CHAPTER 7: *DROSOPHILA* SPECIES MANAGEMENT

7.1 BACKGROUND

Fourteen species of Hawaiian picture wing *Drosophila* flies are currently listed as threatened or endangered, and many more are equally rare. Six listed species are endemic to Oahu, and three – *D. montgomeryi*, *D. obatai*, and *D. substenoptera* – are currently known to occur on Army lands and are managed by the Army natural resource program on Oahu (OANRP). OANRP work on *Drosophila* began in March 2013, focusing on monitoring known populations, surveying for new ones, and restoring habitat.

After several years of poor conditions and low population of both rare and common species, winter and spring 2018 saw a return to higher numbers in wet-mesic forests not seen since 2015. Those in drier forests remained low, possibly due to a continued shortage of breeding material. Many of the host trees outplanted in previous years are now reaching the size where they can support *Drosophila* breeding.

The endangered damselfly *Megalagrion xanthomelas* is also currently being managed. Its sole Oahu population is monitored monthly and has been stable for approximately 20 years. Efforts to reintroduce it to another site are ongoing and we expect to report on results next year.

7.2 SURVEY METHODS

Many species of Hawaiian *Drosophila*, including the picture wing group to which all of the endangered species belong, are readily attracted to baits of fermented banana and mushrooms. Both baits are spread on a cellulose sponge which is hung from a tree in a cool, shaded, sheltered site, and checked for flies after about one hour. Depending on the quality of the site (number and size of host plants, and microclimate) and the density of baiting spots, surveys typically consist of setting out 16–24 sponges, in groups of 4 or 8 with groups separated by 20–100 m. Baits are checked at least every hour, as flies do not necessarily stay at baits for long periods; number and species of all picture wings on each sponge are recorded at each check. The greatest activity is typically during the cooler hours before 10 AM and after 2 PM, but flies may appear at any time. Direct quantification of *Drosophila* populations is difficult, since populations may fluctuate not only seasonally but from day to day. However, repeated surveys can yield useful data on long-term trends. Abundance numbers are reported as the maximum number of individuals observed on a survey day (compiled by adding the maximum observed at each discrete group of bait sponges at any one time, assuming that the same individual flies may move between sponges within a group but are unlikely to be seen at two different groups), since numbers fluctuate through the day.

Known, significant populations of *D. montgomeryi* at Kaluaa Management Unit (MU) and *D. substenoptera* at Palikea MU, where flies occur relatively consistently, are monitored monthly in order to determine approximate population trends through the year. For *D. montgomeryi*, Pualii (designated as a management site for *D. montgomeryi*) and Waianae Kai (not a managed population, but the largest known population) were designated to be monitored quarterly; however, due to apparent loss of the population at Pualii due to a demographic gap in the host plant, and higher priorities elsewhere, only one monitoring visit was made there this year (see below for other actions). Other known populations (Kaala and Lower Opaeula for *D. substenoptera*, Lihue and Manuwai for *D. obatai*) are visited periodically through the year, typically quarterly or less. New populations of endangered *Drosophila* were searched for by looking in similar habitat both in areas suggested by other staff as having host plants, at historic collecting localities, and in new sites where surveys have been minimal. Numbers of *Vespula pensylvanica* (western yellowjacket), a potentially serious invasive predator, are monitored at Palikea and Puu Hapapa with 10 traps at each site baited with heptyl butyrate and checked monthly.

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Figure 1. Distribution of *Drosophila montgomeryi* observations in the 2017-18 reporting year (including sites where it was previously found) and earlier records from 2009-17, with known *Urera* spp. sites and all survey points in the Waianae range. Labels indicate major *Drosophila* survey areas.

7.3 RESULTS

7.3.1 *Drosophila montgomeryi*

Drosophila montgomeryi is a small yellow-brown species that breeds in rotting bark of *Urera kaalae* and *Urera glabra* (opuhe). While *Urera glabra* occurs widely across the Waianae range, it often occurs as scattered clumps of one or a few individuals, unsuited for survival of *D. montgomeryi* and probably not viable for long-term survival of this dioecious, wind-pollinated tree. *Urera kaalae* is critically endangered and only a handful of wild plants remain, although several hundred have been outplanted. *Drosophila montgomeryi* is currently known from ten sites that are regarded as five population units (PUs) (discussed individually below, except Lihue), effectively covering nearly its entire historic range in the Waianae Mountains (Figure 1). It has not been found at the Pualii PU in over two years, and the Lihue PU has not been surveyed recently due to access issues. However, one individual was found this year at Palikea PU, two and half years after the previous sighting. Field work this year has focused on monitoring known populations rather than searching for new sites, but sites in the northwest part of the range, from Pahole west, continue to be searched (Table 1).

