

Earthstars (*Geastrum*, *Myriostoma*) of the Hawaiian Islands Including Two New Species, *Geastrum litchiforme* and *Geastrum reticulatum*¹

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Abstract: An updated, annotated list of earthstars found in the Hawaiian Islands is presented that includes 19 species of *Geastrum* and *Myriostoma coliforme*. Favored habitats for these gasteroid fungi include periodically wet windward coastal *Casuarina* groves, windward *Leucaena* thickets, and leeward coastal *Prosopis* groves. In contrast to these nonnative vegetation zones, earthstars such as *Geastrum minimum*, *G. campestre*, and *G. corollinum* are found also in largely native leeward montane *Sophora/Myoporum* forests, whereas *Geastrum velutinum* and *G. reticulatum* appear in montane native *Acacia koa/Metrosideros* forests. Eighty-two percent of the collections were made between September and February, although *Geastrum triplex* may be found earlier during the summer months. Two species, *Geastrum litchiforme* Desjardin & Hemmes and *Geastrum reticulatum* Desjardin & Hemmes, are described as new, accompanied by illustrations and comparisons with allied taxa. *Geastrum xerophilum*, originally published without Latin diagnosis, is formally validated. Specific collections are documented and island distribution and preferred habitats of the various species are listed. An artificial dichotomous key to aid in identification is provided.

AN INITIAL REPORT on the earthstars of the Hawaiian Islands listed nine species of *Geastrum* in addition to *Myriostoma coliforme* and provided some information on their distribution in the Islands (Smith and Ponce de Leon 1982). During extensive collecting on all of the major Hawaiian Islands since then, under the auspices of a Biotic Surveys and Inventories Grant from the National Science Foundation, all 10 of those species were found plus 10 additional species of *Geastrum* including two that are described herein as new.

Earthstars favor a number of alien or introduced vegetation types in the Hawaiian Islands, including the duff under the periodically wet *Casuarina* groves that line the windward shorelines, and under *Cupressus*. The coastal *Casuarina* groves near Hāna on Maui, those fronting Hālawa Valley on Molokaʻi, and those at the mouth of Waipiʻo Valley and lining the shorelines from Hilo to MacKenzie Park on Hawaiʻi Island are especially rich in these fungi. *Leucaena* thickets exposed to trade winds on the hillsides at Keolu Hills and Kailua/Lanikai on the windward coast of Oʻahu, and the dry *Prosopis pallida* groves near the Puakō petroglyph fields at Kawaihae, Hawaiʻi Island, both support the growth of a number of species of *Geastrum*. Favored native forest habitats include the dry montane *Sophora/Myoporum* forests surrounding Puʻu Lāʻau on the leeward side of Mauna Kea on Hawaiʻi Island; the mesic montane *Acacia koa/Metrosideros* forests at Kōkeʻe on Kauaʻi; and kīpukas (islands of old forest) along the Saddle Road and in Hawaiʻi Volcanoes National Park on Hawaiʻi Island. An annotated list of all known species is provided, with distribution and favored habitats for each species. Descriptions and illustrations of two species new

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to science, *Geastrum litchiforme* Desjardin & Hemmes and *Geastrum reticulatum* Desjardin & Hemmes, and an artificial dichotomous key to aid in the identification of Hawaiian earthstars are included.

MATERIALS AND METHODS

The search for earthstars in various vegetation zones of the major Hawaiian Islands over the past 15 yr was concentrated from September through February, the rainy season of each year. Major collecting sites included the following: the extensive trails in the Kōke'e State Park region on Kaua'i (mixed koa, *Acacia koa*; karakanut, *Corynocarpus laevigatus*; and other alien species); Keolu Hills on O'ahu (haole koa, *Leucaena leucocephala*); the Hāna coastline (ironwood, *Casuarina equisetifolia*) and Polipoli Springs Road (black wattle, *Acacia mearnsii*) on Maui; Pālā'au State Park on Moloka'i (*Casuarina equisetifolia*, *Acacia mearnsii*); Shipwreck Beach on Lāna'i (kiawe, *Prosopis pallida*); and MacKenzie Park (coastal *Casuarina* and coconut, *Cocos nucifera*), Pu'u Lā'au (māmāne, *Sophora chrysophylla*; and naio, *Myoporum sandwicense*), Pu'u Huluhulu (*Acacia koa* and sandalwood, *Santalum paniculatum*), and the Puakō-Hāwī coastline (*Prosopis pallida*) on Hawai'i Island. Most sites on Hawai'i Island were monitored on a monthly to bi-monthly basis. Other areas on the major islands were searched, but the largest concentrations of earthstars were at these listed sites.

Both unexpanded and expanded fruiting bodies were photographed in the field and

collected. Characteristics including whether the fruiting bodies were epigeous or hypogeous and had adhering debris were noted, and morphological details such as the structure of the peristome, size of the endoperidium, and number of rays were recorded. Species determinations were based on comparisons with pertinent literature (cited in the descriptions) and an examination of representative herbarium specimens. All specimens are deposited in the H. D. Thiers Herbarium at San Francisco State University (SFSU).

For each of the newly described species, spores were prepared for scanning electron microscopy (SEM) by dusting small portions of the gleba on double-sided adhesive tape on a specimen holder, coated with gold/palladium using a sputter coater (Hummer 6.2), and examined with a FESEM (field emission SEM) (Hitachi S-800) operating at 15 kV.

RESULTS

Nineteen species of *Geastrum* and *Myriostoma coliforme* are reported from the Hawaiian archipelago, of which eight represent new distribution records for the Islands, and two are described herein as new species. Records of collections of earthstars over the past 15 yr show that 82% (320/388) of the recorded vouchers produce fruiting bodies from September through February. *Geastrum triplex* and *G. saccatum* were two exceptions, and these species were collected year-round.

ARTIFICIAL KEY TO HAWAIIAN EARTHSTARS

- 1. Endoperidium opening by numerous pores 1. *Myriostoma coliforme*
- 1'. Endoperidium opening by a single apical pore 2
- 2. Peristome sulcate to plicate or of distinct folds 3
- 2'. Peristome fibrillose-fimbriate 10
- 3. Rays on expanded basidiomes hygroscopic 2. *Geastrum campestre*
- 3'. Rays on expanded basidiomes not hygroscopic 4
- 4. Unexpanded basidiomes epigeous; exoperidial surface not adhering debris; endoperidial body sessile 5
- 4'. Unexpanded basidiomes hypogeous; exoperidial surface adhering debris; endoperidial body stalked 6

- 5. Exoperidial surface felted, smooth, reddish brown; peristome of distinct folds, indistinctly delimited 10. *Geastrum morgani*
- 5'. Exoperidial surface covered with a reticulate network of raised hairs, orangish brown to brown; peristome plicate, distinctly delimited 12. *Geastrum reticulatum*, n. sp.
- 6. Endoperidial stalk with a collarlike or ringlike apophysis; known in the Hawaiian Islands only from O'ahu under haole koa 16. *Geastrum striatum*
- 6'. Endoperidial stalk lacking a collarlike or ringlike apophysis 7
- 7. Endoperidial body small, 6–14 mm diam. (avg. 8.8 mm), glabrous; known in the Hawaiian Islands from coastal kiawe habitat 15. *Geastrum schmidelii*
- 7'. Endoperidial body larger, 10–27 mm diam. (avg. 15–18 mm), ornamented; habitat different 8
- 8. Base of endoperidial body vertically folded; endoperidium globose, surface with bluish gray tones 11. *Geastrum pectinatum*
- 8'. Base of endoperidial body smooth, lacking folds; endoperidium depressed-globose, surface grayish brown to brown 9
- 9. Surface of endoperidium coarsely roughened to verrucose (like sandpaper); common in coastal casuarina, cypress, or guava groves 1. *Geastrum berkeleyi*
- 9'. Surface of endoperidium furfuraceous when young, glabrous in age; common in upland māmane-naio habitat 19. *Geastrum xerophilum*
- 10. Basidiomes fornicate 6. *Geastrum fornicatum*
- 10'. Basidiomes not fornicate 11
- 11. Rays on expanded basidiomes hygroscopic 12
- 11'. Rays on expanded basidiomes not hygroscopic 13
- 12. Unexpanded basidiomes hypogeous; exoperidial surface adhering debris 5. *Geastrum floriforme*
- 12'. Unexpanded basidiomes epigeous; exoperidial surface not adhering debris 3. *Geastrum corollinum*
- 13. Unexpanded basidiomes hypogeous; exoperidial surface adhering debris 14
- 13'. Unexpanded basidiomes epigeous; exoperidial surface not adhering debris 16
- 14. Endoperidial body small, 4–12 mm diam. (avg. 7.9 mm), with a well-developed stalk and apophysis; peristome distinctly delimited 9. *Geastrum minimum*
- 14'. Endoperidial body larger, 10–24 mm diam. (avg. 17–20 mm), sessile or short-stalked; peristome not distinctly delimited 15
- 15. Pseudoparenchymatous layer of expanded rays pink to reddish brown; endoperidial body short-stalked at maturity; known in the Hawaiian Islands only from composted wood chips 13. *Geastrum rufescens*
- 15'. Pseudoparenchymatous layer of expanded rays tan to beige or pale ochraceous; endoperidial body sessile; known from coastal coconut and *Casuarina* groves 4. *Geastrum fimbriatum*
- 16. Basidiomes arising from extensive subiculose mycelium, in clusters on senescent coconut fronds or composted wood chips 7. *Geastrum javanicum*
- 16'. Basidiomes not arising from subiculose mycelium; habitat variable 17
- 17. Surface of unexpanded basidiomes covered with dark brown pyramidal tufts of fibrils in an areolate pattern resembling a lychee fruit; peristome indistinctly delimited 8. *Geastrum litchiforme*, n. sp.

