, growing in floor of crater near Kapalaoa Cabin, infrequent, 7,200 ft [2,190 m], 14 Jun 1969, *J. Henrickson & R. Vogl 3477*; *loc. cit.,* near Waikeke‘ehia, few individuals, 1,950 m, Jul 2000, *G. Weller s.n.* (BISH 713676); *loc. cit.,* near Silversword Loop, few individuals, 2,194 m, Jul 2000, *G. Weller s.n.* (BISH 713675); *loc. cit.,* near Kalu‘uoka‘ō‘ō, few individuals, 2,194 m, Jul 2000, *G. Weller s.n.* (BISH 713674); *loc. cit.,* in front of Kapalaoa Cabin, common in *Deschampsia* grassland, 2,218 m, Jul 2000, *G. Weller s.n.* (BISH 713679); *loc. cit.,* near Kawilinau (Bottomless Pit), few individuals, 2,255 m, Jul 2000, *G. Weller s.n.* (BISH 713677); *loc. cit.,* near Pu‘unaue, few individuals, 2,255 m, Jul 2000, *G. Weller s.n.* (BISH 713683); *loc. cit.,* near Kamoa o Pele, common, 2,255 m, Jul 2000, *G. Weller s.n.* (BISH 713682); *loc. cit.,* Sliding Sands Trail, common along trail’s edge, 2,852 m, Jul 2000, *G. Weller s.n.* (BISH 713681); *loc. cit.,* near horse loading facilities, Sliding Sands trailhead, common, 2,980 m, Jul 2000, *G. Weller s.n.* (BISH 713678); *loc. cit.,* Red Hill Overlook, few individuals, 3,055 m, Jul 2000, *G. Weller s.n.* (BISH 713680); *loc. cit.,* Sliding Sands Trail west of Kapalaoa Cabin, locally common in cinder and ash substrate, 7,250 ft [2,210 m], 16 May 2011, *H.L. Oppenheimer, P. Welton, K. Bustamente, & S. Gabriel H51108*.

Cynodon nlemfuensis Vanderyst **New island record**

A larger version of Bermuda grass (*Cynodon dactylon*), *C. nlemfuensis* was considered to be at least adventive on Moloka‘i and Hawai‘i (Wagner *et al.* 1990, 1999: 1520). Reevaluated in 1999, the status on both islands was changed to naturalized (Herbst & Wagner 1999: 25). In 2001, it was reported as naturalized in Wailuku, West Maui (Oppenheimer 2003: 20). It is now documented from O‘ahu, based on identification of a 2005 collection by Thomas Cope of the Royal Botanic Gardens, Kew. This stoloniferous grass, native from eastern and central Africa, is naturalized at least in southern Texas in the U.S. (Barkworth 2003).

Material examined. **O‘AHU**: Pearl Harbor National Wildlife Refuge, at back of refuge, growing roadside in drier area, 13 ft [4 m], 23 Feb 2005, *L.M. Crago, C. Imada, & M. Silbernagle 2005-068.*

Digitaria abyssinica (Hochst. ex A. Rich.) Stapf **New island record**

First recorded in the Hawaiian Islands from Kaua‘i and East Maui (Herbst & Clayton 1998: 23), this grass has now been recorded on O‘ahu. This species is considered a high-risk weed (Hawaii-Pacific Weed Risk Assessment 2009a).

Material examined. **O‘AHU**: Kawailoa, Drum Rd., mesic roadside setting, 09 Mar 2016, *J. Hawkins & P. Rellenos USARMY 427*; Kawailoa Drum Rd., near mile marker 11 after side dirt road meets with Drum Rd., patch estimate 500 ft² [45 m²], 1,100 ft [335 m], 05 May 2016, *J. Hawkins & J. Rellamas USARMY 442*.

Digitaria bicornis (Lam.) Roem. & Schult. **New island record; range extension**

First recorded as naturalized in Hawai‘i based on a 2008 collection (*Oppenheimer H20816*) from a pasture in Waikapū, West Maui (Snow & Lau 2010: 50), additional records have come to light following a review of Hawaiian specimens of *D. ciliaris* at *Herbarium Pacificum* by J.F. Veldkamp (Leiden) in 2011. Reidentification of vouchers from Midway and East Maui as *D. bicornis* now extend the range of the species in the state. The *Digitaria* key in Clayton & Snow (2010: 70) separates the two similar species by the following characters: *D. bicornis* with ribbed equidistant veins on the lower lemma of the sessile spikelet, and usually 2 stiff racemes; *D. ciliaris* without ribs, the veins usually unequally spaced on the lower lemma of the sessile spikelet, and 2–12 stiff or flexible racemes.

Material examined. **MIDWAY ATOLL**: no locality, Aug 1959, *Mr. Cornelison s.n.* (BISH 118698). **MAUI**: East Maui, along Haleakalā Hwy, on mowed road shoulder, 07 May 1982, *R.W. Hobdy 1385.*

Digitaria radicosa (J. Presl) Miq. **New island records**

Documented in Wagner *et al.* (1990, 1999: 1530) as adventive in lawns and gardens on O‘ahu, reexamination of *Digitaria* vouchers at BISH by W.D. Clayton (Kew) and J.F. Veldkamp (Leiden) resulted in the reidentification of several *D. ciliaris* specimens as *D. radicosa* on O‘ahu. Thus its year of first collection on O‘ahu (and the state) is pushed back to 1909 (*Faurie 1297*) from the previously recorded 1938 (*Pukui s.n.,* BISH 118592), and its establishment as a naturalized grass on O‘ahu is confirmed. The species is also documented as naturalized on Kaua‘i (Herbst & Clayton 1998: 23), Hawai‘i (Staples *et al.* 2003: 18), and now on East Maui.

Material examined. **O‘AHU**: Honolulu, 1909, *U. Faurie 1297*; Nu‘uanu, 42 Coelho Way, weedy grass in garden beds, 25 Jul 1957, *M.C. Neal s.n.* (BISH 118716); Lanikai, Mokulua (North Island), 07 Feb 1978, *D. Herbst 6002*; Kahana, Mokoli‘i Island, 19 Apr 2005, *F. Starr et al. 050419-60*; Kahuku Training Area, Opana Road, 31 Jan 2018, *K. Kawelo & J. Beachy USARMY 477*. **MAUI**: East Maui, Kokomo, in decumbent patches, 1,400 ft [425 m], 16 Oct 2005, *R.W. Hobdy 4225.*

Eragrostis brownii (Kunth) Nees ex Steud. **New island record**

This Australian grass, first collected in Hawai‘i on the Big Island in 1916 by A.S. Hitchcock, was recorded as naturalized on Moloka‘i, Maui, and Hawai‘i by Wagner *et al.* (1990, 1999: 1540–41), and later documented on Kaua‘i (Lorence & Flynn 1999: 5). Now sheepgrass has been recorded on O‘ahu as a roadside weed in a military training area.

Material examined. **O‘AHU**: Kahuku Training Area, RS-KTA-04, roadside, naturalized, 600 ft [185 m], 30 Jan 2018, *K. Kawelo & K. Cloward USARMY 473*.

Eragrostis leptostachya (R. Br.) Steud. **New island records**

This species has an interesting history in the Hawaiian Islands. The first collection was made in 1937 on an arid, windswept slope at Puu Nānā, Mauna Loa, Molokaʻi, elevation 1,300 feet [395 m] (*E.Y. Hosaka 1848*). Botanist Otto Degener described it as a new endemic grass, *E. hosakai* O. Deg., in 1940 (Degener 1940). Since it remained the only collection of the species, Wagner *et al.* (1990: 1542) considered it to be extinct. Study of the Hosaka type specimen by Lazarides (1997), however, revealed that it was identical to *E. leptostachya*, an Australian species already naturalized in England, Belgium (a contaminant with wool imported from Australia), and Easter Island (Clayton & Herbst 1998: 27). While it has still not been recollected on Molokaʻi, *E. leptostachya* has since been recorded on West Maui (Staples *et al.* 2002: 14), and additional records are recorded here for Oʻahu, East Maui, and Kahoʻolawe. We thank former Bishop Museum botanist Neil Snow for the determinations.

Material examined. **OʻAHU**: Dillingham Military Reserve, collected from a naturalized population of about 20 plants in the immediate area, growing with *Sida ciliaris, Euphorbia hirta*, 06 Jan 2016, *S. Heintzman USARMY 403*. **MAUI**: East Maui, Ulupalakua, adjacent to Tedeschi Winery, NW of Puʻu Mahoe, occasional bunchgrass on open mesic slope in alien vegetation, 2100 ft [640 m], 16 Jul 2002, *C. Imada, C. Puttock, P. Bily, A. Lyons, & J. Brown 2002-24*; Makawao Distr., Pāʻia, volunteer in sidewalk crack, 40 ft [12 m], 20 Jan 2010, *H. Oppenheimer H11009*. **KAHOʻOLAWE**: Honokanaiʻa, at base camp, occasional, 20 ft [6 m], 20 Jan 2004, *H. Oppenheimer & G. Hansen H10404*.

Eragrostis parviflora (R. Br.) Trin. **New island record**

This species was first recorded as naturalized on Kauaʻi based on a 1996 collection (*T. Flynn 2925*) from the Port Allen area in Hanapēpē (Flynn & Lorence 1998: 5), identified by Derek Clayton (Kew) in 1997. Subsequently, in 2002 Clayton identified an earlier collection of *E. parviflora* from 1989 (*Flynn et al. 3287*) on Kauaʻi further southwest at the Russian Fort Elizabeth State Historical Park in the town of Waimea, originally called *E. pectinacea*. A 2018 collection extends its coastal range to western Oʻahu, where it was associated with alien vegetation, including *Syzygium cumini, Prosopis pallida, Schinus terebinthifolius*, and *Megathyrsus maximus* [=*Urochloa maxima*].

Material examined. **OʻAHU**: Waiʻanae Mts., Dillingham Airfield, near westernmost gate, 25 plants, sea level, 16 Jan 2018, *K. Tschannen et al. USARMY 469.*

Eriochloa procera (Retz.) C.E. Hubb. **New island record**

First recorded as naturalized on Molokaʻi at Kaunakakai Wharf in 2006 (Oppenheimer 2008: 32) and later on Midway Atoll (Snow & Lau 2010: 52; Starr & Starr 2011: 30), J.F. Veldkamp (Leiden) in 2011 identified this naturalizing grass for the first time on Oʻahu from a 1996 collection.

Material examined. **OʻAHU**: Kāneʻohe, Marine Corps Base Hawaiʻi, junction of Nuʻupia Ponds causeway and old Hawaiian wall, sea level, 29 May 1996, *D.R. Herbst 9769.*

Panicum fauriei Hitchc.

var. ***carteri*** (Hosaka) Davidse **Retraction of new island record**

Federally listed as Endangered, *Panicum fauriei* var. *carteri* was recorded from Oʻahu, Molokaʻi, and Maui in Wagner *et al.* (1990, 1999: 1568). A new record from Lānaʻi was later added, based on a 1993 collection (Herbst & Clayton 1998: 30). Reexamination of the specimen by M. LeGrande in 2002 resulted in its reidentification as *P. fauriei* var.

latius (H. St. John) Davidse, a variety already well established on the island. The varieties are separated by spikelet morphology and pubescence: var. *latius* with acute to acuminate spikelets 2–4.2 mm long, short-pubescent with short to long tufts of hairs at glume apices; var. *carteri* with acute spikelets 1.8–2.3 mm long, short-pubescent (Wagner *et al.* (1990, 1999: 1568).

Material examined. **LĀNA‘I**: Kukui Point, near sea level, 07 Mar 1993, *R.W. Hobdy et al. 3581*.

Panicum* sp. A** identified as ***P. antidotale Retz.