Kaluaa

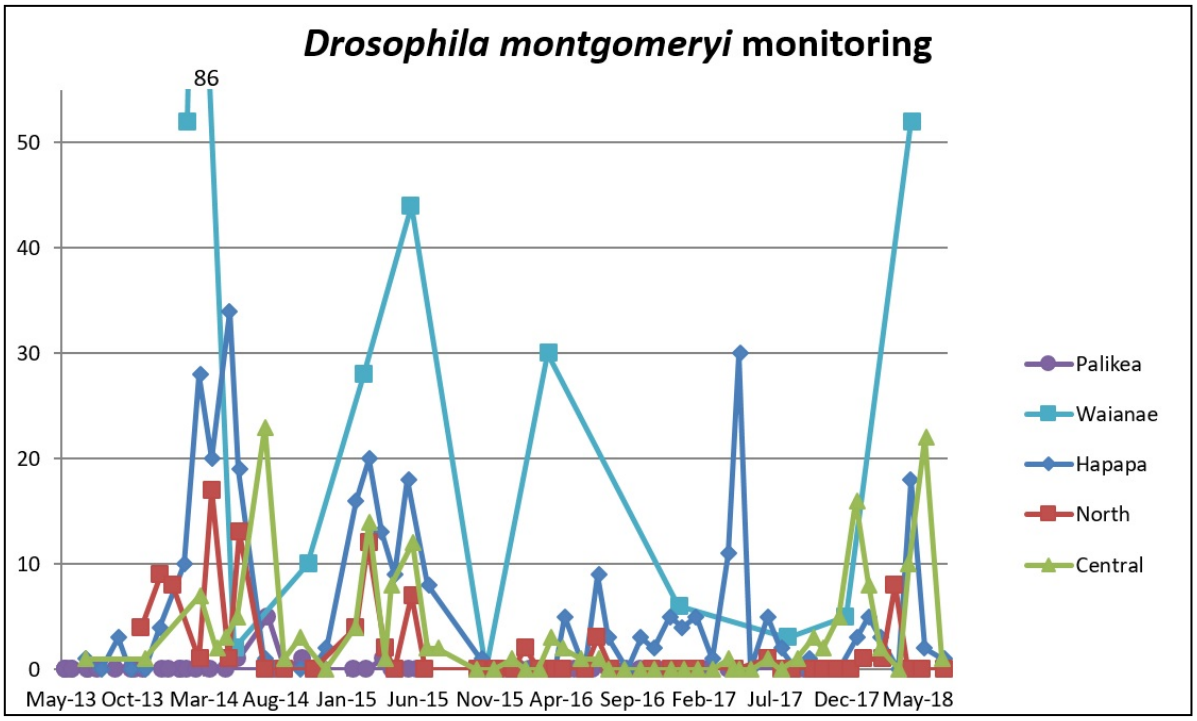

Figure 2. *Drosophila montgomeryi* numbers during monthly monitoring at three sites in Kaluaa PU (Puu Hapapa, North Kaluaa, and Central Kaluaa) and Palikea, and quarterly monitoring at Waianae. Y axis is the maximum number observed across the entire site on the survey day (see Survey Methods, section 7.2).

Three sites in this PU – Puu Hapapa, North Kaluaa, and Central Kaluaa gulch 1 – have been monitored monthly since June 2013 (though not every site was visited each month) over a total of 150 survey days. Abundance of *D. montgomeryi* generally follows a distinct seasonal pattern, increasing dramatically over the winter months to a peak between January and May, more or less in synchrony with several common *Drosophila* species (Figure 2). This is most likely due to increased rain and treefalls from storms that cause death or branch breakage of *Urera* near monitoring sites. During 2015-16 and again in the 2016-17 sampling season, there was no such winter pulse in *D. montgomeryi*, with only relatively few scattered individuals aside from a brief late spring spike at Puu Hapapa in 2017.