- 17'. Surface of unexpanded basidiomes smooth, velutinous, or scaly, lacking pyramidal tufts; peristome distinctly delimited 18
18. Pseudoparenchymatous layer of expanded rays usually breaking at maturity to form a cup around base of endoperidial body; surface of unexpanded basidiomes covered with small brown scales 17. *Geastrum triplex*
- 18'. Pseudoparenchymatous layer not breaking to form a cup around endoperidial body; surface of unexpanded basidiomes glabrous to minutely felty or velutinous 19
19. Surface of unexpanded basidiomes velutinous, dark brown; pseudoparenchymatous layer of expanded rays with a pink hue 18. *Geastrum velutinum*
- 19'. Surface of unexpanded basidiomes glabrous to minutely felted, ochraceous to pale brown; pseudoparenchymatous layer of expanded rays pale ochraceous to pale brown 14. *Geastrum saccatum*

TAXONOMY

1. *Geastrum berkeleyi* Masee, Ann. Bot., Lond. 4:79, 1889.

DESCRIPTIONS: Sunhede (1989), Pegler et al. (1995), Calonge (1998), Hemmes and Desjardin (2002).

SPECIMENS EXAMINED: Hawai'i Island: Hilo, 333 Kalili Street, scattered in leaves under *Psidium cattleianum*, 7 November 2000, DEH 2019; Hilo, University of Hawai'i campus, Loulu Garden, August 1995, DEH 441; Hilo, Keaukaha, scattered in duff under *Casuarina equisetifolia*, 21 October 2001, DEH 2168; same location and habitat, 3 July 2004, DEH 2489; Hilo, Lili'uokalani Park, scattered in duff under *Casuarina equisetifolia*, 23 September 2005, DEH 2588; same location and habitat, 11 December 2005, DEH 2607; same location and habitat, 16 January 2007, DEH 2680; Lava Tree State Park, scattered in duff under *Casuarina cunninghamiana*, 14 November 2001, DEH 2190; MacKenzie Park, scattered in duff under *Casuarina equisetifolia*, 15 February 1994, DEH 423; same location and habitat, 16 January 2000, DEH 1924; same location and habitat, 18 April 2000, DEH 1947; same location and habitat, 19 February 2001, DEH 2069; same location and habitat, 12 October 2001, DEH 2152; same location and habitat, 12 October 2001, DEH 2153; same location and habitat, 14 November 2001, DEH 2191; same location and habitat, 16 November 2001, DEH 2197; same location and habitat, 22 January 2002,

DEH 2248; same location and habitat, 31 August 2002, DEH 2314; same location and habitat, 18 September 2002, DEH 2333; same location and habitat, 15 September 2005, DEH 2581; same location and habitat, 1 February 2007, DEH 2688; Pāhoa, Mike Au's farm, scattered in duff under *Cupressus lusitanica*, 16 November 2001, DEH 2192; same location and habitat, 10 November 2000, DEH 2022.

NOTES: *Geastrum berkeleyi* is found in scattered groups in a variety of habitats including under coastal ironwoods (*Casuarina equisetifolia*), groves of Portuguese cypress (*Cupressus lusitanica*), and thickets of strawberry guava (*Psidium cattleianum*). The unexpanded fruiting body is hypogeous, depressed-globose, and the exterior is encrusted with debris. The exoperidium splits into 5–9 rays that are usually arched. In Hawaiian specimens, the endoperidium averages 17.1 mm in diameter (9–23 mm; 63 specimens) and is depressed-globose, brown to grayish brown, verrucose to coarsely roughened, stalked with a distinct apophysis, and topped with a conical, plicate peristome. This species can readily be distinguished from *G. pectinatum*, a superficially similar species that has a more globose, bluish gray endoperidium that is covered with a whitish pruina and has folds on the lower surface that can be seen easily with the naked eye. Hemmes and Desjardin (2002) were the first to report *G. berkeleyi* from the Hawaiian Islands, where it is relatively common on Hawai'i Island.

2. *Geastrum campestre* Morgan, Am. Nat. 21:1027, 1887.

DESCRIPTIONS: Sunhede (1989), Pegler et al. (1995), Calonge (1998).

SPECIMENS EXAMINED: Hawai'i Island: MacKenzie Park, solitary in duff under *Casuarina equisetifolia*, 14 November 2001, DEH 2188; Pu'u Lā'au, scattered on soil under *Sophora-Myoporum*, 24 September 1996, DEH 1258; same location and habitat, 27 August 1997, DEH 1517; same location and habitat, 23 September 1997, DEH 1534; same location and habitat, 21 October 1997, DEH 1604; same location and habitat, 21 October 1997, DEH 1605; same location and habitat, 21 October 1997, DEH 1796; same location and habitat, 15 July 2009, DEH 2798; same location and habitat, 10 August 2009, DEH 2811.

NOTES: *Geastrum campestre* is one of the hygroscopic species, along with *G. corollinum* and *G. floriforme*, commonly found in the dry montane māmane-naio habitat at high elevations on the leeward side of Mauna Kea. In *G. campestre*, the size of the endoperidium varies widely (5–18 mm diam.; avg. 11.8 mm; 40 specimens) and the peristome is sulcate to plicate. *Geastrum corollinum* and *G. floriforme* are smaller species with fimbriate-fibrillose peristomes. *Geastrum campestre* was previously recorded from the Hawaiian Islands by Gilbertson et al. (2001) and Hemmes and Desjardin (2002).

3. *Geastrum corollinum* (Batsch) Hollós, Gassterom. Ung. 65:154, 1904.

DESCRIPTIONS: Sunhede (1989), Pegler et al. (1995), Calonge (1998), Hemmes and Desjardin (2002).

SPECIMENS EXAMINED: Hawai'i Island: Pōhakuloa, scattered in dirt under *Myoporum*, 2 December 2000, DEH 2041 and DEH 2042; Puakō, scattered in soil under coastal kiawe, *Prosopis pallida*, 19 March 2007, DEH 2689; same location and habitat, 22 December 2007, DEH 2730; same location and habitat, 7 February 2009, DEH 2791; same location and habitat, 19 February 2009, DEH 2796; same location and habitat, 10 August

2009, DEH 2812; Pu'u Lā'au, scattered under *Sophora-Myoporum*, 23 September 1997, DEH 1535 and DEH 1536; same location and habitat, 21 October 1997, DEH 1565 and DEH 1566; same location and habitat, 2 January 1998, DEH 1798.

NOTES: *Geastrum corollinum* is a small, strongly hygroscopic species with fimbriate-fibrillose peristome found in dry māmane-naio forests on the leeward slopes of Mauna Kea on Hawai'i Island and in dry leeward coastal kiawe forests (*Prosopis pallida*). The species differs from the very similar *G. floriforme* in being epigeous, strongly hygroscopic, and thus curled in tight little balls with no adhering debris on the exterior mycelial layer. *Geastrum floriforme* is approximately the same size, only slightly hygroscopic, but is typically hypogeous and has conspicuous adhering debris on the outer surface. The Hawaiian specimens of *G. corollinum* are typically smaller than those reported from Europe and North America, with endoperidia averaging 10 mm in diameter (6–12 mm; 16 specimens). The species was reported from Hawai'i Island by Gilbertson et al. (2001) and Hemmes and Desjardin (2002) and from O'ahu by Smith and Ponce de Leon (1982; as *Geastrum recoligens* (With.) Desv.).

4. *Geastrum fimbriatum* Fr., Syst. Mycol. 3:16, 1829.

DESCRIPTIONS: Sunhede (1989), Pegler et al. (1995), Calonge (1998), Hemmes and Desjardin (2002).

SPECIMENS EXAMINED: Hawai'i Island: Lili'uokalani Park, Hilo, clustered to scattered in *Casuarina* duff, 13 September 2005, DEH 2574; MacKenzie Park, scattered in duff under *Casuarina equisetifolia*, 29 November 1994, DEH 650; same location and habitat, 24 November 1998, DEH 1761; same location and habitat, 18 April 2000, DEH 1948; same location and habitat, 6 October 2005, DEH 2594; same location and habitat, 29 October 2005, DEH 2601; same location and habitat, 13 December 2005, DEH 2611; MacKenzie Park, scattered in coconuts and coconut fronds under *Cocos nucifera*, 7 November 2000, DEH 2020; same location and

habitat, 16 November 2001, DEH 2196; same location and habitat, 11 December 2001, DEH 2213; same location and habitat, 31 August 2002, DEH 2309; same location and habitat, 17 September 2002, DEH 2328; same location and habitat, 18 September 2002, DEH 2331; same location and habitat, 23 February 2003, DEH 2372; same location and habitat, 7 December 2003, DEH 2447; same location and habitat, 11 January 2005, DEH 2549; Waipi'o Valley, scattered in black sand of coastal dunes under *Casuarina equisetifolia*, 12 November 2001, DEH 2182.