A 1986 grass collection from Mo‘omomi, Moloka‘i (*Takeuchi & Imada 2970)* was identified as the first naturalized record of *Panicum coloratum* (blue panic grass) from that island. In the *Manual* (Wagner *et al.* 1990: 1567), this collection and one from Maui (*Hosaka 2448*) were recorded as proof that this species was naturalized in the state. Subsequently, Herbst & Clayton (1998: 30) published a correction stating that the Hosaka voucher was actually collected in a Hawaii Agricultural Experimental Station plot in Makawao, Maui, not as an escaped weed, and that the *Takeuchi & Imada* voucher was not *P. coloratum*, but a yet-to-be-identified species of *Panicum*. Thus, *P. coloratum* was removed as a confirmed naturalized member of the Hawaiian grass flora. The unidentified *Panicum*, subsequently referred to as *Panicum* sp. A, was identified in 2010 by Gerrit Davidse of Missouri Botanical Garden as *P. antidotale* Retz. (giant panic grass), a species already recorded from Moloka‘i, as well as O‘ahu and Hawai‘i (Wagner *et al.* (1990, 1999: 1567). Starr *et al.* (2003: 30) extended its range to include both East and West Maui. The two species are quite similar; in the *Manual* (Wagner *et al.* 1990, 1999: 1566), they are distinguished by glume and lemma characters: margins of second glume and first lemma hyaline in *antidotale*, herbaceous in *coloratum*; first glume 1/2–2/3 as long as the spikelet in *antidotale*, 1/4–1/3 as long in *coloratum*.

Material examined. **MOLOKA‘I**: Mo‘omomi, proposed sand-mining tract, *Prosopis* overstory, 30 Oct 1986, *W. Takeuchi & C. Imada 2970.*

Paspalum notatum Flüggé **New island record**

First documented on Kaua‘i (Lorence & Flynn 1999: 6), Bahia grass has since been recorded as naturalized on East and West Maui (Oppenheimer 2007: 29; Oppenheimer noted that the species did not yet appear to be aggressive but needed to be watched), and Moloka‘i (Oppenheimer 2008: 33). Now a record from the herbarium backlog has been identified as *P. notatum*, not only extending its Hawaiian range to the island of Hawai‘i, but also pushing back its date of first collection to 1981, 16 years earlier than the 1997 Kaua‘i collection. This Central and South American grass has been rated by Hawaii-Pacific Weed Risk Assessment (n.d.) as a high-risk species.

Material examined. **HAWAI‘I**: Kapāpala Ranch, Ka‘ū District, growing in pasture beside jeep trail, ca 4,000 ft [1,220 m], 20 Oct 1981, *L.W. Cuddihy 917*.

Paspalum paniculatum L. **New island record**

Considered an adventive species on O‘ahu and Hawai‘i by O’Connor (1990: 1575), upon reevaluation Herbst and Wagner (1999: 28) determined that *Paspalum paniculatum* was naturalized on both islands. It has since been documented on West Maui (Oppenheimer 2004: 16). The following specimen, collected in 2005 on Kaua‘i, represents the first naturalized record of the species on that island. In CABI (2020d), this

weedy grass, native to tropical America, is listed as invasive in Hawai‘i, Cuba, Trinidad and Tobago, Samoa, Northern Marianas Islands, Micronesia, Fiji, French Polynesia, New Caledonia, Niue, Palau, and the Solomon Islands, where it invades primarily disturbed sites, forest margins, and secondary forests.

Material examined. **KAUA‘I**: Hanalei National Wildlife Refuge, growing on upper bank of irrigation ditch ca 0.25 mi [0.4 km] up the road from the NWR gates, 02 Aug 2005, *L.M. Crago & C. Imada 2005-159*.

Sporobolus indicus (L.) R.Br. **New island record**

West Indian dropseed, also known as smutgrass, was originally documented on Midway Atoll, Kaua‘i, O‘ahu, Lāna‘i, Maui, and Hawai‘i (Wagner *et al.* 1990, 1999: 1597), and soon after on Kaho‘olawe (Warren 1993: 43). Upon reevaluation, the Maui and Kaho‘olawe records were reidentified as the very similar *Sporobolus africanus* (Herbst & Clayton 1998: 36). Three subsequent collections from Maui, made between 1999 and 2005 on both East and West Maui, now reestablish that *S. indicus* is naturalized on Maui.

Material examined. **MAUI**: West Maui, west of Kahakuloa on Hwy 340, coastal bluff, 50 m, 17 Feb 1999, *C.R. Annable & L. Nelson 3920*; East Maui, Hāna Ranch pasture land mauka of Hāna Ranch Store, open pasture land with *Digitaria ciliaris, Eragrostis pectinacea, Mimosa pudica, Sida rhombifolia, Chamaesyce prostrata, Elephantopus spicatus,* dominant bunchgrass in the pasture, ca 400 ft [120 m], 07 Nov 2002, *C. Imada, C. Puttock, T. Kelley, M. LeGrande, & R. Ganske 2002-71*; East Maui, ‘Ālau, rare, one plant, first collected during this survey, 05 Apr 2005, *F. Starr, K. Starr, & K. Wood 050405-27.*

Sporobolus pyramidatus (Lam.) Hitchc. **New island record**

Treated as a note in the *Sporobolus* treatment for *Manual of the Flowering Plants of Hawai‘i*, O’Connor (1990: 1596) considered whorled dropseed to be an adventive weed in coastal sites on Kure Atoll, French Frigate Shoals, and O‘ahu. Wagner and Herbst (1995: 24) confirmed the naturalized status of *S. pyramidatus* on those islands, in addition to Laysan, citing that label data on *Herbarium Pacificum* specimens clearly made a case for this species to be fairly widely naturalized in the archipelago. Since then, in quick succession, the species has been recorded on Moloka‘i (Starr *et al.* 2006: 40), Kaua‘i (Wood 2006: 18), Hawai‘i (Snow & Lau 2010: 56), Midway Atoll (Starr *et al.* 2010: 66), and Kaho‘olawe (Starr & Starr 2011: 31). Now a 2009 voucher by Robert Hobdy, recently unearthed from backlog and identified in 2019, confirms the presence of *S. pyramidatus* in Kīhei on East Maui. Native to North and South America and the Caribbean, CABI (2020e) notes that it is weedy within this geographic range in coastal areas, a variety of well-drained sandy soils inland, and roadsides and other disturbed places, and attributes its competitive ability to its allelopathic qualities. The Hawaii-Pacific Weed Risk Assessment (2009d) has rated this grass as a high-risk species.

Material examined. **MAUI**: East Maui, Kīhei, spreading on disturbed ground on Lower Piikea St., 06 Mar 2009, *R.W. Hobdy 4305.*

Urochloa brizantha (Hochst. ex A. Rich.) R.D. Webster **New island record**

First recorded as naturalized in the Hawaiian Islands on Kaho‘olawe (Starr *et al.* 2006: 39), and later on East Maui (Oppenheimer 2008: 31) under the name *Brachiaria brizantha*, Snow & Lau (2010: 49) removed the Kaho‘olawe record after reidentifying that island record as *B. decumbens* [= *Urochloa decumbens*]. Now a recently unearthed 1966

collection by Derral Herbst adds a new island record of this species for O‘ahu. The name change from *Brachiaria* to *Urochloa* follows Zuloaga *et al.* (2003: 630).

Material examined. **O‘AHU**: Ko‘olauloa Distr., Ka‘a‘awa, Bill Hoe’s beach house, growing with *Urochloa mutica*, culms decumbent, 7–8 ft [2–2.5 m] long, forming dense mats 3 ft [1 m] high, 12 Jun 1966, *D.R. Herbst 144.*

Urochloa distachya (L.) T.Q. Nguyen **New island record**

In O’Connor (1990: 1503), what merges into this species starts out as a note discussing two *Brachiaria* species of uncertain naturalization status, *B. distachya* (known from a single Kaua‘i collection from 1946) and *B. subquadripara* (possibly naturalizing on O‘ahu, Moloka‘i, and Maui in pastures and along roadsides). Lorence *et al.* (1995: 44) reported the first authentic naturalized record for *B. subquadripara* from Kaua‘i. Then, in 2003, *Herbarium Pacificum* chose to follow Zuloaga *et al.* (2003: 631) in adopting the sinking of *Brachiaria* into *Urochloa*, as well as the synonymization of *B. subquadripara* into *Urochloa distachya*. Subsequently, new island records for *U. distachya* have been recorded on O‘ahu (Frohlich & Lau 2014: 13) and Lāna‘i (Oppenheimer & Bogner 2019: 23). The following vouchers also confirm its naturalized presence on both East and West Maui. The updated distribution of *U. distachya* in Hawai‘i: recorded on Kaua‘i, O‘ahu, Lāna‘i, and East and West Maui, but no vouchers at BISH from Moloka‘i.

Material examined. **MAUI**: East Maui, HC&S field, sprawling, rooting at nodes, mat-forming, May 1967, *T. Yamada O-82*; East Maui, HC&S cane fields, weed along cane roads, forming dense, decumbent patches, 31 Jan 1984, *R. Hobdy 1931*; West Maui, mauka of Lahainaluna School, along cane field road, a common weed in West Maui canefields during the last decade, 800 ft [245 m], 12 Feb 1986, *R. Hobdy 2500*; West Maui, Lahaina Distr., ‘Alaeloa, vicinity of Pu‘ukalauliko, at edge of dirt road in pineapple field, 500 ft [150 m], 24 Oct 2000, *H. Oppenheimer H100038*; central plains southwest of Kahului, mat-forming grass growing in sandy soil, 100 ft [30 m], 17 Jun 2004, *R. Hobdy 4192*; East Maui, Hāna Distr., Pu‘uhaoa, edge of pasture, 350 ft [105 m], 17 Dec 2005, *H. Oppenheimer H120507.*

Rubiaceae

Spermacoce latifolia Aubl. **New island record**

Spermacoce latifolia, native to tropical South America and the West Indies and now a common weed in many tropical regions, was first recorded as a naturalized species in the state from collections made in a southern Kaua‘i sugarcane field in 1990 (Lorence *et al.* 1995: 51–52). It was subsequently documented from East Maui (Oppenheimer 2004: 17) and Moloka‘i (Oppenheimer 2010: 38). Recently, it was collected for the first time on O‘ahu, in the lowlands of the northern Ko‘olau Mountains, growing in a lush patch 0.5 m tall and several meters wide, stems upright but delicate and sprawling. The collector speculated that the patch represented either one massive clone or hundreds of individuals. The inflorescence was noted to have a faint, pleasant scent. The associated vegetation was largely alien. There is apparent disagreement among Rubiaceae specialists about the taxonomic placement of this species. Several recent floras have included *S. latifolia* as a synonym under *S. alata* Aubl. (*e.g.,* Tao & Taylor 2011; Adams & Taylor 2012; Taylor & Hammel 2014). Wiersema *et al.* (2017) take an opposing view in recognizing both species.

Material examined. **O‘AHU**: northern Ko‘olau Mts., Kahuku Training Area, dense patch in shaded, damp area on ridge between Kea‘aulu and Lamaloa Gulches, 450 ft [135 m], 25 Mar 2019, *J. Beachy, A. Woods, & J. Dedrick USARMY 512.*

Salviniaceae

Azolla caroliniana Willd. **New naturalized records**

Azolla is a genus of 5–7 species found throughout tropical and temperate regions of the world (Lumpkin 1993; Mabberley 2017). These tiny water ferns are well known for their association with nitrogen-fixing blue-green algae, leading to their economic use as a green fertilizer. They have also been exported horticulturally as water plants, leading to their spread as invasive weeds of slow-moving waterways. *Azolla filiculoides* and *A. caroliniana* are among three North American species that have become naturalized in Europe and South Africa, and introduced horticulturally into Hawai‘i and agriculturally into Asia (Lumpkin 1993). In Hawai‘i it can often be found covering the water surface in taro paddies. While *A. filiculoides* has a long history of presence in Hawai‘i, with *Herbarium Pacificum* vouchers dating back to 1937, *A. caroliniana* was apparently relatively recently introduced, represented in the herbarium by only two Hawaiian vouchers collected in 1985 (O‘ahu) and 1994 (Moloka‘i), both identified in 1994 by Alan R. Smith (UC-Berkeley). The two naturalized *Azolla* species in the state are distinguished by the following difficult-to-observe characters: *filiculoides* with the largest hairs on upper leaf lobe unicellular, and the megaspores warty with raised angular bumps; *caroliniana* with the largest hairs on upper leaf lobe 2- or more-celled, and the megaspores without raised angular bumps (Lumpkin 1993).