Table 1. Survey effort for *D. montgomeryi* across all potential sites in 2017-18 reporting period, in survey days. "Max No." is the highest number of flies observed in a single day.

Site	Days	Max No.
Kaluaa - Central	12	22
Kaluaa - North	12	8
Puu Hapapa	12	18
Palikea	13	1
Waianae	3	52
Pualii	1	0
Makaha	1	0
Kahanahaiki	1	0

Pualii PU

This site was visited for the first time in 2014, and quarterly monitoring began in 2015. At the time of the first visit, the last wild *Urera kaalae* tree in North Pualii Gulch had recently fallen and the decaying trunk was supporting a large number of *D. montgomeryi*. Unfortunately, the fly has not been seen since the second visit there, and the survival of this population is uncertain. Only one of the original *U. kaalae* outplants remains, but at least 10 natural offspring of these plants have grown up, and several have now reached substantial height. This appears to be the only site where outplanted trees of this species are successfully recruiting. There are no *U. glabra* aside from recent outplants, which have not grown as much as those at other sites. Nevertheless, it is an area of high-quality native habitat, both in the immediate vicinity and further

downslope in the gulch, where light gaps provide better outplanting spots. It may be a potential *D. montgomeryi* reintroduction site after additional host plant restoration.

In July 2016, big-headed ants (*Pheidole megacephala*) were found in the lower portion of the fenced unit around the recent *Urera kaalae* outplantings. Although present in the gulch well below the fence, they had not previously been noted at this site, and would be a threat to *Drosophila* there. Over the past year, ant control has been successfully implemented, first across the entire population and then targeting remnants. Currently only one small patch of *Pheidole* remains in the gulch bottom above the fence.

Palikea

Despite continuous monitoring here since May 2013 (targeting *D. substenoptera*, which is consistently found in the area), *D. montgomeryi* was not detected until May 2014. Four of the five records here have been of single individuals, indicating that the population remains low. After a year of occasional sightings it disappeared, possibly due in part to drying of the site from canopy clearing needed to allow the plants to thrive; survival and growth of *Urera* are dramatically reduced under alien canopy. However, there are other patches of *Urera* around the Palikea MU that may also harbor small or transient populations of *D. montgomeryi*. The area where they were found is already a target for weed management and restoration, and has high potential for management to benefit *D. montgomeryi*. *Urera glabra* had already begun to increase naturally as weed control reduced alien cover, and outplanting has significantly boosted the

Figure 3. Habitat restoration for *D. montgomeryi* at Palikea. The photos in each column were taken from the same viewpoint on opposite ends of a clearing where invasive plants had been removed (October 2014) and *Urera glabra* and other natives planted in February 2015. Note the large stump in the left photos and the hapuu in the right ones for reference.

population. Outplanted *U. glabra* here have done exceptionally well – many of them are 6–8 feet tall after only 18 months. *Urera kaalae* have also been planted here by Oahu PEPP, and are thriving. Weed control is ongoing as some parts of the restoration area lack canopy cover and are susceptible to heavy invasion by weeds such as *Rubus rosifolius*, *Buddleia asiatica*, and *Erechtites valerianifolia*. In October 2017, *D. montgomeryi* was resighted at the outplant site for the first time in two and a half years.

Waianae Kai

The largest known population of *D. montgomeryi* occurs in the northeastern subgulches of Kumaipo stream, Waianae Valley. Four sites have been discovered so far, all at the base of Mt. Kaala and consisting of small patches (~0.5 ha) of diverse native forest constrained by alien-dominated vegetation above and below. All are located on or just below steep slopes that are vulnerable to landslides, which may preclude fencing as a matter of practicality. The largest has been surveyed repeatedly and had a very large population of flies, but this has been severely reduced by damage from falling boulders and subsequent weed invasion over the past several years. Although still degraded from the condition it was originally discovered in, numbers of *D. montgomeryi* were found to have rebounded to their previous high level during the most recent survey (Figure 2). Much of the area further east in Hiu and Honua drainages, as well as the western half of Kumaipo, remains to be surveyed and may contain additional sites.

