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Multiple records of monoecy and leakiness in dioecious taxa of Hawaiian *Coprosma* spp. (Rubiaceae)[1]

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The breeding systems of the 110+ species of *Coprosma* J.R. Forst. & G. Forst. across the Pacific are largely considered dioecious, with male and female flowers occurring on separate plants (Oliver 1935). However, for many species, particularly of New Zealand, the dioecious breeding system is leaky. *Coprosma* species exhibiting leaky dioecy are primarily dioecious, with male and female flowers on separate plants, but individuals occasionally develop apparently functional bisexual flowers, which sporadically occur among an abundance of unisexual flowers. A putative monoecious *Coprosma* taxon was once reported for the Macquarie Island individuals of *C. perpusilla* Colenso (= *C. pumila* Hook.f.), but later dispelled as being dioecious (Lloyd & Horning 1979).

In March 2016, the first author of this paper embarked on an archipelago-wide trip of the Hawaiian Islands aiming to collect and observe multiple populations of all endemic Hawaiian species of *Coprosma* (Rubiaceae). As a result, four confirmed cases of monoecious individuals were documented for Hawaiian *Coprosma* for the first time. Three additional instances may represent either monoecious or leaky dioecious observations. The collection results are detailed below. All specimens are deposited at BISH and duplicates were either sent to PTBG or US herbaria. Figure 1 depicts photos of monoecious individuals collected in the field.

Confirmed Cases of Monoecious Individuals

Confirmation of monoecy occurred if both male and female flowers were observed on the same plant at the same time. Collections were made where possible.

Coprosma ochracea W.R.B. Oliv., Mt. Ka'ala Bog, O'ahu.
One 2 m tall individual of *C. ochracea* was observed in the Mt. Ka'ala Bog on March 10, 2016. The plant was fully exposed in light and had a few female flowers. Flowers otherwise were male. Apparently, each inflorescence on terminal branches were of one sex. No inflorescence included male and female flowers in the same inflorescence. At least 30 other individuals were observed along the boardwalk of the bog without noting further monoecious individuals.

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Figure 1. Photos of monoecious *Coprosma* taxa. **A**) *C. montana* in Haleakalā Crater, Maui, showing immature fruit (right) and male flower with anthers not yet fully exserted (left). **B**) *C. waimeae* showing immature green fruit (left) and male flowers (right). **C**) Monoecious individual of *C.* aff. *pubens* 'B' from Munro Trail Lāna'i. **D**) *C. menziesii* showing dimorphic female (upper left) and male (lower right) branches. **E**) Closer view of old male inflorescences with orange fleshy receptacle tissue. **F**) Monoecious branch of *C.* aff. *pubens* 'A' from Waihe'e Trail, West Maui.

Material examined. **O'AHU**: Wai'anae Mountains, Mt. Ka'ala Bog, individual growing along boardwalk, 10 March 2016, *J.T. Cantley JC-1077*.

Coprosma menziesii A. Gray, Hawai'i Volcanoes National Park, Hawai'i Island.
One monoecious individual was noted on 8 March 2016 along Chain of Craters Road just downslope of Pauahi Crater. The shrub was around 2.5 m tall, and had male and female flowers on separate branches of the plant. Two main branches with nearly a 5 cm diameter separated the male portion of the plant from the female portion. Differently-sexed branches varied vegetatively in the number and distribution of leaves. The male branch was much more foliose, whereas the female branch had fewer, more loosely-arranged leaves, with fruits conspicuously presented on peduncles hanging below the leaves. Curiously, the basal receptacle area of each male flower developed a fleshy orange tissue similar to female fruit tissue in color, but much smaller than fully-developed fruits borne from the female portion of the plant (2–4 mm wide vs. 8–12 mm wide). It was not determined if aborted ovules were present in this tissue. Approximately 30–50 individual plants were observed in the vicinity of Pauahi Crater along Chain of Craters Road without noting further instances of monoecious individuals.

Material examined. **HAWAI'I**: Hawai'i Volcanoes National Park, individual growing along Chain of Craters Road near Pauahi Crater, 8 March 2016, *J.T. Cantley JC-1066*.