Material examined. **O‘AHU**: Honolulu, Kānewai area, Dole St., floating plant carpeting the surface of a sparsely planted taro patch, 06 Nov 1985, *J. Lau 1616*. **MOLOKA‘I**: Near Smith-Bronte Landing site, floating in water in taro patch, 05 Jun 1994, *K.A. Wilson, D.D. Palmer, & J. Aidem 2447*.

Thelypteridaceae

Christella dentata (Forssk.)
Brownsey & Jermy **New island record**

Only the fifth naturalized fern documented from Kaho‘olawe [*Nephrolepis brownii*, *Adiantum hispidulum*, *Pityrogramma austroamericana*, and *P. calomelanos* are the others; see Imada 2019], *Christella dentata* was collected as a single specimen in 1980 in a shaded gully. As 40 years have passed since it was collected, its current status needs to be verified. The species has now been collected on all eight main islands (Palmer 2003: 88; Imada 2007: 39). Its generic placement has flip-flopped between *Christella*, *Cyclosorus*, and *Thelypteris*; here we follow the Pteridophyte Phylogeny Group (2016) and Ranker *et al.* (2019) in accepting its placement in *Christella*.

Material examined. **KAHO‘OLAWE**: Northeast part of island near Wa‘aiki Gulch, single fern growing near bottom of gully in shade of *Prosopis pallida* and *Nicotiana glauca* trees, ca 1,100 ft [335 m], 24 Apr 1980, *L.W. Cuddihy & G. Clarke 405*.

TAXA SHOWING SIGNS OF NATURALIZATION

Malvaceae

Corchorus olitorius L.

Easily grown and with a variety of culinary uses (Philippine okra and Filipino spinach are among its local common names), *Corchorus olitorius* is popular with local growers. The species is native to India and is widely cultivated in northern Africa, the Middle East, and Asia, both as a food and fiber source; however it sometimes escapes from cultivation and can become weedy (Staples & Herbst 2005: 548). Wagner *et al.* (1990: 1291) noted the

historical eradication of a naturalized population in Lāwa‘i Valley, Kaua‘i, and an undocumented report of escaping plants along lotus pond banks at Hale‘iwa, O‘ahu. The following vouchers suggest that it may again be escaping from cultivation on Kaua‘i, as well as on Maui. Given its popularity among local growers and its propensity to become weedy, we recommend that invasive species and natural resources field staff be on the lookout for this species. With its yellow-petaled flowers and cylindrical capsules, *Corchorus olitorius* superficially resembles *Ludwigia octovalvis* in wetland habitats; a description of *Corchorus* can be found in Staples & Herbst (2005: 548).

Material examined. **KAUA‘I**: Hanalei National Wildlife Refuge, 2017, *K. Uyehara s.n.* (BISH 775086). **MAUI**: central Maui, southern coast of isthmus, Keālia Pond National Wildlife Refuge, west of Keālia Pond, 5 ft [1.5 m], 07 Oct 1998, *C. Imada & K. Evans 98-31*; East Maui, Kula, Ka‘ono‘ulu, highly disturbed site 150 ft [45 m] below Pi‘ilani Hwy., ca 5 plants, 35 ft [11 m], 23 Jan 2014, *R.W. Hobdy 4349*.

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Marine Benthic Algae from Ni‘ihau and Adjacent Lehua Islet, Main Hawaiian Islands[1]

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The published records of marine benthic algal species from the privately-owned island of Ni‘ihau (Hawaiian Islands) are represented by four species cited in Abbott (1999) and Abbott & Huisman (2004). The species consist of the red alga *Chondrophycus dotyi* (Y. Saito) K.W. Nam [= *Laurencia dotyi* Y. Saito], two brown algae *Dictyopteris plagiogramma* (Montagne) Vickers and *Distromium flabellatum* Womersley, and the green alga *Pseudochlorodesmis parva* W. J. Gilbert [= *Siphonogramen parvum* (W.J. Gilbert) I.A. Abbott & Huisman]. *Distromium flabellatum* and *Pseudochlorodesmis parva* were collected in waters between Ni‘ihau and Lehua Islet. The paucity of algal records from Ni‘ihau is not surprising, very few collections have been made along its coastline because of its remoteness and general lack of access.

The U.S. Fish and Wildlife Service, however, funded field surveys between 2001 and 2004 to study the biodiversity of Lehua Islet, located just 1.2 km north of Ni‘ihau. Lehua Islet is a Hawai‘i Seabird Sanctuary federally owned by the U.S. Coast Guard and maintained by the Hawai‘i Department of Land and Natural Resources. Forty species of marine

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benthic algal species were reported by Wood *et al*. (2004) from Lehua Islet. The specimens were collected by Maya LeGrande in March and May 2003 "… from inter-tidal and shallow marine areas near the rock bench fronting the sea caves along Lehua's south shore." The algae recorded from Lehua Islet (see Appendix) included 2 species of Cyanobacteria, 21 species of Rhodophyta, 12 species of Phaeophyceae, and 5 species of Chlorophyta. All of the above specimens were databased and deposited in the *Herbarium Pacificum* (BISH) at the Bernice P. Bishop Museum.

This paper is based on algal specimens collected in the intertidal zone, shallow coral reefs (SCR, <30 m depth) and the mesophotic coral ecosystem (MCE, 30–150 m depth) from Ni'ihau and adjacent Lehua Islet. In this paper, Lehua Islet is considered part of Ni'ihau; thus algae collected from Lehua Islet are considered a "New island record" for Ni'ihau. BISH specimens are deposited at the Bishop Museum and MHI (Main Hawaiian Islands) specimens are deposited at Alison R. Sherwood's (ARS) Laboratory at the University of Hawai'i Department of Botany.

Guiry & Guiry (2020) and Brummitt & Powell (1992) were, respectively, consulted for currently accepted algal names and synonyms, and for spelling of authors of algal names.

Most unpublished algal collections from Ni'ihau and Lehua Islet were hand collected by Lynn M. Hodgson from Lehua Islet on 26–27 May 2001 via SCUBA at depths of 12.2–27.4 m, and by Ryan Okano, aboard NOAA R/V *Hi'ialakai,* from Ni'ihau on 9–11 Aug 2006 via SCUBA at depths of 10.7–13.7 m, and from the intertidal and SCR off Lehua Islet on 12 Aug 2006. Heather Spalding, Randall Kosaki, Jason Leonard and Steve Matadobra, aboard NOAA R/V *Hi'ialakai*, hand collected specimens from the SCR and/or MCE on 14–15 Sep 2018. A fourth algal collection was retrieved by Louise M. Giuseffi and Annika Little from NOAA freezers which held algae collected from Lehua Islet and Ni'ihau. Additional specimens collected by Ryan Okano, Aline Tribollet, and Stefane Charette from Lehua Islet and Ni'ihau on 9–12 Aug 2006 via SCUBA at depths of 9–16 m were also retrieved from the freezers.

Ten species collected from Lehua Islet (Wood *et al*. 2004) and one species collected from Ni'ihau (Abbott & Huisman 2004), each preceded by an asterisk (*), were reported in the past literature. Forty-seven species represent new records for Ni'ihau (includes adjacent Lehua Islet) in the Main Hawaiian Islands (MHI). Information on species distribution in the coastal waters of the 10 islands, atolls and shoals of Papahānaumokuākea Marine National Monument (PMNM) can be obtained from Tsuda (2014) and Tsuda *et al.* (2015). One green alga, *Codium hawaiiense* P.C. Silva & Chacana, represents a new record for Ni'ihau and the MHI. Two Cyanobacteria, *Rivularia atra* Roth and *Symploca atlantica* Gomont, may also represent new published records for the MHI. Specimens of the two species of Cyanobacteria, however, are documented from the MHI in BISH.

Of the 68 species of marine benthic algae reported from Ni'ihau (including Lehua Islet), only 11 species (16%) were collected from the MCE (30–150 m depth). The species included three species of Rhodophyta (*Amansia glomerata* C. Agardh, *Haloplegma duperreyi* Mont., *Plocamium sandvicense* J. Agardh), three species of Phaeophyceae (*Dictyota ceylanica* Kütz*, Dictyota* sp., *Distromium* sp.) and five species of Chlorophyta (*Cladophora* sp., *Codium mamillosum* Harv., *Halimeda opuntia* (L.) J.V. Lamour., *Phyllodictyon anastomosans* (Harv.) Kraft & M.J. Wynne, *Siphonocladus tropicus* (P. Crouan & H. Crouan) J. Agardh).

Phylum CYANOBACTERIA

Blennothrix cantharidosum (Gomont ex Gomont) **New island record**

[Anagnost. & Komárek [= *Hydrocoleum cantharidosum* Gomont]

MHI distribution. Kauaʻi (Tilden 1910); Oʻahu (Khan 1967).

Material examined. NIʻIHAU: BISH 589663, coll. M. Reed, 14 Aug 1905.

Note. The specimen, initially identified by F. Drouet as *Hydrocoleum cantharidosum* Gomont in May 1987, was dark green and formed slimy rocks in shallow water.

Leptolyngbya crosbyana (Tilden) Anagnost. & Komárek **New island record**

[= *Phormidium crosbyanum* Tilden]

MHI distribution. Oʻahu (Tilden 1910, Huisman *et al.* 2007), Kahoʻolawe (Coles *et al.* 1998, Tsuda & Abbott 2018).

Material examined. LEHUA ISLET: MHI 061, NFWF cruise 2018, 8 m depth, coll. H. Spalding, 14 Sep 2018.

Lyngbya confervoides C. Agardh **New island record**

MHI distribution. Hawaiian Islands (Tilden 1910).

Material examined. LEHUA ISLET: BISH 777664 (NOAA 167-1312), LEH 3, 15 m depth, coll. unspecified, 18 Jul 2005; BISH 777665 (NOAA 167-1313), LEH 3, 15 m depth, coll. unspecified, 18 Jul 2005; BISH 777666 (NOAA 167-1314), LEH 3, 15 m depth, coll. unspecified, 18 Jul 2005.

Note. All trichomes were 12–24 µm dia.

Phormidium sp.

Material examined. LEHUA ISLET: MHI 060, NFWF cruise 2018, 11 m depth, coll. H. Spalding, 14 Sep 2018.

Rivularia atra P.H. Roth ex Bornet & Flahault **New island record**

Material examined. LEHUA ISLET: BISH 777667 (NOAA 167-1315), LEH 03, 15 m depth, coll. unspecified, 18 Jul 2005.

Schizothrix* cf. *calcicola Gomont **New island record**

MHI distribution. Oʻahu (Khan 1967).

Material examined. LEHUA ISLET: BISH 777662 (NOAA 167-1310), LEH 3, 15 m depth, coll. unspecified, 18 Jul 2005.

Symploca atlantica Gomont **New island record**

Material examined. LEHUA ISLET: MHI 043, NFWF cruise 2018, 9 m depth, coll. H. Spalding, 14 Sep 2018; MHI 044, NFWF cruise 2018, 9 m depth, coll. H. Spalding, 14 Sep 2018; MHI 051, NFWF cruise 2018, 11 m depth, coll. H. Spalding, 14 Sep 2018; MHI 052, NFWF cruise 2018, 8 m depth, coll. H. Spalding, 14 Sep 2018; MHI 070, NFWF cruise 2018, 8 m depth, coll. H. Spalding, 14 Sep 2018.

Phylum RHODOPHYTA

Acanthophora pacifica (Setch.) Kraft **New island record**

MHI distribution. Kauaʻi, Oʻahu, Maui, Lānaʻi, Kahoʻolawe, Hawaiʻi (Abbott 1999).

Material examined. NIʻIHAU: BISH 725042 (IA 31752), NOAA R/V *Hiʻialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; BISH 777683 (NOAA 167-1333), NII 05, 12–14 m depth, coll. R. Okano & S. Charette, 11 Aug 2006; BISH 777672 (NOAA 167-1320), NII05, 11–12 m depth, coll. C. Richards, 10 Nov 2008. LEHUA ISLET: BISH 716747 (IA 28411), key hole, 15.2–24.4 m, coll. L.M. Hodgson, 27 May 2001.