Habitat restoration

This was the fourth year of active habitat management for *D. montgomeryi*. Since fall 2014, approximately 300 *U. glabra* and 300 *U. kaalae* have been planted at North Kaluaa, Central Kaluaa, Pualii, and Palikea, achieving the goals set out in the 2014 three-year plan (summarized in the 2017 Year

Figure 4. Underside of a *Urera kaalae* leaf at Puu Hapapa, showing a dense covering of yellow urediniospores characteristic of heavy mamaki rust (*Pucciniastrum boehmeriae*) infection.

End Report). This year, an additional 32 *U. glabra* and 10 *U. kaalae* were planted at North Kaluaa, where a large treefall opened up a light gap and killed some of the previous *U. kaalae* outplants. All sites are exhibiting high survivorship (87–100%) and good growth, especially Kaluaa and Palikea (Figure 3), with some already at the size where they can support *D. montgomeryi* breeding. Observations of some individuals suggests that pruning of tip shoots of *U. glabra* may promote extremely vigorous growth of side branches and ultimately larger, more robust trees that will be better habitat for flies as they mature. *Urera glabra* is also being used in general restoration plantings, including in snail enclosures, that are near existing *D. montgomeryi* populations, so these may also become breeding sites. This year, 47 *U. glabra* were planted at a new restoration site at Palikea; hopefully these will eventually become breeding locations. Recent clearing of dense weed patches at Pualii and a major treefall at North Kaluaa in the past year and a half have created new outplanting opportunities, and more plants will be placed at those sites in the coming year.

In May 2016, the alien fungal pathogen mamaki rust (*Pucciniastrum boehmeriae*) was first noticed on *U. kaalae* (Figure 4), and positively identified by HDOA. Two years on, it does not appear to be causing significant effects on *U. kaalae* despite some plants having very heavy infections. While other native Urticaceae such as *Pipturus albidus* and *Boehmeria grandis* can be infected, *U. glabra* apparently is not.

7.3.2 *Drosophila substenoptera*

Surveys for this species have focused on finding new populations. Based on collection records, it requires moderately tall, non-boggy wet forest with its host plants, *Cheirodendron* spp. (olapa) and *Polyscias*

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Figure 5. Distribution of *Drosophila substenoptera* observations in the 2017-18 reporting year and earlier records from 2009-17, with selected *Cheirodendron* spp. sites and all survey points.