NOTES: The endoperidium of *G. fimbriatum* averages 17.3 mm in diameter (10–23 mm; 73 specimens) and the peristome is finely fimbriate-fibrillose and indistinctly delimited. This medium to large species often grows in clusters or scattered groups in black sand mixed with vegetative debris under coastal coconuts and coastal *Casuarina*. The expanded fruiting bodies are similar in size and morphology to those of *G. litchiforme*, which grows in the same habitat, but the two can be distinguished easily in that the unexpanded fruiting bodies of *G. fimbriatum* are hypogeous and encrusted with debris, whereas unexpanded fruiting bodies of *G. litchiforme* are epigeous and lack encrusted debris. In addition, the surface of the unexpanded fruiting bodies of *G. litchiforme* is covered with pyramidal tufts of fibrils in an areolate pattern. *Gastrum fimbriatum* was first reported from the Hawaiian Islands by Hemmes and Desjardin (2002).

5. *Gastrum floriforme* Vittad., Monograph Lyc.: 23, 1842.

DESCRIPTIONS: Sunhede (1989), Pegler et al. (1995), Calonge (1998).

SPECIMENS EXAMINED: Hawai'i Island: Pu'u Huluhulu, on dirt path, 31 December 2003, DEH 2457; same location and habitat, 12 October 2005, DEH 2595; same location and habitat, 14 March 2006, DEH 2613.

NOTES: *Gastrum floriforme* was reported from O'ahu by Smith and Ponce de Leon (1982). This small, hygroscopic species is hypogeous until it expands and has considerable adhering debris on the exterior mycelial layer.

The endoperidium is 10–12 mm diam., furfureaceous, and has an indistinct, finely fibrillose peristome. The relatively thin rays range from 7 to 10 or more in number, are dark brown on their dorsal surface in age, and spread out flat like ray flowers of a sunflower in moist conditions. *Gastrum corollinum* is a strongly hygroscopic species and Hawaiian populations are of comparable size (endoperidium 10–13 mm diam.), but basidiomes of *G. corollinum* are epigeous with no adhering debris. In European *G. corollinum* the peristome is rather distinctly delimited, and the species is easily distinguished from *G. floriforme* with its non-delimited peristome. It is not as clear-cut in Hawaiian populations, however, where we find the best distinction is in the presence of adhering debris on the unopened hypogeous basidiomes of *G. floriforme* in comparison with the absence of adhering debris on the unopened epigeous basidiomes of *G. corollinum*.

6. *Gastrum fornicatum* (Huds.) Hook., Curtis Fl. Londin. 4:575, 1821.

DESCRIPTIONS: Sunhede (1989), Pegler et al. (1995), Calonge (1998), Hemmes and Desjardin (2002).

SPECIMENS EXAMINED: Hawai'i Island: Hāwī Road, scattered in duff under *Casuarina equisetifolia*, 25 October 2005, DEH 2597; Māhukona, under *Prosopis pallida*, 26 November 2000, DEH 2034; Puakō, under *Prosopis pallida*, 19 March 2007, DEH 2685; same location and habitat, 22 December 2007, DEH 2729; same location and habitat, 7 February 2009, DEH 2792; same location and habitat, 19 February 2009, DEH 2797; same location and habitat, 10 August 2009, DEH 2813; Pu'u Huluhulu, scattered to clustered under *Acacia koa*, 23 November 1998, DEH 1762; Pu'u Lā'au, scattered to clustered under *Sophora-Myoporum*, 24 September 1996, DEH 1260; Saddle Road near Mauna Kea State Park, scattered to clustered under *Sophora-Myoporum*, 17 January 1996, DEH 1271; Pu'u Lā'au, scattered to clustered under *Sophora-Myoporum*, 23 November 1998, DEH 1754; same location and habitat, 2 January 1999, DEH 1795; same location and habitat, 2 Jan-

uary 1998, DEH 1794; same location and habitat, 21 March 2001, DEH 2083; same location and habitat, 15 November 2002, DEH 2345; Saddle Road, on Kona side of Mauna Kea access road, scattered under *Sophora-Myoporum*, 30 January 1996, DEH 1029. Maui: Polipoli, scattered to clustered under *Acacia mearnsii*, 22 November 1996, DEH 1341.

NOTES: *Geastrum fornicatum* is found in the drier portions of the Islands under coastal kiawe (*Prosopis pallida*) along the leeward coasts, and under koa (*Acacia koa*) and māmane-naio (*Myoporum/Sophora*) in leeward montane habitats. This is the only species with fornicate basidiomes from these regions and usually appears in large troops of dozens of fruiting bodies. Endoperidia average 12.5 mm in diameter (10–20 mm; 50 specimens) and the peristome is tubular and fibrillose. Smith and Ponce De Leon (1982) did not report *G. fornicatum* from the Hawaiian Islands, but they did report a single collection of *G. quadrifidum* DC. ex Pers. from Hawai'i. This specimen, collected by Otto Degener in 1926 and deposited at the New York Botanical Garden, was examined and represents old, poor-quality material of *G. fornicatum* that lacks endoperidia. We have not seen any material of *G. quadrifidum* from the Hawaiian Islands. *Geastrum fornicatum* was previously recorded from māmane-naio habitat on Hawai'i Island by Gilbertson et al. (2001) and Hemmes and Desjardin (2002).

7. *Geastrum javanicum* Lév., Ann. Sci. Nat. Bot., Ser. 3, 5:161, 1846.

DESCRIPTION: Ponce de Leon (1968).

SPECIMENS EXAMINED: Hawai'i Island: MacKenzie Park, clustered in duff under *Casuarina equisetifolia*, 1 October 1998, DEH 1720; same location and habitat, 24 November 1998, DEH 1763; MacKenzie Park, clustered on fallen fronds under *Cocos nucifera*, 28 October 2000, DEH 2003; same location and habitat, 12 October 2001, DEH 2151; same location and habitat, 14 November 2001, DEH 2187; same location and habitat, 31 August 2002, DEH 2312; same location and habitat, 17 September 2002, DEH 2329; same

location and habitat, 18 November 2003, DEH 2438; same location and habitat, 7 December 2003, DEH 2449; same location and habitat, 6 October 2005, DEH 2593. O'ahu: clustered in composted wood chips, 31 January 2010, DEH 2811.

NOTES: Unexpanded fruiting bodies of *Geastrum javanicum* are medium sized, globose, and epigeous with no adhering debris. When expanded, the dark brown endoperidia that average 12.9 mm in diameter (8–17 mm; 27 specimens) contrast with the lighter pseudoparenchymatous layer of the expanded rays. Clusters of basidiomes held together by a thick, underlying subiculose mycelium appear on and around senescent coconut fronds at MacKenzie Park on Hawai'i or in composted wood chips at Koko Crater Botanical Garden on O'ahu. This subiculose mycelium is unique to this species in the Hawaiian Islands and aids in its easy recognition. *Geastrum javanicum* was reported by Smith and Ponce de Leon (1982) from O'ahu growing under *Leucaena leucocephala*.

8. *Geastrum litchiforme* Desjardin & Hemmes, n. sp.

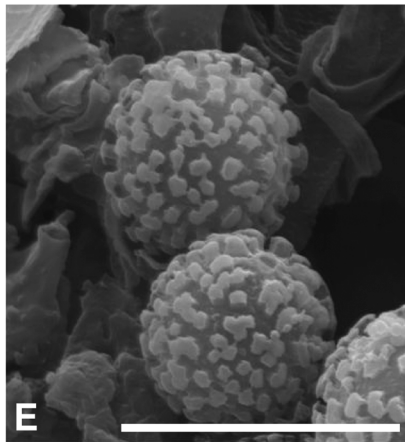
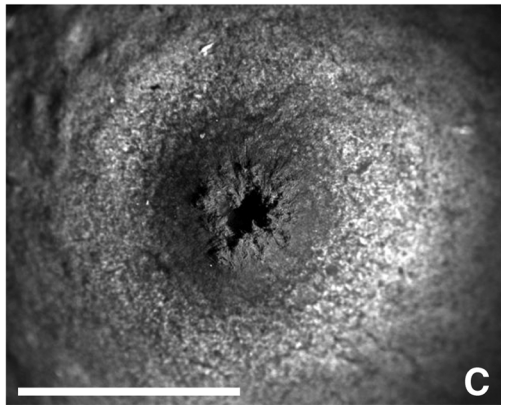
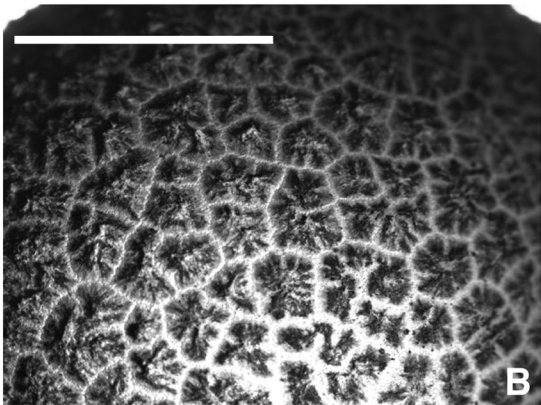
Figure 1A–E

Mycobank MB 519175

Geastrum aff. *welwitschii* Mont. Hemmes and Desjardin, 2002:86.