Actinotrichia fragilis (Forssk.) Børgesen **New island record**

MHI distribution. Kauaʻi, Oʻahu, Molokaʻi, Lānaʻi, Maui, Kahoʻolawe, Hawaiʻi (Abbott 1999).

Material examined. NIʻIHAU: BISH 725030 (IA 31728), NOAA R/V *Hiʻialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; BISH 725036 (IA 31736), NOAA R/V *Hiʻialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; BISH 777687 (NOAA 167-1337), NII 05, 12–14 m depth, coll. R. Okano, 11 Aug 2006.

Aglaothamnion cordatum (Børgesen) Feldm.-Maz. **New island record**

MHI distribution. Kauaʻi, Oʻahu, Molokaʻi, Maui (Abbott 1999).

Material examined. LEHUA ISLET: BISH 701349 (LR 003), 15.2–27.4 m depth, coll. L.M. Hodgson, 26 May 2001.

****Amansia glomerata*** C. Agardh

MHI distribution. Lehua Islet (Wood *et al.* 2004); Kauaʻi, Oʻahu, Maui, Kahoʻolawe, Hawaiʻi (Abbott 1999).

Material examined. NIʻIHAU: BISH 777652 (NOAA 167-1300), NII 09, 13–16 m depth, coll. R. Okano & S. Charette, 11 Aug 2006; BISH 777680 (NOAA 167-1328), NII 05, 12–14 m depth, coll. R. Okano & S. Charette, 11 Aug 2006; BISH 777671 (NOAA 167-1319), NII 05, 11–12 m depth, coll. C. Richards, 10 Nov 2008; MHI 079 (ARS 09530), NFWF cruise 2018, 73 m depth, coll. R. Kosaki, 15 Sep 2018; MHI 105 (ARS 09536), NFWF cruise 2018, 73 m depth, coll. J. Leonard, 15 Sep 2018. LEHUA ISLET: BISH 692134 (IA 28402), Vertical Awareness Pinnacle, 27.4 m depth, coll. L.M. Hodgson, 26 May 2001; BISH 701902 (LR 007), 15.2–27.4 m depth, coll. L.M. Hodgson, 26 May 2001; BISH 777673 (NOAA 67-1321), 9–12 m depth, coll. A. Tribollet & R. Okano, 12 Aug 2006; MHI 024 (ARS 09495), NFWF cruise 2018, 74 m depth, coll. R. Kosaki, 14 Sep 2018; MHI 040 (ARS 09511), NFWF cruise 2018, 49 m depth, coll. S. Matadobra, 14 Sep 2018; MHI 049, NFWF cruise 2018, 11 m depth, coll. H. Spalding, 14 Sep 2018.

Antithamnionella breviramosa (E.Y. Dawson) E.M. Woll. **New island record**

MHI distribution. Oʻahu, Maui (Abbott 1999).

Material examined. LEHUA ISLET: BISH 7019005 (LR 010), 15.2–27.4 m depth, coll. L.M. Hodgson, 26 May 2001.

****Asparagopsis taxiformis*** (Delile) Trevis.

MHI distribution. Lehua Islet (Wood *et al*. 2004); Kauaʻi, Oʻahu, Molokaʻi, Hawaiʻi (Abbott 1999).

Material examined. LEHUA ISLET: BISH 725047 (IA 31758), NOAA R/V *Hiʻialakai*, intertidal, coll. R. Okano, 12 Aug 2006.

Ceramium sp.

Material examined. LEHUA ISLET: BISH 691247, key hole, epizoic on hydroid, 15.2–24.4 m depth, coll. L.M. Hodgson, 27 May 2001.

Note. Only a few immature specimens of this approximately 40 µm dia *Ceramium* sp. were available for identification.

Ceratodictyon variabile (J. Agardh)
R.E. Norris **New island record**
MHI distribution. O‘ahu, Lāna‘i, Hawai‘i (Abbott 1999).
Material examined. LEHUA ISLET: BISH 725054 (IA 31767), NOAA R/V *Hi‘ialakai*, intertidal, coll. R. Okano, 12 Aug 2006.

Chrysymenia okamurae Yamada & Segawa **New island record**
MHI distribution. Maui, Hawai‘i (Abbott 1999).
Material examined. LEHUA ISLET: BISH 725052 (IA 31764), NOAA R/V *Hi‘ialakai*, intertidal, coll. R. Okano, 12 Aug 2006.

Exophyllum sp.
Material examined. NI‘IHAU: BISH 725028 (IA 31726), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006.
Note. Although only one species, *Exophyllum wentii* Weber-van Bosse, is recognized in the genus, the Hawaii specimens differ from the type material (Indonesia) as per detailed study by Indy *et al.* (2006). Further studies are necessary on this Hawaiian specimen.

Galaxaura divaricata (L.) Huisman &
R.A. Towns. **New island record**
[= *Galaxaura fasciculata* Kjellm.]
MHI distribution. O‘ahu, Moloka‘i, Kaho‘olawe (Abbott 1999).
Material examined. NI‘IHAU: BISH 725027 (IA 31725), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006. LEHUA ISLET: BISH 725049 (IA 31760), NOAA R/V *Hi‘ialakai*, intertidal, coll. R. Okano, 12 Aug 2006.

Gibsmithia hawaiiensis Doty **New island record**
MHI distribution. Kaua‘i, O‘ahu, Lāna‘i, Kaho‘olawe, Hawai‘i (Abbott 1999).
Material examined. NI‘IHAU: BISH 725029 (IA 31727), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006.

Haloplegma duperreyi Mont. **New island record**
MHI distribution. Kaua‘i, O‘ahu, Moloka‘i, Maui, Hawai‘i (Abbott 1999); Kaho‘olawe (Tsuda & Abbott 2018).
Material examined. LEHUA ISLET: MHI 039 (ARS 09510), NFWF cruise 2018, 49 m depth, coll. S. Matadobra, 14 Sep 2018.

Halymenia sp.
Material examined. NI‘IHAU: BISH 725033 (IA 31733), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006.
Note. The specimens are represented by two sterile blades, 2 and 3 cm high, respectively.

Herposiphonia crassa Hollenb. **New island record**
MHI distribution. O‘ahu, Maui, Hawai‘i (Abbott 1999).
Material examined. LEHUA ISLET: BISH 701347 (LR 001), 15.2–27.4 m depth, coll. L.M. Hodgson, 27 May 2001.

Jania adhaerens J.V. Lamour. **New island record**

MHI distribution. O‘ahu, Maui, Hawai‘i (Abbott 1999).

Material examined. LEHUA ISLET: BISH 701904 (LR 009), 15.2–27.4 m depth, coll. L.M. Hodgson, 27 May 2001.

Jania pumila J.V. Lamour. **New island record**

MHI distribution. O‘ahu, Maui, Hawai‘i (Abbott 1999).

Material examined. NI‘IHAU: BISH 777657 (NOAA 167-1305), NII09, 13–16 m depth, coll. R. Okano & S. Charette, 11 Aug 2006. LEHUA ISLET: BISH 777670 (NOAA 167-1318), LEH 03, on hydroid, 15 m depth, coll. unspecified, 18 Jul 2005.

Jania subulata (J. Ellis & Sol.) Sond. **New island record**

[= *Haliptilon subulatum* (Ellis & Solander) H.W. Johans.]

MHI distribution. Kaua‘i, O‘ahu, Moloka‘i, Lāna‘i, Maui, Hawai‘i (Abbott 1999).

Material examined. NI‘IHAU: BISH 725017 (IA 31712), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; BISH 777679 (NOAA 167-1327), NII 03, 15 m depth, coll. A. Tribollet & R. Okano, 9 Aug 2006.

Laurencia sp.

Material examined. LEHUA ISLET: BISH 725056 (IA 31769) & BISH 725051 (IA 31755), NOAA R/V *Hi‘ialakai*, intertidal, coll. R. Okano, 12 Aug 2006.

Note. Specimens appear similar to *Laurencia galtsoffii* M. Howe, however, cortical cells are clearly not protruding.

Martensia hawaiiensis A.R. Sherwood & S.M. Lin **New island record**

MHI distribution. Kaua‘i, O‘ahu, Lāna‘i, Maui (Sherwood *et al*. 2019).

Material examined. NI‘IHAU: BISH 725032 (IA 31732), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; BISH 725034 (IA 31734), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; BISH 725035 (IA 31735), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; BISH 725038 (IA 31738), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; MHI 129 (ARS 09542), NFWF cruise 2018, 20 m depth, coll. H. Spalding, 15 Sep 2018; MHI 131 (ARS 09579), NFWF cruise 2018, 11 m depth, coll. H. Spalding, 15 Sep 2018.

Note. The newly described species was also recorded from Midway Atoll in the PMNM (Sherwood *et al.* 2019).

Peyssonnelia* cf. *inamoena Pilg. **New island record**

Material examined. NI‘IHAU: BISH 777660 (NOAA 167-1308), NII 09, 13–16 m depth, coll. R. Okano & S. Charette, 11 Aug 2006.

****Plocamium sandvicense*** J. Agardh

MHI distribution. Lehua Islet (Wood *et al*. 2004); Kaua‘i, O‘ahu, Maui, Hawai‘i (Abbott 1999).

Material examined. NI‘IHAU: MHI 106 (ARS 09537), NFWF cruise 2018, 73 m depth, coll. J. Leonard, 15 Sep 2018. LEHUA ISLET: MHI 031 (ARS 09498) NFWF cruise 2018, 49 m depth, coll. R. Kosaki, 14 Sep 2018.

Spyridea filamentosa (Wulfen) Harv. **New island record**

MHI distribution. Kaua‘i, O‘ahu, Maui, Kaho‘olawe, Hawai‘i (Abbott 1999).

Material examined. LEHUA ISLET: BISH 725044a (IA 31755) & BISH 725057 (IA 31770), NOAA R/V *Hi'ialakai*, intertidal, coll. R. Okano, 12 Aug 2006.

Tolypiocladia glomerulata (C. Agardh) F. Schmitz **New island record**

MHI distribution. O'ahu, Maui, Kaho'olawe, Hawai'i (Abbott 1999).

Material examined. LEHUA ISLET: BISH 693512 (IA 28405), key hole, 15.2–24.4 m depth, coll. L.M. Hodgson, 26 May 2001; BISH 701909 (LR 014), 15.2–24.4 m depth, coll. L.M. Hodgson, 26 May 2001.

Class PHAEOPHYCEAE

****Chnoospora minima*** (K. Hering) Papenf.

MHI distribution. Lehua Islet (Wood *et al*. 2004); O'ahu, Maui, Kaho'olawe, Hawai'i (Abbott & Huisman 2004).

Material examined. LEHUA ISLET: BISH 725043 (IA 31754), NOAA R/V *Hi'ialakai*, intertidal, coll. R. Okano, 12 Aug 2006.

****Colpomenia sinuosa*** (K. Mert. ex Roth) Derbès & Solier

MHI distribution. Lehua Islet (Wood *et al*. 2004); Kaua'i, O'ahu, Maui, Hawai'i (Abbott & Huisman 2004).

Material examined. LEHUA ISLET: BISH 725046 (IA 31757), NOAA R/V *Hi'ialakai*, intertidal, coll. R. Okano, 12 Aug 2006.

Dictyopteris australis (Sond.) Askenasy **New island record**

MHI distribution. Kaua'i, O'ahu, Moloka'i, Lāna'i, Maui, Hawai'i (Abbott & Huisman 2004); Kaho'olawe (Tsuda & Abbott 2018).

Material examined. NI'IHAU: BISH 777682 (NOAA 167-1330), NII 05, 12–14 m depth, coll. R. Okano & S. Charette, 11 Aug 2006.

Dictyopteris repens (Okamura) Børgesen **New island record**

MHI distribution. O'ahu, Moloka'i, Maui, Hawai'i (Abbott & Huisman 2004).