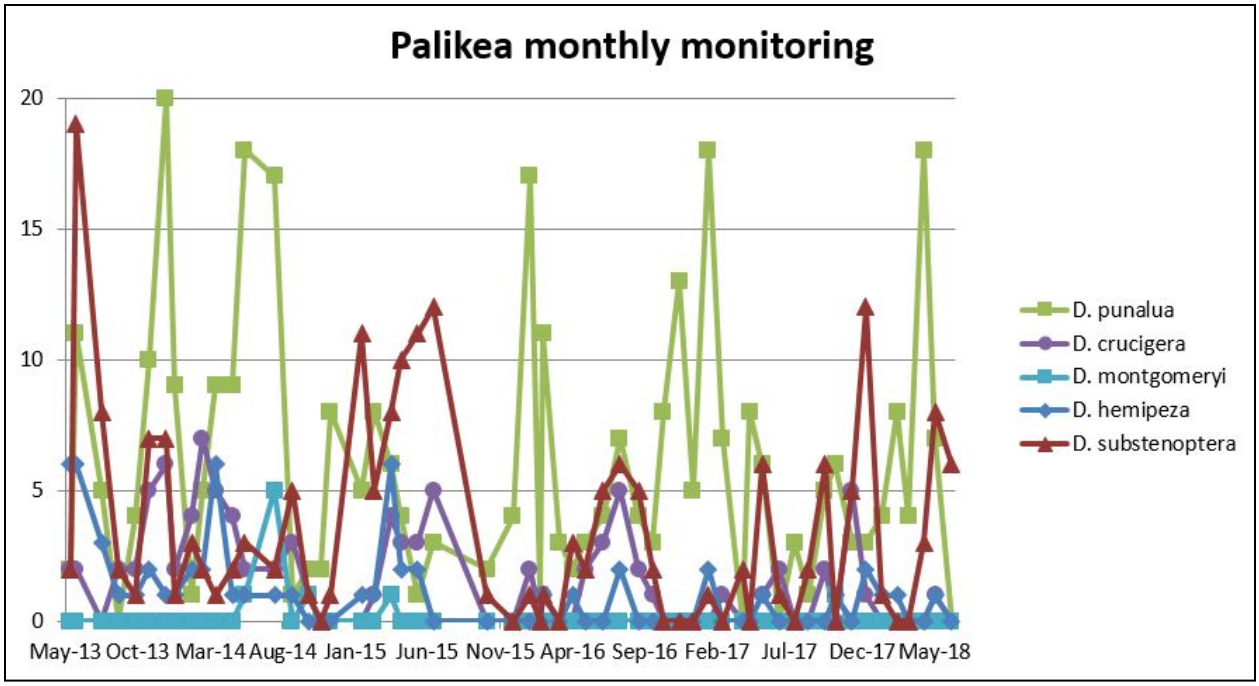

Figure 6. Monthly monitoring results for all picture-wing *Drosophila* species at Palikea, from May 2013 to June 2017.

(=*Tetraplasandra*) *oahuensis* (ohe mauka), a habitat which is relatively uncommon since these trees tend to occur most abundantly in boggy, short-stature forest near summit crestlines. Compared to other islands, *Cheirodendron* is rather uncommon on Oahu relative to available habitat, and a large proportion occurs on steep slopes or in the bottom of drainages that are weedy and difficult to access. Currently, there are three known PUs for *D. substenoptera* – Palikea, Kaala-Kalena, and Lower Opaeula (Figure 5). PU trends are only graphed for Palikea as the other two PUs have insufficient numbers of survey days. At other PUs *D. substenoptera* is highly sporadic, typically occurring as single individuals observed only once during a day. This rarity has undoubtedly hampered our ability to detect it at new sites.

Table 2. Survey effort for *D. substenoptera* and number of flies found across all potential sites in the 2017-18 reporting period, in survey days. "Max No." is the highest number of flies observed in a single day.

Site	Days	Max No.
Palikea	12	12
Kaala	3	0
Lihue	1	0
Lower Opaeula	6	0
Koloa	2	0

Waianae Range

Monthly monitoring in the northern portion of Palikea MU has been ongoing since May 2013 (57 survey days total, 12 in the current reporting period; Table 2). Aside from a large flush in late May 2013, numbers of *D. substenoptera* and another endangered species, *D. hemipeza*, have been consistently low to modest, but they have almost always been present. In contrast to *D. montgomeryi*, abundance of *D. substenoptera* tends to increase in the summer rather than winter, somewhat correlated with *D. hemipeza* and the common *D. crucigera* but not *D. punalua* (Figure 6), indicating differences in host availability. *Cheirodendron trigynum* is being used for restoration at sites across Palikea, so habitat can be expected to increase in the future. At the Kaala-Kalena PU, two sites were surveyed (Kalena summit ridge and Kaala west face). No flies were found in this area.

Koolau Range

In December 2013, a single *D. substenoptera* was observed at Opaeula Lower MU, the first record of the species in the Koolau range since 1972. In early 2015, it was sighted again in the same area. Historically, *D. substenoptera* was more widespread and abundant in the Koolaus than in the Waianae range. However, collection effort has been limited due to the difficulty in accessing areas of intact habitat for this species. OANRP survey trips in the Koolaus are now relatively few due to higher priorities elsewhere, and concentrated in only a few sites. In 2017-18, Lower Opaeula was visited three times for a total of six days; none were found. Finding additional Koolau populations is a high priority for this species; Helemano, Poamoho, and Kaukonahua have yet to be surveyed. Lower Opaeula and Koloa will continue to be checked given the extremely high quality of habitat there and low observation rate at sites where *D. substenoptera* is known to be present.

Table 3. Survey effort for *D. obatai* across all potential sites in 2017-18 reporting period, in survey days.

Site	Days	Max No.
Manuwai	6	1
Lihue – Pulee	3	0
Ohikilolo	5	0

7.3.3 *Drosophila obatai*

Drosophila obatai was rediscovered in Manuwai Gulch MU in 2011, 40 years after the previous record in 1971. It breeds in rotting stems of *Chrysodracon* (=*Pleomele*) spp. (halapepe), which suffers from very low reproduction rates but remains widespread in the northern Waianae range thanks to its longevity. *Drosophila obatai* is currently known from seven sites in four potential PUs (Makaleha, Manuwai,

Map removed to protect rare resources

Figure 7. Distribution of *Drosophila obatai* observations in the 2017-18 reporting year and earlier records from 2013-17, with known *Chrysodracon* spp. sites and all survey points in the Waianae range.

