

Drosophilids of the Northwest

A ROAD TRIP THROUGH THE NORTHWEST WITH A MOBILE FRUIT FLY LAB

Thomas Werner | 2022 | July and August

Introduction and Purpose of the Study

On September 15th, 2012, the idea was born to produce a field guide about the fruit flies of the Midwest and Northeast of the US. My then external faculty mentor from the University of Rochester, NY, Dr. John Jaenike, taught me how to identify all the wild fruit fly species of the area, and I took high-quality images of them. In 2017, our first book was published, which was followed by our second book about the fruit flies of the Southeast in 2020. Both books are freely available:

1) The Encyclopedia of North American Drosophilids (Volume 1): Drosophilids of the Midwest and Northeast (https://digitalcommons.mtu.edu/oabooks/1/)
2) The Encyclopedia of North American Drosophilids (Volume 2): Drosophilids of the Southeast (https://digitalcommons.mtu.edu/oabooks/3/)

We decided that it would be worthwhile to write field guides about the western part of the US. As there are approximately 80 drosophilid species in the Northwest and about 180 species in the Southwest, we decided to start with the Northwest before concluding our encyclopedia with the final volume about the Southwest. In 2022, I collected wild fruit flies in the Northwest, which are reported here, for the planned third book:

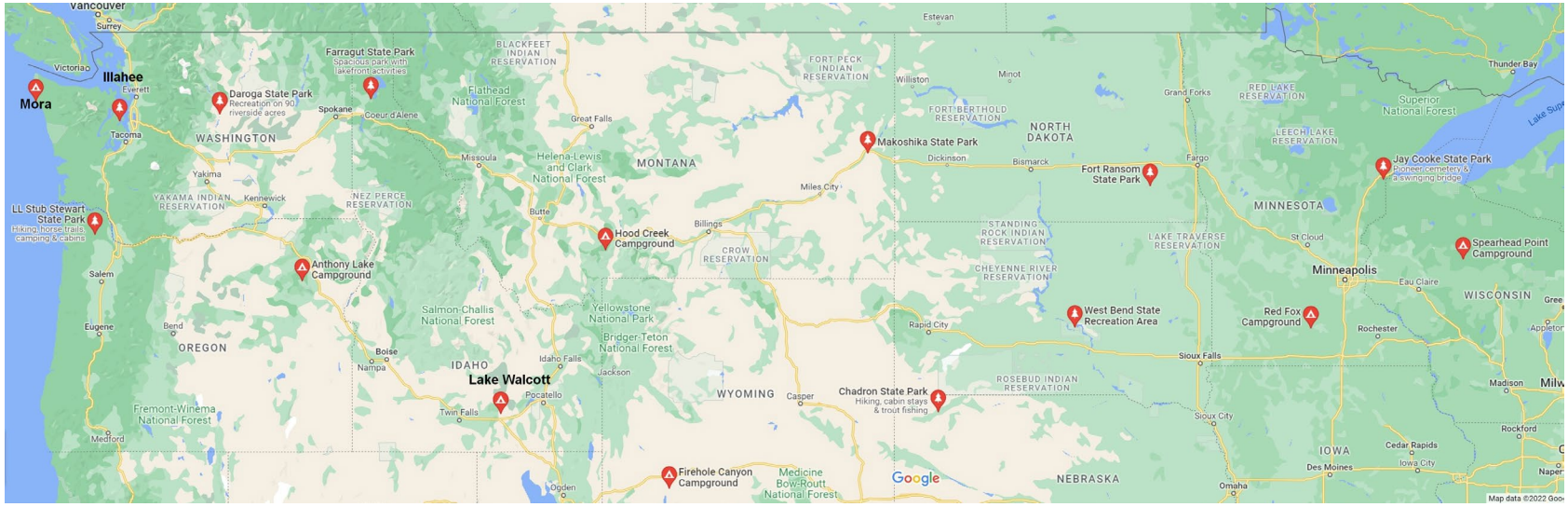
The Encyclopedia of North American Drosophilids (Volume 3): Drosophilids of the Northwest

Trip Logistics

I went with my family on a road trip from July 8th through August 14th, 2022, starting in Houghton, MI, where Michigan Tech has its home. We drove in two minivans approximately 4 to 6 hours per day and tent-camped at campgrounds. We stayed one night at campgrounds if we were just traveling through or 5 nights if I collected flies. The fly collections were performed in the following places and times:

1) **Montana** 7/11 – 7/16, near Hood Creek Campground
2) **Idaho** 7/16 – 7/21, in Farragut State Park
3) **Washington** 7/23 – 7/28, near Mora Campground (non-wilderness forest)
4) **Oregon** 7/28 – 8/2, in L.L. Stewart State Park
5) **Colorado** 8/5 – 8/10, near Flatiron Campground (Big Thompson Canyon)

The following map shows all campgrounds visited (both for one-night and five-night stays). North is to the left, and South to the right. The northern alignment of campgrounds was visited on the way to the Pacific coast, while the southern row of campgrounds was used on the way back home.