Material examined. LEHUA ISLET: BISH 701901 (LR 006), 15.2–24.4 m depth, coll. L.M. Hodgson, 26 May 2001.

Dictyopteris sp.

Material examined. LEHUA ISLET: BISH 701906 (LR 011), 15.2–24.4 m depth, coll. L.M. Hodgson, 26 May 2001.

Note. The 5 mm long "leaf" was initially identified as *Dictyopteris plagiogramma* (Montagne) Vickers; however, the veinlets, which extend from midrib to margin, are absent.

Dictyota acutiloba J. Agardh **New island record**

MHI distribution. Kaho'olawe (Coles *et al*. 1998); O'ahu, Moloka'i, Lāna'i, Maui, Hawai'i (Abbott & Huisman 2004).

Material examined. NI'IHAU: BISH 725022 (IA 31715), NOAA R/V *Hi'ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006.

****Dictyota bartayresiana*** J.V. Lamour.

MHI distribution. Lehua Islet (Wood *et a*l. 2004); Kaua'i, O'ahu, Lāna'i, Maui (Abbott & Huisman 2004).

Material examined. NI‘IHAU: BISH 725026 (IA 31724), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006.

Dictyota ceylanica Kütz. **New island record**

MHI distribution. Kaua‘i, O‘ahu, Moloka‘i, Lāna‘i, Maui, Kaho‘olawe, Hawai‘i (Abbott & Huisman 2004).

Material examined. NI‘IHAU: BISH 777653 (NOAA 167-1301), NII 09, 13–16 m depth, coll. R. Okano & S. Charette, 11 Aug 2006; BISH 777654 (NOAA 167-1302), NII 09, 13–16 m depth, coll. R. Okano & S. Charette, 11 Aug 2006; BISH 777685 (NOAA 167-1335), NII 05, 12–14 m depth, coll. R. Okano & S. Charette, 11 Aug 2006. LEHUA ISLET: BISH 777663 (NOAA 167-1311), LEH 03, 15 m depth, coll. unspecified, 18 Jul 2005; MHI 042a (ARS 09513), NFWF cruise 2018, 49 m depth, coll. S. Matadobra, 14 Sep 2018; MHI 047 (ARS 09518), NFWF cruise 2018, 9 m depth, coll. H. Spalding, 14 Sep 2018.

Dictyota friabilis Setch. **New island record**

MHI distribution. Kaua‘i, O‘ahu, Lāna‘i, Maui, Kaho‘olawe, Hawai‘i (Abbott & Huisman 2004).

Material examined. LEHUA ISLET: MHI 046 (ARS 09517). NFWF cruise 2018, 9 m depth, coll. H. Spalding, 14 Sep 2018; MHI 071, NFWF cruise 2018, 8 m depth, coll. H. Spalding, 14 Sep 2018.

Dictyota sp.

Material examined. NI‘IHAU: MHI 082 (ARS 09533), NFWF cruise 2018, 73 m depth, coll. R. Kosaki, 15 Sep 2018.

Note. The entire specimen is a 3 mm long apical fragment from the MCE depth which is, morphologically, not possible to identify to species.

Distromium sp.

Material examined. NI‘IHAU: BISH 700665 (IA 28415), between Ni‘ihau and Lehua, 12.2–18.3 m depth, coll. L.M. Hodgson, 26 May 2001; MHI 081 (ARS 09532), NFWF cruise 2018, 73 m depth, coll. R. Kosaki, 15 Sep 2018; MHI 100 (ARS 09544), NFWF cruise 2018, 73 m depth, coll. J. Leonard, 15 Sep 2018; MHI 116 (ARS 09540), NFWF cruise 2018, 55 m depth, coll. S. Matadobra, 15 Sep 2018. LEHUA ISLET: BISH 681171 (IA 28401), Vertical Awareness Pinnacle, 27.4 m depth, coll. L.M. Hodgson, 26 May 2001; BISH 700666 (IA 28401), Vertical Awareness Pinnacle, 27.4 m depth, coll. L.M. Hodgson, 26 May 2001; MHI 022 (ARS 09493), NFWF cruise 2018, 74 m depth, coll. R. Kosaki, 14 Sep 2018; MHI 035a (ARS 09507), NFWF cruise 2018, 76 m depth, coll. J. Leonard, 14 Sep 2018; MHI 036 (ARS 09508), NFWF cruise 2018, 76 m depth, coll. J. Leonard, 14 Sep 2018; MHI 041 (ARS 09512), NFWF cruise 2018, 49 m depth, coll. S. Matadobra, 14 Sep 2018.

Note. Studies are presently underway on separating the molecular, morphological and ecological characteristics of Hawaiian *Distromium.*

Lobophora *sp.*

Material examined. NI‘IHAU: BISH 725023 (IA 31720), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; BISH 725037 (IA 31737), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006. LEHUA ISLET: MHI-045, NFWF cruise 2018, 9 m depth, coll. H. Spalding, 14 Sep 2018.

Note. The descriptions of 10 new species of *Lobophora* from New Caledonia (Vieira *et al*. 2014) and 8 new species from the western Atlantic and eastern Pacific (Camacho *et al*. 2019) clearly prompt further detailed studies on Hawaiian *Lobophora.*

****Padina sanctae-crucis*** Børgesen
MHI distribution. Lehua Islet (Wood *et al*. 2004); Kauaʻi, Oʻahu, Lānaʻi, Maui, Hawaiʻi (Abbott & Huisman 2004).

Material examined. NIʻIHAU: BISH 777655 (NOAA 167-1303), NII 09, 13–16 m depth, coll. R. Okano & S. Charette, 11 Aug 2006. LEHUA ISLET: BISH 725053 (IA 31765), intertidal, coll. R. Okano, 12 Aug 2006; MHI-050, NFWF cruise 2018, 11 m depth, coll. H. Spalding, 14 Sep 2018.

Sargassum obtusifolium J. Agardh **New island record**
[= *Sargassum hawaiiensis* Doty & Newhouse]
MHI distribution. Oʻahu, Molokaʻi, Maui, Hawaiʻi (Abbott & Huisman 2004); Kahoʻolawe (Tsuda & Abbott 2018).

Material examined. LEHUA ISLET: BISH 700824 (IA 28403), Vertical Awareness Pinnacle, 27.4 m depth, coll. L.M. Hodgson, 26 May 2001; BISH 777668 (NOAA 167-1316), LEH 03, 15 m depth, coll. unspecified, 18 Jul 2005.

Sargassum polyphyllum J. Agardh **New island record**
MHI distribution. Kauaʻi, Maui, Kahoʻolawe, Hawaiʻi (Abbott & Huisman 2004).

Material examined. LEHUA ISLET: BISH 725045 (IA 31756), intertidal, coll. R. Okano, 12 Aug 2006.

****Turbinaria ornata*** (Turner) J. Agardh
MHI distribution. Lehua Islet (Wood *et al.* 2004); Oʻahu, Maui, Hawaiʻi (Abbott & Huisman 2004); Kahoʻolawe (Tsuda & Abbott 2018).

Material examined. NIʻIHAU: BISH 725031 (IA 31729), NOAA R/V *Hiʻialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; BISH 725040 (IA 31740), NOAA R/V *Hiʻialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006. LEHUA ISLET: BISH 725048 (IA 31759), intertidal, coll. R. Okano, 12 Aug 2006.

Phylum CHLOROPHYTA
Boodlea composita (Harv.) F. Brand **New island record**
MHI distribution. Kauaʻi, Oʻahu, Lānaʻi, Maui (Abbott & Huisman 2004).

Material examined. NIʻIHAU: BISH 725012 (IA 31707), NOAA R/V *Hiʻialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006.

Bornetella sphaerica (Zanardini) Solms **New island record**
MHI distribution. Kauaʻi, Oʻahu, Molokaʻi, Lānaʻi, Maui, Kahoʻolawe (Abbott & Huisman 2004).

Material examined. NIʻIHAU: BISH 725010 (IA 31705), NOAA R/V *Hiʻialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006.

Caulerpa taxifolia (Vahl) C. Agardh **New island record**
MHI distribution. Oʻahu, Lānaʻi, Maui, Kahoʻolawe, Hawaiʻi (Abbott & Huisman 2004).

Material examined. NIʻIHAU: BISH 725015 (IA 31710), NOAA R/V *Hiʻialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006.

Caulerpa webbiana Mont. **New island record**
MHI distribution. Kauaʻi, Oʻahu, Maui, Kahoʻolawe (Abbott & Huisman 2004).

Material examined. NIʻIHAU: BISH 777681 (NOAA 167-1329), NII 05, 12–14 m depth, coll. R. Okano & S. Charette, 11 Aug 2006.

Chaetomorpha antennina (Bory) Kütz. **New island record**
MHI distribution. Kauaʻi, Oʻahu, Molokaʻi, Lānaʻi, Maui, Hawaiʻi (Abbott & Huisman 2004).

Material examined. LEHUA ISLET: BISH 725044b (IA 31755), NOAA R/V *Hiʻialakai*, intertidal, coll. R. Okano, 12 Aug 2006.

Cladophora sp.

Material examined. NIʻIHAU: MHI 080 (ARS 09531), NFWF cruise 2018, 73 m depth, coll. R. Kosaki, 15 Sep 2018; MHI 104 (ARS 09535), NFWF cruise 2018, 73 m depth, coll. J. Leonard, 15 Sep 2018.

Note. The apical cells of the 4 cm tall erect filaments are up to 1 mm dia and appear to resemble the branching pattern of *Cladophoropsis* except for the cell wall closure.

Codium hawaiiense P.C. Silva & Chacana **New MHI record**

Material examined. NIʻIHAU: BISH 725011 (IA 31706), NOAA R/V *Hiʻialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; BISH 725018 (IA 31713), NOAA R/V *Hiʻialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006.

Note. BISH 725011 is a 1 cm long branched fragment.

Codium mamillosum Harv. **New island record**
MHI distribution. Oʻahu, Molokaʻi, Maui (Abbott & Huisman 2004).

Material examined. NIʻIHAU: MHI 078 (ARS 09529), NFWF cruise 2018, 73 m depth, coll. R. Kosaki, 15 Sep 2018; MHI 125 (ARS 09541), NFWF cruise 2018, 55 m depth, coll. S. Matadobra, 15 Sep 2018.

Dictyosphaeria cavernosa (Forssk.) Børgesen **New island record**
MHI distribution. Oʻahu, Molokaʻi, Lānaʻi, Maui, Kahoʻolawe (Abbott & Huisman 2004).

Material examined. NIʻIHAU: BISH 777677 (NOAA 167-1325), NII 03, 15 m depth, coll. A. Tribollet & R. Okano, 9 Aug 2006. LEHUA ISLET: BISH 725055 (IA 31768), NOAA R/V *Hiʻialakai*, intertidal, coll. R. Okano, 12 Aug 2006.

Dictyosphaeria versluysii Weber-van Bosse **New island record**
MHI distribution. Kauaʻi, Oʻahu, Lānaʻi, Kahoʻolawe, Hawaiʻi (Abbott & Huisman 2004).

Material examined. LEHUA ISLET: BISH 777669 (NOAA 167-1317), LEH 03, 15 m depth, coll. unspecified, 18 Jul 2005.

Halimeda discoidea Decne. **New island record**
MHI distribution. Oʻahu, Molokaʻi, Kahoʻolawe (Abbott & Huisman 2004).

Material examined. NIʻIHAU: BISH 725016 (IA 31711), NOAA R/V *Hiʻialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; BISH 777676 (NOAA 167-1324), NII 03, 15 m depth, coll. A. Tribollet & R. Okano, 9 Aug 2006.

Halimeda opuntia (L.) J.V. Lamour. **New island record**
MHI distribution. Molokaʻi, Lānaʻi, Kahoʻolawe (Abbott & Huisman 2004).

Material examined. NIʻIHAU: BISH 777658 (NOAA 167-1306), NII 09, 13–16 m depth, coll. R. Okano & S. Charette, 11 Aug 2006; MHI 109, NFWF cruise 2018, 73 m depth, coll. J. Leonard, 15 Sep 2018. LEHUA ISLET: MHI 023 (ARS 09494), NFWF cruise 2018, 74 m depth, coll. R. Kosaki, 14 Sep 2018.