Palikea Gulch, and Pulee), although three of these are within 1,200 m of each other and could potentially form one population. While the populations were almost certainly contiguous until recently, native forest in general and *Chrysodracon* in particular is now much more fragmented, and moving between patches of host trees is more difficult for the flies. However, more *Chrysodracon* plants exist than are mapped, due to their tendency to grow on steep, difficult to access slopes.

Surveys for *D. obatai* in 2017–18 were few due to difficulty accessing SBW and Manuwai, limited survey time available, and focus on monitoring *D. montgomeryi* (Table 3). Three sites at Manuwai, two in Pulee (SBW), and one at Ohikilolo were visited; only a single *D. obatai* was seen, at Manuwai (Figure 7). The lower elevation site at Manuwai was visited for the first time since 2015 and found to be overrun by yellow crazy ants (*Anoplolepis gracilipes*), attracted by invading lobate lac scales (*Paratachardina pseudolobata*, Kerriidae) on lama trees (Figure 8). One picture wing *Drosophila* was still found there, but it is likely that the high abundance of ants has or will render this site inhospitable for *D. obatai*. The facilitation of ant invasions by other invasive insects also reveals another threat to *Drosophila* populations, which may become more significant as the scale spreads.

Between November 2017 and February 2018, A24 rat traps were set up around concentrations of *Chrysodracon halapepe* where *D. obatai* has been found. Six traps were installed at Manuwai east, seven at Guava Gulch in Pulee, and ten at Coffee Gulch in Pulee. The former was covered by the aerial rodenticide broadcast, while the latter was not (see Chapter 8). All of these sites have not had recruitment of *Chrysodracon* in many years, while older trees continue to die. Trapping will hopefully reduce rat

Figure 8. Lobate lac scale, *Paratachardina pseudolobata* Kondo & Gullan, a serious new pest of both agricultural and native plants. The thick waxy shell protects it from most predators and parasites, while the mobile nymphs (small red spots on the branch) allow for rapid dispersal.

predation on seeds and seedlings and allow them to increase. Rebaiting at Pulee has been limited due to access restrictions in SBW, but only trapping during the fruiting season is critical to success.

Chrysodracon grows extremely slowly, limiting the usefulness of outplanting as a management tool for *D. obatai*. Plants grown from seed in the wild are often under two feet tall after five years under good conditions, and may remain small seedlings after that time when suppressed by shade. The seed lab is currently working on techniques to better propagate *Chrysodracon* and store seeds.

7.3.4 Other Rare *Drosophila*

During the course of surveys, eight additional rare but non-listed *Drosophila* were found in management units where *D. montgomeryi*, *D. obatai*, and *D. substenoptera* occur (Table 4). Many of the rare species that had been found as of 2014 (*D. kinoole*, *D. paucicilia*, *D. reynoldsiae*, *D. sobrina*, *D. spaniothrix*, and *D.* n. sp. nr. *truncipenna*) were not seen this year, despite the improved conditions and overall higher insect populations.

Table 4. Non-target rare *Drosophila* observed during surveys, July 2017–June 2018

Species	Sites	Total Observed	Max. No.
D. craddockae	Lower Opaeula, Ohikilolo	7	2
D. divaricata	Kaluaa, Hapapa	31	7
D. flexipes	Manuwai	1	1
D. hemipeza	Palikea, Hapapa	6	2
D. hexachaetae	Manuwai, Waianae	3	2
D. nigribasis	Kaala	1	1
D. oahuensis	Kaala, Koloa, Lower Opaeula	10	5
D. pilimana	Manuwai	2	1

Drosophila craddockae is closely related to *D. pullipes* of Hawaii and *D. grimshawi* of Maui Nui. Like the former, it is a specialist on *Wikstroemia* spp., an unusual host for *Drosophila*. While its host is abundant, *D. craddockae* is rarely observed, and tends to be found only sporadically at widely separated localities. It was found during both trips to Ohikilolo and Lower Opaeula this year, both sites where it had been found previously.