LATIN DESCRIPTION: Basidiomata juvencula epigaeum, nonfornicatum, ad clausum globulare vel depresso globulare, 22–30 mm altum, 27–40 mm latum. Exoperidium apertum 50–70 mm latum in 8–10 radios acutos, recurvos fissum, nonhygroscopicum; stratum myceliale atrobrunneum, pyramidale-squamosum; stratum myceliale et stratum fibrillosum deciduum; stratum pseudoparenchymaticum satis tenue (1–2 mm), griseobrunneum. Endoperidium sessile, globulare, 20–30 mm latum, pruinatum, griseobrunneum. Peristomium nondelimitatum, fibrillosum. Gleba atrobrunnea. Basidiosporae globulare, 3.2–3.8 µm latae, verrucosae, brunnea.

TYPE MATERIAL: Holotype: Hawai'i Island, MacKenzie Park, scattered to clustered in duff under *Casuarina equisetifolia*, 15 Sep-



tember 2005, collected by D. E. Hemmes, DEH 2583 (SFSU).

DESCRIPTION: *Unexpanded basidiomes* 22–30 mm tall × 27–40 mm diam. ($x = 26.5 \times 33.5$ mm, $n = 15$ specimens), globose or subglobose to depressed-globose, epigeous, lacking encrusting debris, attached to the substrate by fine white rhizoids; surface (mycelial layer) covered with small pyramidal tufts of fibers that produce an areolate pattern (Figure 1A) similar to the surface of a lychee fruit; dark brown (6–8F4–8) overall; odor of crushed unexpanded basidiomes strong, similar to that of bok choy (Chinese cabbage). *Mycelial layer* easily separable from the expanding basidiome, very thin and papery, remaining as a cuplike structure (Figure 1A); nonfornicate. *Expanded basidiomes* 50–70 mm in diameter, splitting into 8–10 rays, saccate; rays nonhygroscopic, somewhat recurved, often splitting to form a collarlike structure surrounding the endoperidial body (Figure 1D). *Pseudoparenchymatous layer* fleshy, 1–2 mm thick, grayish brown (7E3–4) to brown (6F6). *Endoperidium* sessile, without an apophysis, globose, 20–30 mm in diameter ($x = 24.7$ mm diam.; $n = 46$ specimens), smooth, minutely pruinose, grayish brown (6–7E3–4). *Peristome* flattened, fibrillose-fimbriate, dark brown, not distinctly delimited. *Mature gleba* dark brown.

Basidiospores globose, 3.2–3.8 μ m diam. ($x_r = 3.51$ –3.53 μ m, $n = 25$, $s = 5$), finely verrucose, verrucae very low, crowded, brown, thick-walled. *Basidia* 10–14 × 7–9 μ m, broadly clavate to subvesiculose, 4–7 sterigmate (mostly 6), hyaline, basally clamped; interspersed with many broadly clavate to clavate-mucronate or bladderlike cells 8–18 μ m diam., hyaline, inamyloid, thin-walled. *Subbasidial hyphae* 1–2.5 μ m diam., cylindrical, hyaline, inamyloid, thin-walled, clamped. *Hyphae of tramal plates* similar to subbasidial hyphae but parallel and up to 4 mm diam. *Columella hyphae* in upper part and adjacent to gleba in-

terwoven, 1–2.5 μ m diam., cylindrical, hyaline, inamyloid, thin-walled; columella hyphae near base of columella 1.5–5 μ m diam., parallel, hyaline, inamyloid, thin- to thick-walled. *Capillitial hyphae* (2.5–)4–7 μ m diam., cylindrical, very long, unbranched, coarsely roughened, pale grayish brown to dark brown, dextrinoid, thick-walled (0.5–2.5 μ m), often with very narrow lumen. *Endoperidial hyphae* interwoven, 3–7.5 μ m diam., cylindrical, smooth or very weakly roughened, hyaline to pale yellowish brown, inamyloid, thick-walled (0.8–4 μ m); protruding hyphae common, scattered, 5.5–9 μ m diam., irregularly cylindrical to sinuous, often narrowed toward the obtuse tip, pale yellowish brown, inamyloid, thick-walled (2.5–4 μ m). *Peristome hyphae* subparallel to intertwined, 4–8 μ m diam., subcylindrical to sinuous with the tip narrowed to a fine point, smooth, pale yellowish brown, inamyloid, thick-walled (1.5–3.5 μ m), lumen nearly occluded. *Pseudoparenchymatous layer* composed of inflated, bladderlike cells 12–24(–30) μ m diam., hyaline to pale yellow, inamyloid, thin-walled; with protruding hyphae 6.5–11.5 μ m diam., cylindrical to subclavate, yellow, inamyloid, thick-walled (3–4.8 μ m) with lumen nearly occluded. *Mycelial layer* composed of tufts of subparallel hyphae irregular in outline to acuminate, with a broad base and apically narrowed to a fine point, sinuous, 9–20 μ m at broadest area, smooth or roughened, pale yellowish brown, inamyloid, thick-walled (1–2.5 μ m); inside of dehiscent cups composed of loosely interwoven hyphae 4.5–10 μ m diam., covered with an amorphous layer of crystalline matter.

HABIT, HABITAT, AND KNOWN DISTRIBUTION: Scattered to gregarious in duff under coastal *Casuarina* (*Casuarina equisetifolia*) or on coconut fronds and coconuts (*Cocos nucifera*) in coastal coconut groves at MacKenzie Park, Puna District; James Kealoha Beach Park, Hilo; and Lelewi Beach Park, Hilo.

FIGURE 1. Features of *Geastrum litchiforme* Desjardin & Hemmes, n. sp. (A) Unexpanded and expanded basidiomes growing in duff under *Casuarina equisetifolia*. Note the tufted areolate pattern on the surface of the unexpanded basidiomes and the husk or outer layer of the exoperidium on the right that easily separates from the expanded basidiome. (B) Higher magnification of the pyramidal tufts and areolate pattern on the surface of the exoperidium. (C) A finely fibrillose-fimbriate peristome blackened with dark brown spores. (D) Mature basidiomes where the rays have systematically broken to form a cup around the endoperidium, much like basidiomes of *Geastrum triplex*. (E) Scanning electron micrograph of basidiospores. Scale bars for A–D = 1 cm; for E = 1 μ m.

SPECIMENS EXAMINED: Hawai'i Island: Hilo, James Kealoha Park, clustered in duff under *Casuarina equisetifolia*, 21 October 2001, DEH 2167; same location and habitat, 7 December 2001, DEH 2204; same location and habitat, 8 October 2002, DEH 2342; same location and habitat, 1 November 2002, DEH 2361; Hilo, Leleiwi, scattered and clustered in duff under *Casuarina equisetifolia*, 28 October 2000, DEH 2001; Hilo, University of Hawai'i campus, Loulu Garden, 16 August 1995, DEH 865; MacKenzie Park, scattered to clustered in duff under *Casuarina equisetifolia*, 22 January 1994, DEH 410; same location and habitat, 18 December 1994, DEH 669; same location and habitat, 27 February 1996, DEH 1033; same location and habitat, 6 August 1996, DEH 1193; same location and habitat, 19 August 1996, DEH 1212; same location and habitat, 28 October 2000, DEH 2000; same location and habitat, 19 February 2001, DEH 2070; same location and habitat, 11 January 2005, DEH 2544; same location and habitat, 11 January 2005, DEH 2545; same location and habitat, 15 September 2005, DEH 2583 (holotype: sfsu); MacKenzie Park, scattered and clustered on coconut and coconut frond debris under *Cocos nucifera*, 16 January 2000, DEH 1923; same location and habitat, 7 November 2000, DEH 2018; same location and habitat, 12 October 2001, DEH 2155; same location and habitat, 9 November 2001, DEH 2173; same location and habitat, 16 November 2001, DEH 2194; same location and habitat, 11 December 2001, DEH 2212; same location and habitat, 22 January 2002, DEH 2245; same location and habitat, 31 August 2002, DEH 2308; same location and habitat, 18 September 2002, DEH 2332; same location and habitat, 15 September 2005, DEH 2585; same location and habitat, 29 October 2005, DEH 2603; same location and habitat, 15 December 2005, DEH 2610; same location and habitat, 16 January 2007, DEH 2681; same location and habitat, 2 February 2008, DEH 2755.

ETYMOLOGY: *Litchi forme*, from the similarity of the size and surface texture of unexpanded basidiomes to lychee fruit.