Microdictyon setchellianum M. Howe
MHI distribution. Lehua Islet (Wood *et al.* 2004), O‘ahu, Moloka‘i, Maui, Kaho‘olawe (Abbott & Huisman 2004).

Material examined. LEHUA ISLET: BISH 777661 (NOAA 167-1309), LEH 03, 15 m depth, coll. unspecified, 18 Jul 2005; BISH 725050 (IA 31761), NOAA R/V *Hi‘ialakai*, intertidal, coll. R. Okano, 12 Aug 2006; MHI 053, NFWF cruise 2018, 11 m depth, coll. H. Spalding, 14 Sep 2018.

Microdictyon umbilicatum (Velley) Zanardini **New island record**
MHI distribution. O‘ahu, Maui, Kaho‘olawe, Hawai‘i. (Abbott & Huisman 2004).

Material examined. LEHUA ISLET: BISH 701734 (IA 28404), key hole, 15.2–24.4 m depth, coll. L.M. Hodgson, 26 May 2001; BISH 777674 (NOAA 167-1322), LEH 01, 9–12 m depth, coll. A. Tribollet & R. Okano, 12 Aug 2006.

Neomeris annulata Dickie **New island record**
MHI distribution. O‘ahu, Maui, Kaho‘olawe, Hawai‘i (Abbott & Huisman 2004).

Material examined. NI‘IHAU: BISH 725013 (IA 31708), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006; BISH 725039 (IA 31739), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006.

****Neomeris vanbosseae*** M. Howe
MHI distribution. Lehua Islet (Wood *et al*. 2004); Kaua‘i, O‘ahu, Lāna‘i (Egerod 1952); Maui, Kaho‘olawe, Hawai‘i (Abbott & Huisman 2004).

Material examined. NI‘IHAU: BISH 777659 (NOAA 167-1307), NII 09, 13–16 m depth, coll. R. Okano and S. Charette, 11 Aug 2006; BISH 777678 (NOAA 167-1326), NII 03, 15 m depth, coll. A. Tribollet and R. Okano, 09 Aug 2006.

Palmophyllum crassum (Naccari) Rabenh. **New island record**
MHI distribution. Oahu (Abbott & Huisman 2004).

Material examined. NI‘IHAU: BISH 777656 (NOAA 167-1304), NII 09, 13–16 m depth, coll. R. Okano & S. Charette, 11 Aug 2006; BISH 777684 (NOAA 167-1334), NII 05, 12–14 m depth, coll. R. Okano & S. Charette, 11 Aug 2006.

Phyllodictyon anastomosans (Harv.) Kraft & M.J. Wynne **New island record**
MHI distribution. Kaua‘i, O‘ahu, Maui (Abbott & Huisman 2004).

Material examined. NI‘IHAU: MHI-107 (ARS 09538), NFWF cruise 2018, 73 m depth, coll. J. Leonard, 15 Sep 2018.

****Pseudochlorodesmis parva*** W.J. Gilbert
[= *Siphonogramen parvum* (W.J. Gilbert) I.A. Abbott & Huisman]
MHI distribution. Ni‘ihau, O‘ahu (Abbott & Huisman 2004).

Material examined. NI‘IHAU: BISH 725014 (IA 31709), NOAA R/V *Hi‘ialakai*, 10.7–13.7 m depth, coll. R. Okano, 9–11 Aug 2006. LEHUA ISLET: MHI 063 (ARS 09525), NFWF cruise 2018, 8 m depth, coll. H. Spalding, 14 Sep 2018.

Note. Guiry & Guiry (2020) cites *Siphonogramen parvum* as the accepted species name of *Pseudochlorodesmis parva.* Verbruggen *et al.* (2009), however, showed convincing molecular evidence to maintain the species *P. parva* over *S. parvum.* The siphons of MHI 063 were 24–37 µm dia.

Rhipidosiphon javensis Mont. **New island record**

MHI distribution. Kauaʻi, Oʻahu, Molokaʻi, Maui (Abbott & Huisman 2004).

Material examined. LEHUA ISLET: BISH 777675 (NOAA 167-1323), LEH 01, 9–12 m depth, coll. A. Tribollet & R. Okano, 12 Aug 2006.

Siphonocladus tropicus (P. Crouan & H. Crouan) J. Agardh **New island record**

MHI distribution. Kauaʻi, Oʻahu, Maui (Abbott & Huisman 2004); Kahoʻolawe (Tsuda & Abbott 2018).

Material examined. NIʻIHAU: MHI 108 (ARS 09539), NFWF cruise 2018, 73 m depth, coll. J. Leonard, 15 Sep 2018.

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APPENDIX
Algal Species with BISH Numbers Reported from Lehua Islet Collected by Maya LeGrande in March and May 2003 in Wood *et al.* (2004).

Phylum Cyanobacteria
Lyngbya majuscula (Dillwyn) Harv. [BISH 696669]
Lyngbya semiplena Gomont [BISH 696668]

Phylum Rhodophyta
Aglaothamnion boergesenii (N. Aponte & D.L. Ballant.) L'Hardy-Halos & Rueness [BISH 695059]
Ahnfeltiopsis concinna (J. Agardh) P.C. Silva & De Cew [BISH 695490]
Amansia glomerata C. Agardh [BISH 695442]
Amphiroa rigida J.V. Lamour. [BISH 695453]
Antithamnion antillanum Børgesen [BISH 695456]
Asparagopsis taxiformis (Delile) Trevis. [BISH 695439]
Botryocladia skottsbergii (Børgesen) Levring [BISH 695449]
Champia parvula (C. Agardh) Harv. [BISH 695448]
Chrysymenia sp. [BISH 695388]
Dasya iridescens (Schlech) A. Millar &. I.A. Abbott [BISH 695438]
Dasya murrayana I.A. Abbott & A. Millar [BISH 695443]
Gayliella fimbriata (Setch. & N.L. Gardner) T.O. Cho & S.M. Boo [= *Ceramium fimbriatum* Setchell & N.L. Gardner] [BISH 695062]
Gayliella flaccida (Kütz.) T.O. Cho & McIvor [= *Ceramium flaccidum* (Kütz.) Ardiss.] [BISH 695450]
Gelidiella machrisiana E.Y. Dawson [BISH 696667]
Griffithsia subcylindrica Okamura [BISH 695447]
Gymnothamnion elegans (Schousb. ex C. Agardh) J. Agardh [BISH 695455 & 696674]
Halichrysis coalescens (Farlow) A. Millar & R.E. Norris [BISH 695450]
Herposiphonia variabilis Hollenb. [BISH 696666]
Jania sp. [BISH 695060 & 695061]
Laurencia sp. [BISH 681178 & 692233]
Plocamium sandvicense J. Agardh [BISH 695445]

Class Phaeophyceae
Asteronema breviarticulatum Ouriques & Bouzon [BISH 695454]
Chnoospora minima (Hering) Papenf. [BISH 695446]
Colpomenia sinuosa (K. Mert. ex Roth) Derbès & Solier [BISH 690591]
Dictyota bartayresiana J.V. Lamour. [BISH 695399]
Dictyota sandvicensis Sond. ex Kütz. [BISH 695444]
Hydroclathrus clathratus (C. Agardh) M. Howe [BISH 690592]
Lobophora variegata (J.V. Lamour.) Womersley [BISH 690595]
Padina sanctae-crucis Børgesen [BISH 695457]
Padina sp. [BISH 695063]
Sargassum aquifolium (Turner) C. Agardh [BISH 695489]
Sphacelaria tribuloides Menegh.[BISH 695441]
Turbinaria ornata (Turner) J. Agardh [BISH 690590]

Phylum Chlorophyta
Caulerpa racemosa var. *peltata* (J.V. Lamour.) Eubank [BISH 690596]
Cladophora laetevirens (Dillwyn) Kütz. [BISH 695058]
Codium edule P.C. Silva [BISH 690593]
Microdictyon setchellianum M. Howe [BISH 695452]
Neomeris vanbosseae M. Howe [BISH 690594]

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Recommendations for reporting records of nonnative plant species in the Hawaiian Islands[1]

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Abstract Reports of nonnative plants found outside of cultivation or human-contained areas for the first time are crucial for invasive species research and management, allowing compilation of species checklists that document the naturalization and rough geographical distribution of Hawai'i's nonnative flora. However, the naturalization status of plants can be difficult to assess in the field and little guidance exists on what criteria are needed to fit the definition of "naturalized". Moreover, disappearances of nonnative plants from Hawai'i's floras are generally not reported even though multiple eradication programs exist. Over time these issues may artificially inflate the number of naturalized species on checklists, confounding biodiversity research and distracting management from problematic species. We reviewed the literature on terminology and the invasion process to provide Hawai'i-specific guidelines on reporting nonnative plant statuses without requiring major changes to current reporting or data collection practices. These guidelines are intended to help authors of reports contribute information needed to update statuses on naturalized species checklists and aid management decisions.

INTRODUCTION

Collectors have been vouchering nonnative plants in the Hawaiian Islands for over 200 years, increasingly integrating data about nonnative species into our knowledge of Hawai'i's natural history (Funk *et al.* 2005; Wester 1992). The long-term curation of voucher specimens combined with effective communication of noteworthy finds has numerous applications. This information has been most prominently used in floristic studies (Funk 2003; Souza & Hawkins 2017; Stern & Eriksson 1996) and collection of nonnative plant data has focused on identifying which species form an established component of Hawai'i's flora (Imada 2012, 2019; Palmer *et al.* 1995; Wagner *et al*. 1999, 2005). However, the past few decades have seen a significant increase in efforts to understand the biogeography and behavior of nonnative plants from the perspective of invasive plant management (Antunes & Schamp 2017; Munekata *et al*. 2016). Today, Hawai'i possess-

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es a well-established network of agencies that fund, conduct research, and enact strategies with diverse and complementary goals, relying on species-specific data to direct their management actions (Munekata *et al*. 2016). Methods for consistently reporting biodiversity data therefore need adjusting to bridge the gap between natural history collections and invasive species managers while maintaining traditional uses.

The *Records of the Hawai'i Biological Survey* provides an effective forum for communicating the taxonomy, status, and basic distribution of nonnative plants in Hawai'i. This forum was officially initiated in 1995 and encourages authors to report records of naturalization in the *Bishop Museum Occasional Papers,* although new weed reports date back to 1911 (Forbes 1911). The vast majority of new records since 1995 have been reported through this system, supported by specimens deposited in herbaria (Evenhuis & Miller 2015), and have subsequently been compiled into species checklists (Imada 2019; Wagner *et al*. 2005). Furthermore, the utility of this system has been leveraged in recent years by the digitization of herbarium vouchers (Allison 2003). At least three herbaria with significant collections of nonnative plants from Hawai'i maintain searchable databases of voucher information, including the Bernice Pauahi Bishop Museum's *Herbarium Pacificum* (BISH) in Honolulu, Hawai'i; the National Tropical Botanical Garden herbarium (PTBG) in Kalāheo, Hawai'i; and the Smithsonian's United States National Herbarium (US) in Washington, D.C. Additionally, many of these data are available globally through free online data platforms that consolidate information from multiple herbaria, such as the Global Biodiversity Information Facility (GBIF) and the Integrated Digitized Biocollections (iDigBio). Field collections are critical for providing a verifiable physical specimen to accompany field observations of invasive plant distribution and behavior. In combination with tools that aggregate data and make them accessible, herbarium vouchers and associated field observations provide the foundation for a taxonomically sound information system to improve invasive plant management strategies.

The basic informational needs of floristic studies and invasive plant management are largely overlapping, although invasion control programs often require more detailed observations of population structure, distribution, and arrival time. However, the terminology used by invasion biologists and invasive species managers to describe the introduction-naturalization-invasion continuum has varied on a global scale since the field emerged (Blackburn *et al*. 2011; Pyšek *et al*. 2004; Richardson *et al*. 2000, 2011). The use of these terms is oftentimes inconsistent with floras and checklists compiled by taxonomists, hindering our ability to apply data collected from taxonomic projects to invasive plant management and vice versa (Pyšek *et al*. 2004). Data submitted to the *Records of the Hawai'i Biological Survey* are likely no exception. In particular, the term "naturalized" may have various definitions amongst contributing authors, and records must be further scrutinized when compiling new information into research projects.