Drosophila divaricata is closely related to the more common *D. inedita*, but can be easily distinguished by its much larger size and slightly different wing pattern. The host plant is unknown. It is generally rare, but has been observed regularly in Kaluaa Gulch. As last year, it was moderately abundant at both North and Central Kaluaa during the months of the winter and spring peak.

Drosophila flexipes breeds in fermenting sap fluxes of *Sapindus oahuensis* (lonomea, Sapindaceae). Although this tree is relatively common in remnant mesic and dry forest, it often occurs at lower elevations where ants prevent *Drosophila* from persisting. After a significant number were found in Manuwai in 2014, none were observed aside from a single fly this year. It was also previously observed at Pualii.

Drosophila hemipeza is the only listed endangered species on Oahu that is known to be extant but does not occur on Army lands or OIP/MIP action areas, although it historically occurred at Kahuku Training Area and West Makaleha Gulch adjacent to Makua. The primary host is probably *Cyanea*, like related species. It has been consistently found at Palikea MU for several years but always in low numbers; in

2014–2015 occasional individuals showed up at Puu Hapapa as well. It was only seen five times (total of six individuals) at Palikea in the past year's monthly monitoring, and none at Hapapa.

Drosophila hexachaetae is a small species similar in appearance to *D. montgomeryi*, but not closely related. It breeds in *Charpentiera* spp. (papala, Amaranthaceae) and *Pisonia* spp. (papala kepau, Nyctaginaceae). Although moderately common prior to 2013, it has been rare since then. Three individuals were seen, at Waianae Kai and Manuwai, the first sightings in nearly two years.

Drosophila nigribasis breeds in *Cheirodendron*; it is related to *D. substenoptera* but appears to favor wetter habitats. In our surveys, it is restricted to Koloa and the vicinity of Kaala summit. Only one was seen this year, but surveys in those areas were fewer than previously.

Drosophila oahuensis is also a *Cheirodendron* breeder, and appears to span the habitat range of *D. nigribasis* and *D. substenoptera*, including both the near-summit area of Kaala and wet-mesic sites such as North Haleauau Gulch in Lihue. Surveys at its preferred sites were relatively few this year, but a total of ten were still found this year, from multiple sites.

Drosophila pilimana is the Oahu representative of a species group with a number of species on Maui Nui and one on Kauai. Host plants are unknown for the entire group. It was formerly one of the more abundant picture wing species on Oahu, found widely across mesic and wet habitats, but its range has contracted dramatically since the 1970s, and it is apparently now found only in the northern Waianae range. Two were found this year at Manuwai, the most consistent site for it.

Figure 9. *Drosophila craddockae*, widespread but extremely rare and sporadic.

Figure 10. *Drosophila divaricata*, restricted to Honouliuli in the southern Waianae range.

Figure 11. *Drosophila hemipeza*, very similar to *D. substenoptera* and also often seen waving its wings.

7.3.5 *Vespula pensylvanica*

This highly invasive social predatory wasp is considered a major factor in the decline of picture wing *Drosophila* on Maui and Hawaii. Little is known of its impacts on Oahu, where it is present but much less conspicuous. The typical life cycle of a yellowjacket colony consists of an individual fertilized queen starting a nest in the spring, building up numbers of workers slowly at first but with exponential growth, peaking in the fall when new reproductives (males and the next generation of queens) are produced. After the reproductives leave the colony it typically declines and the workers die off, but in warm climates such as Hawaii they may persist through the winter and grow to an exceptionally large size during a second summer, with tens or hundreds of thousands of workers.

Ten traps baited with heptyl butyrate are monitored monthly at Palikea and Puu Hapapa. Traps were replaced with a different style in February 2017, which may mean the numbers for 2017 may not be directly comparable to those for 2015–16. *Vespula* numbers were similar at the two sites in 2015, but have increased at Palikea every year since while Hapapa has not had any since that time (Figure 12). Even numbers at Palikea are relatively modest compared to upper elevations of Hawaii or Maui. Still, they show a significant number of *Vespula* are usually present during the summer, coinciding with the low period of *Drosophila* numbers. It is unclear if there is any causal relationship; in 2015 and 2016 the ramp up of *Vespula* numbers at Palikea corresponded with a drop in *D. substenoptera*, but there was not the same correlation in 2017 (in part because *D. substenoptera* was less common overall). This suggests that the benefit to each from weather or other conditions outweighs the negative effect on *Drosophila* from *Vespula* predation. No *Vespula* have been seen so far in 2018, but the spike occurs in the late summer and fall, and this too has shifted later each year.