Coprosma aff. ***pubens*** A. Gray 'A', Waiheʻe Trail, Maui.
One individual monoecious plant was collected from a tree greater than 3 m in height growing in an exposed gully with an understory of *Dicranopteris linearis* (Burm.f.) Underw. and co-occurring with *Metrosideros polymorpha* Gaudich. and *Psychotria* sp. on 5 March 2016. Male and female flowers were found on the same main branch, but terminal branches maintained unisexual inflorescences. Fewer than 10 individuals were observed in this population, but not thoroughly looked for, due to time constraints. At least one individual was completely female, but the remaining were in bud or lacking reproductive parts.

Material examined. **MAUI**: Waiheʻe Trail, West Maui, individual growing in exposed gulch, 5 March 2016, *J.T. Cantley JC-1054*.

Coprosma aff. ***pubens*** A. Gray 'B', Munro Trail, Lānaʻi.
One monoecious individual of this taxon, which shares morphological affinities with *C. pubens*, was noticed along the roadside of the Munro Trail on Lānaʻi. The tree was only around 0.8 m tall, but otherwise shared similar morphological features with *C.* aff. *pubens* 'A'. No other cases of monoecy were observed for the less than 10 other individuals of this taxon observed during the survey.

Material examined. **LĀNAʻI**: Munro Trail Road near Lānaʻihale summit, individual growing just off the road with 25% canopy exposure, 8 March 2016, *J.T. Cantley JC-1055*.

Unconfirmed Cases of Either Monoecy or Bisexually-Facilitated Leaky Dioecy
The four individuals described below may be cases of either monoecious (unisexual) or leaky dioecious (bisexual) flowers, but without the presence of floral parts, it was not possible to determine if the fruits found on each plant were borne from female or bisexual flowers.

Coprosma waimeae Wawra, Mōhihi Trail, Kauaʻi.
One individual of *C. waimeae* was observed along an exposed cliff ridgeline with many male flowers and many immature green fruits.

Material examined. **KAUAʻI**: Mōhihi Trail, individual growing on exposed ridge in a *Dicranopteris linearis* understory, 16 March 2016, *J.T. Cantley JC-1103*.

Coprosma montana Hillebr. (no collection); Haleakalā Crater, near Palikū Cabin, Maui.
An observation in July 2013 documented a male plant with an immature green fruit along the hiking trail leading to Palikū Cabin. The first author's photos document that the fruit was likely not in the same inflorescence as other male flowers, but rather very closely situated to a male inflorescence. The fruit occurred as the next successive inflorescence on a terminal branch approximately separated by less than 1 cm of distance.

Coprosma montana Hillebr. (no collection); Puʻu Huluhulu, Hawaiʻi Island.
Large individuals of *C. montana* occur within Puʻu Huluhulu Tree Sanctuary. In 2014, an orange fruit, smaller than typical female fruits, was observed on a male individual in a male inflorescence. Without a collection, it is not possible to tell if this 'fruit' was similar to the fleshy orange male receptacle tissue as observed for *C. menziesii*, or if the material was a properly formed fruit. Additionally, some fruit of the population were observed with four carpels (four seeds in a fruit).

Coprosma foliosa A. Gray (no collection); unknown location.
A photo exists of two bisexual flowers that are observable in two inflorescences of *C. foliosa s.l.* taxon. The image of the taxon displaying leaky dioecy is currently hosted at http://www.botany.hawaii.edu/faculty/carr/coprosma.htm.

Conclusions

The breeding system of *Coprosma* spp. in the Hawaiian Islands deserves closer investigation. On one short three-week collection trip in March 2016 to six islands, observations confirmed four cases of monoecious individuals in populations of predominately dioecious taxa. It is possible that Hawaiian taxa may also occasionally produce bisexual flowers resulting in leaky dioecious individuals like many of their New Zealand congeners, but no observation was able to directly confirm this. It is difficult not to speculate that the flexible breeding systems of *Coprosma* in the Hawaiian Islands may correlate to the ability to reproduce via geitonogamous selfing when population sizes are small (due to human degradation of habitat, colonization of a new island, or otherwise), which may help explain the fact that almost no species of *Coprosma* are endangered in the Hawaiian Islands, while so many other lineages continue to decline in number.

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