It is our hope that this summary will increase the utility of nonnative plant data in Hawai'i and promote synergisms between future invasive plant research, management, and floristic studies. In particular, we highlight two means of improving Hawai'i's data infrastructure, including: 1) recommendations to local botanists for reporting field data such that it informs invasive plant research/management and is consistent across collectors, and 2) a description of how terminology and statuses should be applied in reports of new records, such that they align with globally recommended frameworks for tracking nonnative plant species. We focus on naturalization and extirpation, as accurate reports of these events are vital for curating a checklist of nonnative plant species existing outside of cultivation.

TERMINOLOGY

Given the immense value of tracking the fate of nonnative species introductions across the Hawaiian archipelago, it is important that nonnative plant records use consistent terminology to ensure that the data generated by numerous individuals is easily understood and comparable. Robust records of nonnative plants are required to prevent misappropriation of conservation resources, as errors in recording invasive behavior can lead managers to address species that are unlikely to pose a threat or miss opportunities to prevent spread before it is too late. Much progress has been made to standardize terminology between taxonomists and invasion biologists within the last two decades alongside several publications that provide broad guidelines to track nonnative plant species in any region (Blackburn *et al*. 2011; Pyšek *et al*. 2004; Richardson *et al*. 2000, 2011; Wilson *et al*. 2014). Thus, the purpose of this paper is not to propose new definitions, but to provide a Hawai‘i-specific guide that aligns with these generalized frameworks while avoiding major changes to current data collection practices.

Definition of Terms Concerning Naturalized Status

Nonnative **(synonyms: alien, exotic, introduced):** any species that is present in Hawai‘i as a result of intentional or accidental human action or has arrived in Hawai‘i without the help of humans from a region where it was also nonnative (Blackburn *et al*. 2011; Pyšek *et al*. 2004). This term can be applied in both a statewide and an island-specific manner (Pyšek *et al*. 2004). For instance, if a plant is native to one island, but is introduced by humans to a second island, it can be said to be nonnative to the second island (e.g., the purposeful introduction of *Sphagnum palustre* L. to O‘ahu from Hawai‘i Island, where it is indigenous; Karlin *et al*. 2012).

Naturalized **(synonym: established)**: nonnative species that reproduce sexually or vegetatively to form self-replacing populations outside of human cultivation or containment (i.e., in the wild), as evidenced by multiple wild-growing individuals of different ages classes, indicating that the population has undergone many reproductive cycles (Blackburn *et al*. 2011; Pyšek *et al*. 2004; Richardson *et al*. 2000; Wagner *et al*. 2005, 2012). This does not include casuals (see below) or species that have so far produced only a single-few generations of offspring. Accidental introductions of seed contaminated soil giving rise to multiple generations in pots or greenhouses are not considered naturalized because although populations may be self-sustaining, they have not yet escaped human containment. Invasive plants are considered a subset of naturalized plants.

Casual*:* nonnative plants that survive and reproduce occasionally outside of cultivation but do not form self-sustaining populations, thus requiring repeat introductions to persist (Pyšek *et al*. 2004; Richardson *et al*. 2000). These plants are difficult to distinguish from cultivated remnants or plants that are just beginning to naturalize because time is needed to determine their behavior. No synonyms are consistently used in the literature, although casuals are sometimes referred to as “spontaneous”, “waifs” or “occasional escapes” (Pyšek *et al*. 2004). The term “adventive” originated as a synonym for casual (De Candolle 1855), but has been used more broadly in the past to include naturalized (Wester 1992, Provost 1999).

Definition of Terms Concerning Extirpation

***Extirpation* (synonyms: local/regional extinction)**: a species that has entirely disappeared from a specific geographical area (e.g., statewide or island-wide) by natural or anthropogenic means, but still persists elsewhere in the world (Riddle *et al.* 2011). Extirpations are more thoroughly discussed in relation to native species but can be applied to nonnative species that previously formed (or were forming) self-sustaining populations outside of their native range (naturalized), where the very last individual within that population has died (Simberloff & Gibbons 2004; Panetta 2015). Akin to the IUCN Red List status "Extinct in the Wild" where captive individuals remain but wild populations no longer exist, nonnative plants that are entirely absent from a region may be considered totally extirpated whereas species with cultivated individuals remaining are considered extirpated in the wild (with wild referring to areas outside of actively maintained cultivation sites). Reports of extirpation should be accompanied by sound reasoning based on time since last sighting, seed bank longevity, and adequate search effort.

Eradication: a subcategory of extirpated referring to a species whose removal was the result of purposeful human intervention (Panetta 2007, 2015; Larson *et al.* 2019). This term may be used in the explanatory paragraph that accompanies record submissions (Evenhuis & Eldredge 2010) to distinguish purposeful extirpations from natural extirpations (occurring without intentional human involvement).

STATUS DESIGNATIONS

Because Hawai‘i is an archipelago (i.e., naturally discrete land areas), opportunity exists to prevent inter-island introductions and accomplish island-wide eradications, requiring language that can distinguish between island and statewide populations. Additionally, studies have established Hawai‘i as a global hotspot for naturalized plant species, many of which have been, and continue to be, introduced purposefully for cultivation (Pyšek *et al*. 2017; Staples & Herbst 2005; Wester 1992). Recent introductions require extra scrutiny and the application of precise terminology to describe the phase of a plant's establishment (Blackburn *et al*. 2011). For instance, plants outside of cultivation are often encountered in Hawai‘i, although it may not be immediately obvious whether a self-sustaining naturalized population exists. Reports of reproduction outside of cultivation should be encouraged because early detection of invasive behavior is valuable for management. However, it is necessary to clearly communicate any uncertainty of naturalization and describe field observations that distinguish these reports from fully naturalized records.

We also encourage vouchering cultivated species and plants in human contained areas (e.g., aquatic plants in a man-made pond) because an accurate tally of these is lacking in Hawai‘i, representing a critical knowledge gap for invasive species management. However, significant improvements in monitoring and data infrastructure are needed to track cultivated species. Unlike naturalized plants (Imada 2019), there is no up-to-date resource listing all known cultivated species statewide, let alone at the island level, making the determination that a species is "new" infeasible. Updates and verification of partial lists compiled for book projects (Staples & Herbst 2005) provide a good starting point, but given the low collection rate for cultivated species, dates attached to new reports are likely to be inaccurate and not useful. Furthermore, thousands of cultivated species exist

in Hawai‘i that have not been vouchered, and an unknown number of others are not documented in any way. Rather than opportunistically reporting these plants through the *Hawai‘i Biological Survey*, a curated working list first needs to be assembled that could expand as new records are vouchered. Thus, we do not recommend reporting cultivated plants in the same manner recommended here for naturalized ones, although we recognize that publishing notes on new arrivals of pest species or accidental seed contaminants could be of immediate value to managers.

Guidelines for reporting to the *Records of the Hawai‘i Biological Survey* were established by Evenhuis & Eldredge (2010), with the inclusion of headings that denote establishment statuses for all organisms. These headings are aligned to the right of each species name in bolded font and indicate whether each record represents a first observation for an island or the entire state. The use of headings and terminology are further described here and in Table 1 to encourage consistent usage for nonnative plant records among all contributing authors. As an interim solution to a tracking system that addresses plant species of all statuses in Hawai‘i, these guidelines encourage accurate reporting to inform the addition or removal of plants from naturalized species checklists.

Applying Naturalized Status Headings

New State Record: the first report of naturalization for a nonnative species within the Hawaiian archipelago that has no documented history of cultivation in Hawai‘i or is thought to be very rarely cultivated (e.g., previously reported from one botanical garden specializing in rare or unusual plant species).

New Naturalized Record: the first report of naturalization for a nonnative species within the Hawaiian archipelago that has been previously observed in cultivation.

New Island Record: the first report of naturalization for a nonnative species on a particular Hawaiian island, where naturalization has already been recorded for at least one other island in the Hawaiian archipelago.

Correction: a heading applied to reports that provide new evidence or arguments to justify the correction of past records. This may include the discovery of misidentified species, analyses showing that previous reports of new naturalized records do not fit the current definition of “naturalized”, and other corrections that may improve the accuracy of Hawai‘i’s checklists and other records.

Distinguishing completely unknown from previously cultivated species as “New State Record” and “New Naturalized Record”, respectively, has been used for over two decades in the *Records of the Hawai‘i Biological Survey* and we have included this distinction for consistency (Table 1). Differentiating reports in this manner is valuable for examining the role of multiple introductions or history of planting in producing invasions (i.e., propagule pressure) and assessing the feasibility of eradication (Colautti *et al*. 2006; Imada *et al*. 2000; Lockwood *et al*. 2009; Panetta 2015). A drawback of this distinction is that it relies heavily on one’s knowledge of Hawai‘i’s cultivated flora. As no comprehensive list of cultivated plants is currently available, a thorough review of available sources is necessary to assign these statuses, minimally including searches of herbaria databases (BPBM 2018;

Table 1. Decision matrix for reporting plant statuses.
Orange boxes indicate status changes for naturalized species checklists. Blue boxes highlight helpful information for invasion management that do not correspond to status changes on any checklist curated in Hawai‘i.

		In cultivation or somehow human contained		Outside of cultivation or containment	
		Intentional	Unintentional	Insufficient evidence of population longevity	Sufficient evidence of population longevity
First Record of Presence	For the Entire Archipelago	Deposit Voucher in Herbaria	Publish Note + Deposit Voucher	Report Status as **Potentially Naturaliz(ed/ing)** + Deposit Voucher	Report Status as **New State Record** or **New Naturalized Record*** + Deposit Voucher
	For an Island	Deposit Voucher in Herbaria	Publish Note + Deposit Voucher	Report Status as **Potentially Naturaliz(ed/ing)** + Deposit Voucher	Report Status as **New Island Record** + Deposit Voucher
First Record of Absence**	For the Entire Archipelago	N/A	N/A	Report Status as **Possible Extirpation**	Report Status as **State Extirpation Record**
	For an Island	Publish Note	Publish Note	Report Status as **Possible Extirpation**	Report Status as **Island Extirpation Record**

* Plants with well-documented cultivation histories are reported as New Naturalized Records while those absent or uncommon in cultivation are reported as New State Records. However, both are simply reflected as naturalized on species checklists.

** Eradication campaigns should voucher their targets throughout the process to allow identifications to be verified after removal.

NMNH 2018; NTBG 2018), publications of species commonly found in Hawai‘i’s gardens (Staples & Herbst 2005), and checklists such as the Bishop Museum’s *Annotated Checklist of Cultivated Plants of Hawai‘i* (Imada *et al*. 2000).

Describing Naturalized Status

As outlined in the guidelines for submissions to the *Records of the Hawai‘i Biological Survey*, status reports should be accompanied by a short note (Evenhuis & Eldredge 2010). Despite attempts to standardize the use of terminology and statuses commonly associated with nonnative plants outside of cultivation, interpretation of data from the field remains subjective and species-specific. Detailed reasons for why species should be designated as naturalized are helpful for placing species along the introduction–naturalization–invasion continuum and predicting future behavior (Blackburn *et al*. 2011; Pyšek *et al*. 2004; Richardson *et al.* 2000). Authors can greatly increase the value of their submissions by providing estimates of the following:

1) The area covered by noncultivated individuals, their density, and a description of the habitat;
2) The number of noncultivated individuals observed, or, for vegetatively reproducing species, evidence that many, disconnected individuals are present s (even if propagules are vegetative and/or dispersal is human assisted);
3) The number and type of life stages present (mature, seedlings, etc.); and
4) The source of naturalization, if apparent (e.g., seed contamination, cultivated plants), or whether it appears to have naturalized a significant distance from its likely introduction site.

Additionally, a search for previously collected vouchers within the geographic area of interest, if available, can be included in a "material examined" section to provide additional distribution information and a timeline of establishment (Pyšek *et al.* 2004).