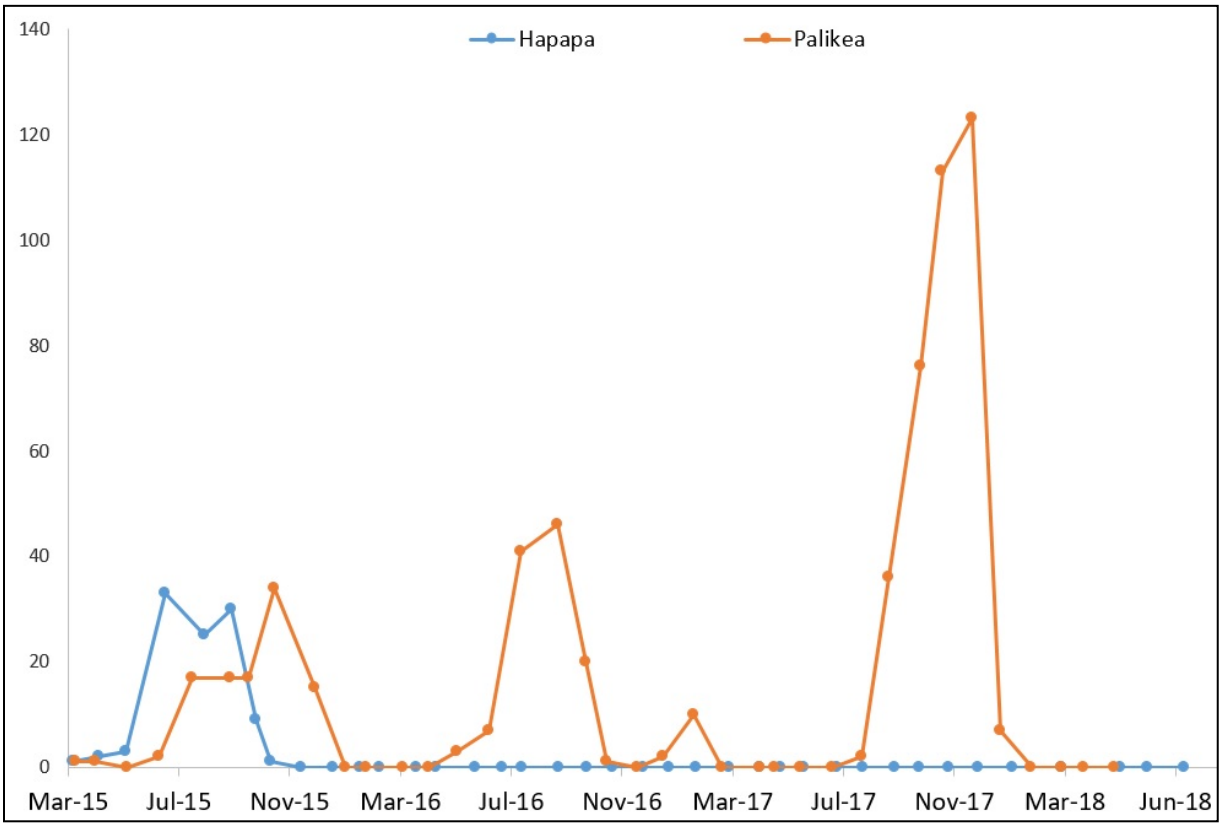

Figure 12. *Vespula pensylvanica* numbers at Palikea and Puu Hapapa (monthly total across 10 traps at each site).

We plan to continue monitoring at Palikea and Hapapa, since maintaining 10 traps at each site can be done in conjunction with the monthly fly monitoring without significant additional effort. No other sites have both significant *Drosophila* populations and relatively open canopy suited to *Vespula* monitoring. At present, there are no plans to conduct control of *Vespula*, but this may be considered if populations increase in the future. Control methods have been developed but are labor-intensive.