NOTES: Unexpanded basidiomes of *G. litchiforme* are flattened-globose and have dis-

tinctive dark brown pyramidal tufts of fibrils in an areolate pattern on the outer surface of the unexpanded peridium (mycelial layer) that resembles a lychee fruit in surface texture. The tufts are composed of irregularly sinuous, aculeate, thick-walled terminal cells that are apically narrowed to a fine point. In addition, the mycelial layer is easily separated from the basidiome during development and expansion and remains as a paper-thin cuplike structure. The fibrillose-fimbriate peristome is indistinctly delimited and characteristically dark brown as if air-brushed. This large species, currently vouchered only from Hawai'i Island, has a strong odor similar to that of bok choy, especially when unexpanded basidiomes are broken open. It is commonly encountered in duff in coastal *Casuarina* groves. *Geastrum litchiforme* was first reported from the Hawaiian Islands as *Geastrum* aff. *welwitschii* by Hemmes and Desjardin (2002). *Geastrum welwitschii* Mont. differs from *G. litchiforme* in being truly fornicate, in lacking the characteristic lycheelike exoperidial surface ornamentation, and in having larger (4.5–5 µm diam.) basidiospores with fewer, larger, and more coalescent verrucae (compare Figure 1D with Fig. 212 D–F of Sunhede [1989]).

In Hawai'i, *G. litchiforme* may be confused with *G. triplex*. Both species form epigeous basidiomes of comparable sizes (unexpanded and expanded), have saccate exoperidial bodies, sessile endoperidial bodies with fibrillose peristomes, and rays in which the pseudoparenchymatous layer cracks and forms a collarlike structure surrounding the endoperidial body (Figure 1D). *Geastrum triplex* differs in forming globose-mammiliform or onion-shaped unexpanded basidiomes with a felted-scaly mycelial layer, and a distinct peristome delimited by a white zone.

9. *Geastrum minimum* Schwein., Schr. Naturf. Ges. Leipzig 1:58, 1822.

DESCRIPTIONS: Sunhede (1989), Pegler et al. (1995), Calonge (1998).

SPECIMENS EXAMINED: Hawai'i Island: Kapoho (Green Lake), in duff under *Casuarina equisetifolia*, 6 August 1996, DEH 1196; MacKenzie Park, in duff under *Casuarina*

equisetifolia, 19 August 1996, DEH 1213; same location and habitat, 7 November 2000, DEH 2017; same location and habitat, 16 November 2001, DEH 2195; same location and habitat, 11 December 2001, DEH 2211; same location and habitat, 8 November 2007, DEH 2714; Pāhoa, Mike Au's farm, in duff under *Cupressus lusitanica*, 10 October 1995, DEH 895; same location and habitat, 10 November 2000, DEH 2021; same location and habitat, 16 November 2001, DEH 2193; Pu'u Lā'au, scattered in dry grass, 21 October 1997, DEH 1568; same location and habitat, 23 November 1998, DEH 1753; same location and habitat, 12 October 2001, DEH 2154; same location and habitat, 31 May 2004, DEH 2484; same location and habitat, 29 November 2004, DEH 2539; same location and habitat, September 2005, DEH 2573; same location and habitat, 20 April 2006, DEH 2616; same location and habitat, 15 January 2007, DEH 2678; same location and habitat, 15 July 2009, DEH 2799; same location and habitat, 10 August 2009, DEH 2811; Saddle Road on Kona side of Mauna Kea access road, scattered in soil among cypress tussocks in māmane-naio grasslands, 30 January 1996, DEH 1028.

NOTES: The distinctly delimited and finely fibrillose peristome, nonhygroscopic rays, and tiny, stalked endoperidium averaging 7.9 mm in diameter (4–12 mm; 64 specimens) are diagnostic of this species. *Geastrum minimum* is found in the dry māmane-naio leeward regions of Mauna Kea on Hawai'i Island and in duff under coastal *Casuarina* and *Cupressus*. This species was reported from Hawai'i and O'ahu by Smith and Ponce de Leon (1982) and Gilbertson et al. (2001).

10. *Geastrum morganii* Lloyd, Mycol. Notes 8:80, 1901.

DESCRIPTION: Sunhede (1989).

SPECIMENS EXAMINED: Hawai'i Island: Pu'u Huluhulu, scattered in grass along trail, 31 December 2003, DEH 2454; same location and habitat, 1 January 2004, DEH 2461.

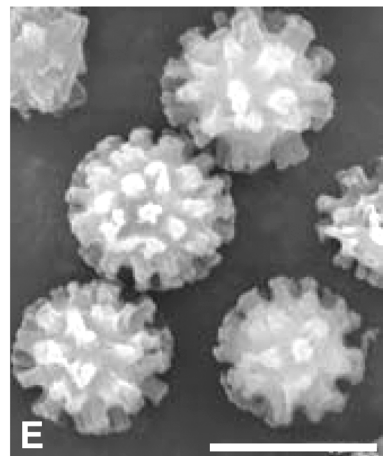
NOTES: *Geastrum morganii* is similar in size and morphology to *G. triplex* and *G. reticulatum*. All are large species and have unex-

panded basidiomes that are onion-shaped with a distinct papilla, and in all three the rays have a tendency to crack near the endoperidial body, forming a collar or cuplike structure. The three species can be readily distinguished by the different texture of the surface of the unexpanded fruiting bodies and the structure of the peristome. The outer surface of primordia of *G. morganii* is reddish brown and evenly felted, whereas the surface of primordia of *G. triplex* is brown with scattered scales. *Geastrum reticulatum* has the characteristic reticulated pattern created by lines of raised hyphae. The peristome of *G. morganii* is irregularly plicate with well-developed folds and no distinct delimitation, whereas the peristome of *G. triplex* is fibrillose and usually distinctly delimited by a circle of lighter color. The peristome of *G. reticulatum* is strongly plicate, conical, and usually slightly sunken into the endoperidium. *Geastrum morganii* has only been found under koa (*Acacia koa*) at Pu'u Huluhulu on Hawai'i. What was reported as *Geastrum* aff. *morganii* by Hemmes and Desjardin (2002) represents the new species *G. reticulatum* (see discussion at no. 12).

11. *Geastrum pectinatum* Pers., Syn. Meth. Fung. (Göttingen) 1:132, 1801.

DESCRIPTIONS: Sunhede (1989), Pegler et al. (1995), Calonge (1998), Hemmes and Desjardin (2002).

SPECIMENS EXAMINED: Hawai'i Island: MacKenzie Park, in duff under *Casuarina equisetifolia*, 24 October 1989, DEH 105; same location and habitat, 25 October 1989, DEH 106; same location and habitat, 15 February 1994, DEH 422; same location and habitat, 28 March 1994, DEH 440; same location and habitat, 22 January 2002, DEH 2247; same location and habitat, 19 November 2003, DEH 2448; same location and habitat, 11 January 2005, DEH 2547; same location and habitat, 18 November 2003, DEH 2437; same location and habitat, 1 March 2007, DEH 2687; same location and habitat, 14 December 2007, DEH 2735. Lāna'i: Kō'ele, under *Cupressus*, 6 January 2007, DEH 2672; same location and habitat, 28 December 2009, DEH 2810.



NOTES: Basidiomes of *Geastrum pectinatum* are most commonly found in duff under coastal *Casuarina* and groves of *Cupressus*. The endoperidium of this species, like that of *G. berkeleyi*, is perched on a distinct stalk with a well-developed apophysis at the base. *Geastrum pectinatum*, however, has distinct folds on the base of the endoperidium, whereas *G. berkeleyi* has none. The endoperidium of *G. pectinatum* is usually globose, averages 18.0 mm in diameter (10–27 mm; 24 specimens) and in fresh specimens has a white, pruinose covering over a lead gray or bluish gray color. In contrast, the endoperidium of *G. berkeleyi* is depressed-globose, averages 17.1 mm in diameter (9–23 mm; 63 specimens), and is coarsely roughened to verrucose and brown overall. The peristomes of both species are acutely conical and strongly plicate. *Geastrum schmidelii* is also similar to *G. pectinatum*, but the former is a much smaller species (endoperidium 6–14 mm diam.) with a glabrous endoperidium and shorter stalk. *Geastrum pectinatum* was reported from O'ahu and Ni'ihau by Smith and Ponce de Leon (1982) and from O'ahu and Hawai'i by Hemmes and Desjardin (2002).

12. *Geastrum reticulatum* Desjardin & Hemmes, n. sp.

Figure 2A–E

Mycobank MB 519176

Geastrum aff. *morganii* Lloyd. Hemmes and Desjardin, 2002:135.

LATIN DESCRIPTION: Basidiomata juvencae epigaeum, nonfornicatum, ad clausum obturbatum, 26–40 mm altum, 25–32 mm latum. Exoperidium apertum 50–75 mm latum in 7–8(–11) radios acutos, recurvos fissum, nonhygroscopicum; stratum myceliale aurantio-brunneum vel atrobrunneum, furfuraceum

vel reticulatum; stratum pseudoparenchymaticum 2–3 mm crassum, griseoaurantiacum vel brunneoaurantiacum. Endoperidium sessile, globulare, 15–26 mm latum, glabrum, griseo-brunneum. Peristomium conicum, 2–6 mm altum, 5–9 mm latum, delimitatum, plicatum, atrobrunneum. Gleba atrobrunnea. Basidiosporae globulare, 4.5–5.5 μm latae, verrucosae, brunnea.