Potentially Naturalized or Naturalizing Species

Contributors are encouraged to provide first reports of nonnative species existing outside of cultivation without direct human assistance, especially those reproducing (sexually or vegetatively), even if the long-term survival of self-sustaining populations is not apparent (Pyšek *et al*. 2004; Richardson *et al*. 2000; Wagner *et al*. 2005). These reports may alert managers to eradication opportunities by identifying species that are possibly beginning to naturalize while not assuming that they will definitely naturalize in the future. Examples of species that may be reported include observations of multiple, widely distributed immature plants for which no mature individuals have been located, or a small number of mature, similarly aged individuals outside of cultivation. Although this information can be used to identify would-be invaders before they spread, species that are beginning to naturalize are often indistinguishable in the field from plants exhibiting a variety of other behaviors, such as 1) casual species, which may also produce offspring outside of cultivation, 2) remnants from cultivation where overgrown adjacent vegetation masks evidence of its cultivated history, and 3) species that have already naturalized but only a few individuals have been detected.

Various terms have been used in the literature to denote species with ambiguous statuses, but either they cause confusion due to inconsistent global use or are somewhat presumptuous of a species' fate. This includes species often described as "adventive", which is variously used both in Hawai'i and worldwide (Pyšek *et al*. 2004; Wester 1992), and "emerging invaders" or "sleeper weeds", which imply that populations will persist and eventually expand. The problem of status uncertainty (whether arising from poorly surveyed populations or from insufficient passage of time to determine behavior) illuminates a pressing need to re-examine terminology and provide guidelines for adapting regional species checklists to existing nonnative species tracking systems. A tracking scheme with 11 population status categories was developed by Blackburn *et al*. (2011) that describe the phases preceding naturalization, but adapting Hawai'i's checklist to these fine-grained statuses would require data that has not been collected for all species, as well as a higher site revisitation rate. Despite the fine scale of Blackburn *et al*.'s (2011) system, it too does not account for uncertainty, and thus, modifications to solve these issues are still needed before implementation (Brock & Daehler, *in press*).

In light of these challenges, we do not recommend any one specific term or status heading to accompany reports of these data-deficient species. Instead, we propose that these records be listed in a section separate from new naturalized records entitled "Potentially Naturalized or Naturalizing", allowing these species to be prioritized for revisitation and monitored for status changes.

Applying Extirpated Status Headings

Eradication programs have been implemented on most of the main Hawaiian Islands (Kraus & Duffy 2010), and some reports in the *Bishop Museum Occasional Papers* mention actions for the immediate removal of recently established plant species with small populations. Determining whether a nonnative plant has been extirpated can be costly and difficult because extensive field monitoring and reconnaissance are required to provide evidence of a species' absence (Butchart *et al*. 2006; Pluess *et al*. 2012). Cases where disappearances have occurred naturally without purposeful removal by humans are especially problematic, as population distributions and declines are less likely to have been documented. Some previously naturalized species appear to have been eradicated from entire islands in Hawai'i (Penniman *et al.* 2011), and these events are occasionally alluded to in outreach materials and progress reports to funders (e.g., DLNR 2009). However, such instances are rarely reported in archived scientific publications and do not contain the information necessary to update plant checklists, likely because no guidance exists on how to report them. This is problematic because the following are all dependent on an accurate account of extirpations: preventative checklists for border biosecurity, quantitative analyses of plant biodiversity, feasibility estimates of species eradications, and determinations of control program success.

To encourage reports of extirpation events, we propose applying aspects of the IUCN guidelines to report extinctions of endangered species (IUCN 2017). In the IUCN system, assignment of species to the official "Extirpated" or "Extinct" categories requires exhaustive surveys to justify, beyond reasonable doubt, that the last individual has died. Consequently, the IUCN allows the additional descriptor of "Possibly Extinct", which, although still evidence-based, explicitly acknowledges uncertainty. This status is especially applicable to recent apparent extinctions where a substantial timeline of disappearance has not been established (IUCN 2017). We recommend applying the following status headings, which are modeled on the IUCN's (2017) Red List criteria, to be formatted in the same style as when describing naturalized taxa (bolded and located to the right of species names). As described in the definition section above, it is useful to report species that are extirpated in the wild but remain in cultivation. However, we do not include separate status headings for species that are entirely extirpated versus those only extirpated from the wild, because reports of both result in losing naturalized status. Nonetheless, it is valuable to indicate whether cultivated individuals are thought to remain because this may be useful when evaluating sources of future invasions, or implementing all-species tracking systems in the future (e.g., demotion from naturalized to either "no longer present" or "in cultivation only").

State Extirpation Record: a report providing evidence to declare that a naturalized or potentially naturalized/naturalizing species is no longer present in the wild in the Hawaiian Islands. Contributors should apply this heading to records of species that

have totally disappeared, as well as those that no longer have populations in the wild, but still exist in cultivation. Presence of remaining cultivated individuals should be described in the report text alongside an account of surveying efforts and time elapsed since last sighting. Criteria to apply this heading versus "Possible Extirpation" are discussed below.

Island Extirpation Record: a report providing evidence to declare a nonnative species as no longer present in the wild on a specific island.

Possible Extirpation: a report providing evidence that a formerly naturalized species is likely to have been extirpated from an island or statewide, but where reduced confidence is appropriate due to missing information or the species is very likely to be reintroduced (e.g., common in cultivation on other islands). Most nonnatives that have been targeted by recent extirpation programs will likely fall into this category because such cases often do not allow for high confidence due to a short time since last sighting (less than several plant generations), a long-lived or uncertain seedbank, or lack of comprehensive searches across the area being reported (i.e., island or Statewide). Further discussion of scenarios and criteria is presented below.

Rediscovery: a heading applied to reports of species that were previously thought to be extirpated, but where individuals have subsequently been found outside of cultivation or areas of human containment. This may include individuals that have likely arisen from the original infestation or from reintroductions of that species, which should be described in the report text. The application of this heading does not necessarily imply a species status should be updated to "Naturalized", as the status of the population may be uncertain or just beginning to naturalize. Thus, authors reporting a rediscovery should communicate field observations that allow assessment of whether the rediscovered species should or should not be considered naturalized or potentially naturalized/naturalizing.

Two scenarios may be commonly encountered when reporting extirpations: 1) recently observed species for which eradication programs have monitored population decline, resulting in the disappearance of the species, and 2) apparently natural extirpations of species previously known from a single or few sites for which there are no recent observations. No single rule exists for how much time must pass before nonnative plants can be reported as extirpated, as these events are highly scenario-specific and dependent on a species' biology (Panetta 2015). However, a general timeline used by the IUCN for endangered organisms, referring to whether a species has disappeared from known sites for ten years or three generations, whichever is longer, is useful for our purposes (IUCN 2017). With regards to seed plants, one generation includes the amount of time necessary for a new seed to develop into a mature, reproductive individual (Moravcova *et al*. 2018). As this period is affected by seed dormancy and factors that may slow maturation (e.g., shade), it may be beneficial to consider a range of generation times that may exist within a single species when proposing extirpation status or implementing control programs.

It is important to note that some plants have propagules that can persist for a very long time in the soil; however, seed longevity data is sparse, and dormancy is affected by

numerous site-related factors including soil moisture, nutrients, pH, and texture (Baskin & Baskin 1998). Relying on seed survival data collected from seed preservation labs, which deliberately maintain humidity and temperature-controlled environments that are improbable in nature, may vastly overestimate time needed for eradication programs and delay the optimal time to report possible extirpations. Thus, in purposeful eradication scenarios where population decline has been carefully monitored, a status of "Possible Extirpation" may be suggested within the timeframe of ten years or three generations (whichever is longer) if detailed distribution and time since last observation data are described (Dodd *et al*. 2015; Panetta 2015). A species' status may later be updated to "Statewide/Island Extirpation Record" if the species is not found after a longer period of time, taking into account the species' biology (e.g., seed bank persistence).

In scenarios where extirpations appear to have occurred naturally, the status of "Possible Extirpation" should be applied if the historic locations have been surveyed recently and at least ten years or three generations (whichever is longest) has elapsed since last voucher collection. As precise distribution and population decline data are usually absent in these cases, the status may be upgraded to "Statewide/Island Extirpation Record" after more extensive surveys have been conducted over multiple years (IUCN 2017). Surveys in support of extirpation reports should consider all adequate habitat within the possible dispersal area while accounting for factors that affect detectability (e.g., phenology, terrain; Dodd *et al*. 2015; Panetta 2015).

RESOURCES USED FOR SPECIES DETERMINATIONS

Plant taxonomy is a difficult, dynamic science where incorrect identifications are common, even amongst specialists, and species circumscriptions are constantly being revised as new research is conducted (Pyšek *et al*. 2013; Rouhan & Gaudeul 2014). Compounding this difficulty is that nonnative plants in Hawai'i arrive from all over the world, and few dichotomous keys compare morphologically similar species across broad geographical regions (Carter *et al*. 2007). We recommend that contributors cite the taxonomic resources and specific traits used to identify a new record to provide a helpful logical pathway that can be examined during the verification of vouchers and taxonomic checklists. Furthermore, reporting these resources can assist those identifying other specimens in the field. A system to periodically review and verify identifications is central to invasive species management in Hawai'i, especially for programs that rely on observations of invasive behavior and impacts from elsewhere in the world (Daehler *et al*. 2004; Munekata *et al*. 2016; Tunison & Zimmer 1992). Incorrect identifications immediately decouple the organism from its life history information, resulting in missed opportunities for rapid response if potentially high impact species are misidentified as relatively innocuous ones, or misdirection of funds if a low-impact nonnative is misidentified as a damaging invader.

PROVIDING VOUCHER SPECIMENS

Voucher specimens are often the primary documentation of a species' presence and should represent the diagnostic characters necessary for accurate identification. When vouchering nonnative plants in support of naturalization records, material should be collected from plants belonging to the naturalized population rather than cultivated plants in the vicinity, in order to decrease the likelihood of false naturalization records (Carter *et al*. 2007; Morais & Reichard 2018). Reports of new records that reference vouchers collect-

ed from multiple areas provide convincing evidence that species should be included in floristic works (Wagner *et al*. 1999). Additionally, eradication programs should collect representative voucher specimens to provide a verifiable taxonomic record of plants they control and potentially eradicate to definitively document the species being reported. Repeat collections of the same population, especially newly naturalized or possibly naturalized species, provide a lasting record of visitation that, in combination with adequate field notes, documents mode of dispersal and changes in population size.

Whenever possible, the collection of duplicate specimens is strongly recommended because 1) a specimen may need to be dissected and effectively destroyed during the identification process, 2) material may be sent to specialists for identification, and 3) duplicates deposited at other herbaria may assist in the verification of specimens from other areas (Carter *et al*. 2007). At least three duplicates are ideal even when identification is simple, as this allows specimens to be sent to institutions with experts in the Hawaiian flora (BISH, PTBG, US). If vouchers are intended to be deposited at PTBG or US, collectors should ensure that a duplicate is sent to BISH, the official state repository for biological specimens. Deliberate collection of reproductive propagules and detailed notes are particularly helpful for nonnative species, whose methods of reproduction and dispersal may be unclear outside of their native ranges (Richardson *et al*. 2000). Photographs to supplement vouchers are extremely valuable to add to reports; close-up shots of diagnostic characters, especially those that do not preserve well (e.g., flower/fruit color and shape, plant habit) can assist with identification, while landscape-level shots are helpful accompaniments to descriptions of population density, structure, and habitat type. Biodiversity data repositories, including those curated by local herbaria, are increasingly integrating the ability to upload photographs when depositing voucher specimens.

CONCLUSIONS

Consistent use of terminology is necessary to accurately track nonnative plant biodiversity and increase communication between botanists, invasion researchers, and on-the-ground conservationists. These improvements will additionally allow for easier analysis/synthesis and review of the current statuses of nonnative plants present in Hawai‘i. When combined with ongoing detection programs, this informational network stands to prevent large ecological and societal costs resulting from delayed or inappropriate responses to invasions.

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