TYPE MATERIAL: Holotype: Hawai'i Island, MacKenzie Park, scattered in duff under *Casuarina equisetifolia*, 6 October 2005, collected by D. E. Hemmes, DEH 2592 (SFSU).

DESCRIPTION: *Unexpanded basidiomes* 26–40 mm tall \times 25–32 mm in diameter ($x = 32.5 \times 30.2$ mm; $n = 10$ specimens), obturbinate to onion-shaped, epigeous, lacking encrusting debris; surface furfuraceous to reticulate, orangish brown (7D4) to brown or dark brown (7–8F5–8); ornamentation composed of a network of raised hairs (Figure 2A) forming diamond-shaped or polygonal areas up to 10 mm diameter. *Expanded basidiome* 50–75 mm diameter, splitting into 7–8(–11) rays; rays nonhygroscopic, arched, sometimes recurved under the basidiome (Figure 2B). *Pseudoparenchymatous layer* fleshy, 2–3 mm thick, grayish orange (5B3–4) to brownish orange (6C4), commonly splitting at the margin of the exoperidial disk and becoming raised into a conspicuous collar. *Endoperidium* sessile, without an apophysis, saccate, globose, 15–26 mm diameter ($x = 21.9$ mm; $n = 25$ specimens), smooth, glabrous, grayish brown (6–7C–D3–4). *Peristome* conical, 2–6 mm tall \times 5–9 mm diam., strongly plicate with 30–40 ridges, distinctly delimited, margin slightly sunken, dark brown (6–7F6–8). *Mature gleba* dark brown (6F6).

Basidiospores globose, 4.5–5.5 μm diam. ($x_r = 4.85$ –5.1 μm , $n = 25$, $s = 5$) including ornamentation, brown; ornamentation of apically rounded, columnar processes up to

FIGURE 2. Features of *Geastrum reticulatum* Desjardin & Hemmes, n. sp. (A) Unexpanded basidiome growing in duff under *Casuarina equisetifolia*. Note the characteristic reticulated pattern of raised hairs on the surface. (B) An expanded basidiome illustrating the conical, plicate, dark brown peristome. (C) Higher magnification of the peristome showing the plications. (D) A basidiome that has just expanded. (E) Scanning electron micrograph of basidiospores. Scale bars for A–D = 1 cm; for E = 1 μm .

0.7 μm tall, rather broad and widely spaced. *Basidia* short-clavate, 4–7 sterigmate (mostly 6–7), basally clamped. *Subbasidial hyphae* 1–2 μm diam., cylindrical, often inflated adjacent to clamp connection, interwoven, branched, hyaline, inamyloid, thin-walled. *Hyphae of the tramal plates* similar to the subbasidial hyphae but parallel and up to 4 μm diam. *Columella hyphae* in upper part and adjacent to gleba 1–3 μm diam., hyaline, inamyloid, thin-walled; columella hyphae near base of columella 1.5–4 μm diam., parallel, hyaline, inamyloid, thin- to thick-walled. *Capillitial hyphae* 1.5–4 μm diam., cylindrical, unbranched, smooth, brown, dextrinoid, thick-walled (0.5–1.6 μm), often with very narrow lumen. *Endoperidial hyphae* interwoven, 3.8–6 μm diam., cylindrical, smooth or roughened, subhyaline to pale yellowish brown, inamyloid, thick-walled (0.5–2.2 μm); protruding hyphae absent; terminal cells often subclavate, up to 8 μm diam. *Peristome hyphae* subparallel, 3–7 μm diam., sinuous, smooth, yellowish brown, dextrinoid, thick-walled (1.2–3 μm), lumen nearly occluded, tips narrowed and obtuse. *Pseudoparenchymatous layer* composed of inflated, bladderlike cells 16–36 μm diam., yellowish brown, inamyloid, thin-walled. *Mycelial layer* composed of interwoven, sinuous hyphae 3.2–7 μm diam., yellowish brown, inamyloid to dextrinoid, thick-walled (1–2.5 μm); terminal cells irregular, swollen to clavate or lobed, 12–24 μm diam., some bladderlike up to 40 μm diam., others tapered to a narrow tip like the capillitial hyphae, inamyloid to dextrinoid, thin- to thick-walled.

HABIT, HABITAT, AND KNOWN DISTRIBUTION: Scattered in duff under coastal “ironwoods” (*Casuarina equisetifolia*) at MacKenzie Park, Puna District, Hawai‘i Island, in leaf mulch in the mixed native forest of koa/‘ōhi‘a (*Acacia koa*/*Metrosideros polymorpha*) and alien strawberry guava (*Psidium cattleianum*) along the Nu‘alolo, Awa‘awapuhi, and ‘Ōhelo Berry Flats trails, Kōke‘e State Park, Kaua‘i, and under slash pines at Kamakou, Moloka‘i.

SPECIMENS EXAMINED: Hawai‘i Island: MacKenzie Park, scattered in duff under *Casuarina equisetifolia*, 7 December 1993, DEH 342; same location and habitat, 27 February 1996, DEH 1032; same location and habitat,

28 September 2000, DEH 1999; same location and habitat, 14 November 2001, DEH 2189; same location and habitat, 22 January 2002, DEH 2246; same location and habitat, 11 January 2005, DEH 2551; same location and habitat, 6 October 2005, DEH 2592 (holotype: SFSU); same location and habitat, 29 October 2005, DEH 2600; same location and habitat, 13 December 2005, DEH 2609; same location and habitat, 7 December 2006, DEH 2661; same location and habitat, 9 January 2007, DEH 2674; same location and habitat, 8 November 2007, DEH 2719; same location and habitat, 2 February 2008, DEH 2753. Kaua‘i: Kōke‘e, Nu‘alolo Trail, scattered on ground in leaves under *Acacia koa* and *Psidium cattleianum*, 7 January 1994, DEH 358; same location and habitat, 8 January 1996, DEH 959 and D. E. Desjardin 6365; same location and habitat, 4 January 1995, DEH 690; same location and habitat, 7 January 1997, DEH 1423; Kōke‘e, Awa‘awapuhi Trail, 5 January 2008, DEH 2747; Mākaha Ridge Trail, scattered on ground under *Eucalyptus*, 6 January 1997, DEH 1413. Moloka‘i: Kamakou Forest Preserve, scattered on ground in duff under *Pinus*, 2 January 1996, DEH 988.

ETYMOLOGY: *Reticulatum*, referring to the widely spread reticulate network of raised hairs on the surface of the unexpanded basidiome.

NOTES: *Geastrum reticulatum* is one of the larger earthstars found in Hawai‘i (endoperidia average 22 mm diam.) and is distinguished by onion-shaped, brown to orangish brown primordia with a raised, reticulate network of hairs on the outer surface that gives the species epithet. The saccate endoperidium features a conical, plicate peristome. This species is easily distinguished from *G. litchiforme*, *G. fimbriatum*, and *G. triplex*, which are of comparable size, because the latter three species have fibrillose-fimbriate peristomes. The rays of *G. reticulatum* break near their base, forming a collar or cup around the endoperidium, much like in *G. litchiforme* and *G. triplex*. *Geastrum morgani* is similar to *G. reticulatum* in forming onion-shaped unexpanded basidiomes with a prominent umbo, but differs in other macromorphological features. *Geastrum morgani* differs in forming

reddish brown unexpanded basidiomes that lack the reticulated pattern of raised hairs on the surface, and the peristome is formed from folds rather than distinct plications. *Geastrum setiferum* Baseia is also similar in overall morphology but differs in forming globose unexpanded basidiomes with squamose (not reticulate) exoperidial surface, a setose endoperidium, fibrillose to sulcate peristome, and smaller basidiospores (2.5–3 µm diam. [Baseia and Milanez 2002]). Hemmes and Desjardin (2002) reported *G. reticulatum* (as *Geastrum* aff. *morganii*) from under karakanut (*Corynocarpus laevigatus*), koa, and 'ōhi'a (*Metrosideros polymorpha*) along the Nu'alolo Trail at Kōke'e State Park on Kaua'i.

13. *Geastrum rufescens* Pers., Syn. Meth. Fung. (Göttingen) 1:134, 1801.

DESCRIPTIONS: Sunhede (1989), Pegler et al. (1995), Calonge (1998).

SPECIMENS EXAMINED: Hawai'i Island: Hilo, bayfront, clustered in composted wood chips under monkeypod trees, *Pithecellobium saman*, 6 December 2001, DEH 2203; same location and habitat, 10 December 2001, DEH 2210; same location and habitat, 15 December 2001, DEH 2214; same location and habitat, 28 August 2002, DEH 2305; same location and habitat, 14 September 2002, DEH 2324.

NOTES: Unexpanded fruiting bodies of *Geastrum rufescens* are globose, somewhat hypogeous, have little encrusting litter on the surface, and appear in coalescent clusters. Expanded fruiting bodies are distinguished by the pink to reddish brown color of the pseudoparenchymatous layer of the extended rays, and an indistinctly delimited, fibrillose-fimbriate peristome on an endoperidial body with a short pedicel (best observed when the pseudoparenchymatous layer has dried). This species is superficially similar to *G. fimbriatum*, but the reddish pseudoparenchymatous layer of *G. rufescens* and its habit of growing in coalescing clusters is distinctive. In addition, the endoperidial body of *G. fimbriatum* is sessile, and the basidiospores are smaller (3.5–4 µm diam. versus 5–6 µm diam. in *G. rufescens*). *Geastrum rufescens* has been collected only in

composted wood chips at the bayfront in Hilo on Hawai'i Island.

14. *Geastrum saccatum* Fr., Syst. Mycol. 3:16, 1829.

DESCRIPTIONS: Sunhede (1989), Calonge (1998).

SPECIMENS EXAMINED: Hawai'i Island: MacKenzie Park, in duff under *Casuarina*, 14 December 2007, DEH 2734; Pu'u Lā'au, scattered in soil under *Sophora-Myoporum*, 26 August 1997, DEH 1518; same location and habitat, scattered in soil, 21 October 1997, DEH 1569; Waipi'o Valley, scattered in black sand in dunes under *Casuarina equisetifolia*, 12 November 2001, DEH 2181; same location and habitat, 3 September 2002, DEH 2315; same location and habitat, 8 July 2006, DEH 2619. Kaua'i: Kukuilono Park, Kalāheo, under *Eucalyptus*, 3 January 2008, DEH 2743. O'ahu: Keolu Hills, Kailua, scattered in soil under koa haole, *Leucaena leucocephala*, 26 March 2002, DEH 2256; same location and habitat, 10 September 2002, DEH 2335; same location and habitat, 5 March 2003, DEH 2375; same location and habitat, 12 July 2004, DEH 2494; same location and habitat, 5 August 2004, DEH 2497 and 2498.

NOTES: Unexpanded basidiomes of *Geastrum saccatum* are small to medium sized, onion-shaped, epigeous, and have no encrusting debris. The well-delimited fibrillose peristome, nonhygroscopic rays, and sessile, saccate endoperidium are diagnostic. Basidiomes are found in the dry māmane-naio (*Sophora-Myoporum*) forests on the leeward side of Mauna Kea, in windward haole koa thickets (*Leucaena leucocephala*) on O'ahu, and in sand dunes along the windward coasts of Hawai'i Island under ironwood (*Casuarina equisetifolia*). Tiny specimens of *G. saccatum* with endoperidia averaging only 2–6 mm in diameter were found at Keolu Hills, Kailua, O'ahu, after heavy rain. The unexpanded primordia of these specimens appeared to have been disturbed by erosion and then developed when still at a small size. The species was reported from O'ahu by Smith and Ponce de Leon (1982) and from Hawai'i Island by Gilbertson et al. (2001).

15. *Geastrum schmidelii* Vittad., Monograph Lyc.: 12, 1842.

DESCRIPTIONS: Sunhede (1989), Pegler et al. (1995).

SPECIMENS EXAMINED: Hawai'i Island: Puakō, scattered in encrusted leaf and twig debris under coastal kiawe, *Prosopis pallida*, 24 February 2007, DEH 2687; same location and habitat, 19 March 2007, DEH 2690; same location and habitat, 22 December 2007, DEH 2731; same location and habitat, 2 February 2009, DEH 2790; same location and habitat, 19 February 2009, DEH 2795. Lana'i: Shipwreck Beach, scattered in encrusted leaf and twig debris under coastal kiawe, *Prosopis pallida*, 27 December 2009, DEH 2808.

NOTES: Basidiomes of *G. schmidelii* are initially hypogeous, encrusted with debris, and expand to small fruiting bodies 20–37 mm in diameter with 6–9 arched rays. The endoperidia are stalked, finely pruinose when fresh to glabrous in age, and range from 6 to 14 mm in diameter (avg. 8.8 mm; 36 specimens). An apophysis is present on some endoperidia but not on others, and the peristome is plicate with no obvious delimitation at the edge. This species is found near the shoreline in sandy leaf litter under coastal kiawe (*Prosopis pallida*). This is the first report of *G. schmidelii* from the Hawaiian Islands.

16. *Geastrum striatum* DC, in Lamarck & de Candolle, Fl. Franç., ed. 3 (Paris) 2:267, 1805.

DESCRIPTIONS: Sunhede (1989), Calonge (1998).

SPECIMENS EXAMINED: O'ahu: Keolu Hills, scattered under haole koa, *Leucaena leucocephala*, 4 December 2003, DEH 2446; same location and habitat, 6 January 2004, DEH 2480; same location and habitat, 12 September 2004, DEH 2492; same location and habitat, 5 August 2004, DEH 2499 and 2500.

NOTES: Unexpanded basidiomes of *Geastrum striatum* are mostly hypogeous and encrusted with adhering debris. The endoperidium of expanded basidiomes is covered with a whitish layer of crystalline material overlaying a bluish surface color, has a conical, strongly plicate peristome, and is prominently

stalked with a distinct apophysis that forms a ringlike collar. *Geastrum pectinatum* is a similar species, but the latter has folds or plications on the apophysis and lacks the distinctive collar. *Geastrum striatum* grows under haole koa (*Leucaena*) at Keolu Hills on the windward side of O'ahu, in the same habitat as *G. saccatum*. This is the first report of *G. striatum* from the Hawaiian Islands.

17. *Geastrum triplex* Jungh., Tijdschr. Nat. Gesch. Physiol. 7:287, 1840.

DESCRIPTIONS: Sunhede (1989), Pegler et al. (1995), Calonge (1998).

SPECIMENS EXAMINED: Hawai'i Island: Keaukaha, scattered in leaf mulch, 27 June 2003, DEH 2424; same location and habitat, 14 August 2003, DEH 2429; same location and habitat, 25 April 2004, DEH 2480; same location and habitat, 28 November 2004, DEH 2538; same location and habitat, 9 August 2005, DEH 2561; same location and habitat, 13 September 2005, DEH 2576; same location and habitat, 25 September 2006, DEH 2626; same location and habitat, 6 October 2006, DEH 2634; Kīpuka Kī, scattered in leaf mulch, 14 March 2007, DEH 2686; MacKenzie Park, scattered in duff of *Casuarina equisetifolia*, 27 October 2004, DEH 2530; same location and habitat, 4 December 2004, DEH 2542; same location and habitat, 11 January 2005, DEH 2546; same location and habitat, 11 January 2005, DEH 2548; same location and habitat, 15 September 2005, DEH 2582; same location and habitat, 29 October 2005, DEH 2602; same location and habitat, 7 December 2006, DEH 2659; same location and habitat, 7 December 2006, DEH 2660; same location and habitat, 2 February 2008, DEH 2754; MacKenzie Park, scattered under coconut, 3 October 2006, DEH 2629; Pu'u Huluhulu, scattered in deep soil and leaf mulch under *Acacia koa*, 12 October 1998, DEH 1733; same location and habitat, 11 November 2000, DEH 2024; same location and habitat, 26 November 2000, DEH 2033; same location and habitat, 20 November 2003, DEH 2444; same location and habitat, 12 December 2003, DEH 2453; same location and habitat, 27

September 2005, DEH 2591; University of Hawai'i, Hilo, Agriculture farm, scattered to clustered in wood chips, 17 November 2004, DEH 2537. Moloka'i: Halawa Valley, scattered in leaf mulch under black wattle (*Acacia mearnsii*) and Christmas berry (*Schinus terebinthifolia*), 4 January 2007, DEH 2668. O'ahu: Wahiawā Botanical Garden, scattered in leaf mulch, 24 November 2002, DEH 2354.

NOTES: *Geastrum triplex* can be locally abundant under coastal *Casuarina* and coastal coconut groves, and in alien wet windward forests. The unexpanded fruiting bodies are onion-shaped, epigeous, lack adhering debris, and are usually covered with small brown, felted scales that help distinguish this species from morphologically similar taxa. The endoperidia have an acute fibrillose peristome that is usually delimited by a lighter color. There is a wide range in basidiome size of various populations of *G. triplex*, with some populations forming large endoperidia averaging 21.6 mm in diameter (50 specimens) and other populations with small endoperidia averaging 13.9 mm in diameter (50 specimens). For a comparison with *G. litchiforme*, see the Notes for that species.

Smith and Ponce de Leon (1982) reported *Geastrum indicum* (Klotsch) Rauchert from Kaua'i, Maui, and Ni'ihau. Sunhede (1989) provided an extensive nomenclatural discussion of *G. indicum* and considered the epithet a nomen dubium. We accept the material reported as *G. indicum* from the Hawaiian Islands to represent *G. triplex*, making this species the most common and widespread earthstar in the archipelago.

18. *Geastrum velutinum* Morgan, J. Cincinnati Soc. Nat. Hist. 18:38, 1895.

DESCRIPTIONS: Lloyd 1902, Hemmes and Desjardin 2002.

SPECIMENS EXAMINED: Hawai'i Island: Kīpuka at 21.0 mile marker, Saddle Road, clustered under *Acacia koa*, 2 January 1998, DEH 1793; Kīpuka Puauulu, Hawai'i Volcanoes National Park, on ground under *Acacia koa*, 28 October 2000, DEH 1998. Kaua'i: Kōke'e, Nu'alolo Trail, in clusters under *Acacia*

koa, 8 January 1996, DEH 961 and D. E. Desjardin 6366; Kōke'e, Awa'awapuhi Trail, scattered under *Acacia koa*, 6 January 2008, DEH 2779; Mākaha Ridge Road, in clusters under *Acacia koa*, 10 January 1996, DEH 972.

NOTES: *Geastrum velutinum* has been found along the Nu'alolo and Awa'awapuhi trails at Kōke'e, Kaua'i, and in high-elevation kīpukas on the Big Island. This species is associated with mixed native-alien forests dominated by koa (*Acacia koa*) and has been found only at higher elevations, approximately 1,000–1,500 m. The very dark brown to nearly black, velutinous exoperidium covering unexpanded, epigeous basidiomes, and fibrillose peristome that is well delimited by a dark ring are diagnostic features. *Geastrum velutinum* was first reported from Hawai'i by Hemmes and Desjardin (2002), and our material matches quite nicely that from Samoa reported by Lloyd (1902).

19. *Geastrum xerophilum* Long ex Desjardin, n. sp.

"*Geaster xerophilus*" Long, Mycologia 34:13, 1942, nom. inval.

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Long (1942) described *Geaster xerophilus* without Latin diagnosis, constituting an invalid binomial (Art. 36.1). The epithet is validated herein with inclusion of a Latin diagnosis, reference to an original description in Long's (1942) protologue, and citation of a holotype specimen and its place of deposition (Arts. 36, 37, 45).

LATIN DESCRIPTION: Basidiomata juvencula hypogaeum, nonfornicatum, ad clausum subglobulare vel depresso globulare, 10–20 mm latum. Exoperidium apertum 10–40 mm latum in 7–12 radios acutos, recurvos fissum; stratum myceliale arena adhaerens; stratum pseudoparenchymaticum bubalinum vel cinnamomeum. Endoperidium sessile vel pedicellate, subglobulare vel depresso globulare, 10–20 mm latum, saccatum, furfuraceum, bubalinum vel pallide-griseum. Peristomium nondelimitatum, sulcatum. Gleba brunnea. Basidiosporae globulare, 4.5–5.5 μm latae, verrucosae, brunnea.

TYPE MATERIAL: Holotype: New Mexico, Dona Ana County, Joranada Experimental Range, 12 November 1938, collected by W. H. Long, no. 8285 (BPI 731707!). This is the specimen indicated by Long (1942) as the type specimen, viz., “8 plants no. 8285 Type.”

DESCRIPTIONS: Long (1942), Ponce de Leon (1968).

SPECIMENS EXAMINED: Hawai‘i: Pu‘u Lā‘au, scattered under *Sophora-Myoporum*, 21 October 1997, DEH 1567; same location and habitat, 21 October 1997, DEH 1604; same location and habitat, 23 November 1998, DEH 1753; same location and habitat, 23 November 1998, DEH 1755; Saddle Road on Kona side of Mauna Kea access road, 6,000 ft. [1,800 m] elev., scattered in soil under *Sophora-Myoporum*, 30 January 1996, DEH 1030. O‘ahu: Keolu Hills, scattered in soil under *Leucaena leucocephala*, 5 August 2004, DEH 2502.

NOTES: *Geastrum xerophilum* is one of two species from the māmane-naio habitat with a sulcate peristome, along with *G. campestre*. *Geastrum campestre* is a strongly hygroscopic species, whereas *G. xerophilum* is nonhygroscopic. *Geastrum xerophilum* was reported from O‘ahu by Smith and Ponce de Leon (1982) and from māmane-naio habitat on Hawai‘i Island by Gilbertson et al. (2001).

Long (1942) published the species without Latin diagnosis and it was not validated by Ponce de Leon (1968) in his revision of the genus *Geastrum*. This well-circumscribed species of xerophytic habitats is formally validated herein. Ponce de Leon (1968) accepted *Geastrum pluriosteus* Long & Stouffer as a synonym of *G. xerophilum*, and the latter species was validly published with Latin diagnosis in 1948, giving it potential priority over the invalid *Geastrum xerophilum*. We do not accept these two taxa as conspecific. *Geastrum pluriosteuum* (orthographic error corrected) differs in forming sessile endoperidia lacking a pedicel, has fewer rays (only 5–6 per basidiome), larger basidiospores (5.5–7 μm diam.), and 1–3 poorly differentiated, apparently non-sulcate peristomes per basidiome (Long and Stouffer 1948).

20. *Myriostoma coliforme* (With.: Pers.) Corda, Anleit. Stud. Mykol., Prag: 131, 1842.

DESCRIPTIONS: Sunhede (1989), Pegler et al. (1995), Calonge (1998).

SPECIMENS EXAMINED: Hawai‘i Island: Kalōpā Park, scattered in leaf mulch, 13 December 2007, DEH 2737; Kilohana, scattered in soil, 2 July 1996, DEH 1144; Manukā Natural Area Reserve, scattered in leaves under *Metrosideros polymorpha*, 20 January 2000, DEH 1931; same location and habitat, 12 September 2000, DEH 1987; Manukā Wayside Park, scattered in leaves under alien trees, 9 November 1999, DEH 1858; same location and habitat, 15 December 1999, DEH 1881; same location and habitat, 12 September 2000, DEH 1986; same location and habitat, 3 July 2004, DEH 2490; Pu‘u Lā‘au, scattered in soil under naio, 24 September 1996, DEH 1255; Pu‘u Lā‘au, scattered in dirt, 23 September 1997, DEH 1537; Pu‘u Lā‘au Cabin, scattered in powdery soil in shade of māmane and naio, 26 August 1997, DEH 1516; Pu‘u Huluhulu, scattered in leaves under *Acacia koa*, 12 October 1998, DEH 1732; same location and habitat, 22 November 1998, DEH 1751; same location and habitat, 31 December 2003, DEH 2456; same location and habitat, 13 September 2005, DEH 2575; Saddle Road near Mauna Kea State Park, scattered in soil under māmane and naio, no date, DEH 1382; Saddle Road at 31 km marker, scattered in soil, 20 August 1996, B. A. Perry 059. Lana‘i: Kō‘ele, scattered in duff under *Cupressus*, 6 January 2007, DEH 2673.

NOTES: *Myriostoma coliforme* is readily identified because of the numerous stomata in the endoperidium that is elevated above the rays by several stalks. The species can be found under māmane-naio on the dry leeward slopes of Mauna Kea and is frequently found at Manukā Wayside Park on the Kona side of Hawai‘i Island under a number of alien trees in the arboretum and in the adjacent dry ‘ōhi‘a forest. The species was reported from māmane-naio habitat on Hawai‘i Island by Smith and Ponce de Leon (1982) and Gilbertson et al. (2001).

DISCUSSION

The substantial number of *Geastrum* species reported herein from the Hawaiian Islands is undoubtedly due to the wide range of habitats on each island, ranging from wet windward vegetation zones with an excess of 500 cm of rain annually, to dry leeward regions with as little as 20 cm of annual precipitation. Many species, such as *G. berkeleyi* and *G. triplex*, can be found in a variety of habitats including the duff under coastal *Casuarina*, under *Cupressus lusitanica*, and in leaf mulch in *Psidium cattleianum* thickets. In comparison, *G. schmidelii* has a preferred habitat in the duff under leeward kiawe (*Prosopis pallida*) groves both at Puakō on Hawai'i Island and at Shipwreck Beach on Lāna'i, and *G. velutinum* has been found exclusively at high elevations (1,000–1,500 m) at Kōke'e on Kaua'i and in kīpukas on Hawai'i Island in native forests dominated by *Acacia koa*. Several species are associated mainly with dry upland native māmane-naio habitat (Gilbertson et al. 2001).

All of the *Geastrum* species reported by Smith and Ponce de Leon (1982 [with clarification below]) were recollected, and nine additional species are added to the checklist of species from the Hawaiian Islands. Although Smith and Ponce de Leon (1982) reported *G. quadrifidum*, we have verified that their material represents *G. fornicatum*, which is relatively common in drier montane and leeward areas. Also, *G. indicum*, as listed by Smith and Ponce de Leon (1982), is considered a nomen dubium, and the correct designation for this taxon is *G. triplex*.

The newly described *Geastrum reticulatum* is widespread from coastal *Casuarina* on the Big Island at MacKenzie Park to the Kōke'e region of Kaua'i, where this species is found associated with koa trees. Unfortunately, we have not encountered *G. reticulatum* on any of the islands in between. *Geastrum litcbiforme* has been collected only at MacKenzie Park on Hawai'i Island associated with coastal *Casuarina*, although we have seen a photograph of a taxon from the Judd Trail on O'ahu that may represent this new species. The habitats of both of these newly described species are heavily disturbed by feral pigs.

Species determinations in this paper were based entirely on morphological characters. DNA sequence data have shown that the genus *Geastrum* belongs to the Geastrales in the Phallomycetidae (Hosaka et al. 2007). Sequencing of the worldwide *Geastrum* species, including those from Hawai'i, is currently under way (Kentaro Hosaka, National Museum of Nature and Science, Ibaraki, Japan) and should help elucidate the relationships of the various species.

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