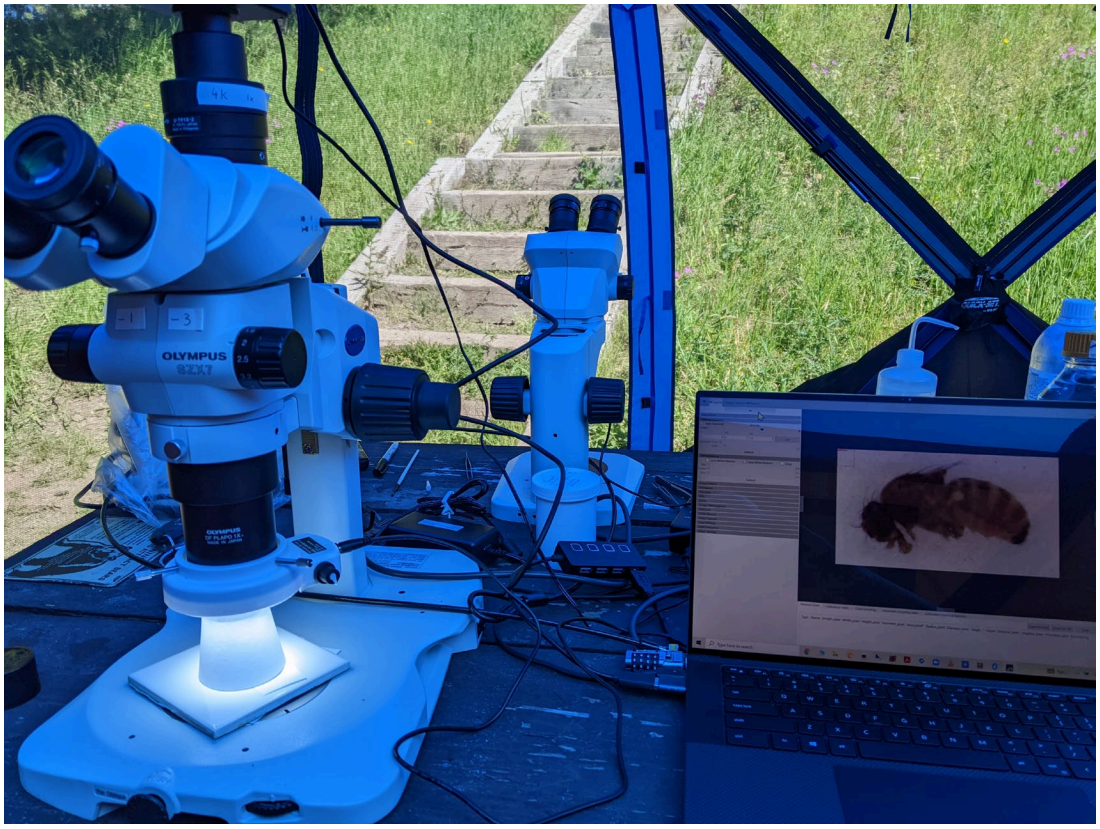

Vancouver
Surrey
Victoria
Illahee
Everett
Mora
Tacoma
Daroga State Park
Recreation on 90 riverside acres
Farragut State Park
Spacious park with lakefront activities
Spokane
Coeur d'Alene
WASHINGTON
Yakima
YAKAMA INDIAN RESERVATION
Kennewick
NEZ PERCE RESERVATION
LL Stub Stewart State Park
Hiking, horse trails, camping & cabins
Salem
Eugene
Bend
OREGON
Anthony Lake Campground
Boise
Nampa
Medford
Fremont-Winema National Forest
Salmon-Challis National Forest
IDAHO
Lake Walcott
Twin Falls
Pocatello
Idaho Falls
Jackson
Yellowstone National Park
Bridger-Teton National Forest
WYOMING
Casper
Ogden
Firehole Canyon Campground
Medicine Bow-Routt National Forest
Flathead National Forest
BLACKFEET INDIAN RESERVATION
Great Falls
Missoula
Helena-Lewis and Clark National Forest
MONTANA
Butte
Billings
Hood Creek Campground
CROW RESERVATION
Miles City
FORT PECK INDIAN RESERVATION
Williston
Minot
FORT BERTHOLD RESERVATION
NORTH DAKOTA
Dickinson
Bismarck
Makoshika State Park
Fort Ransom State Park
Fargo
Grand Forks
RED LAKE RESERVATION
LEECH LAKE RESERVATION
Thunder Bay
Superior National Forest
Jay Cooke State Park
Pioneer cemetery & a swinging bridge
MINNESOTA
STANDING ROCK INDIAN RESERVATION
LAKE TRAVERSE RESERVATION
CHEYENNE RIVER RESERVATION
St Cloud
Minneapolis
Spearhead Point Campground
Eau Claire
WISCONSIN
Rapid City
West Bend State Recreation Area
Red Fox Campground
Rochester
Sioux Falls
ROSEBUD INDIAN RESERVATION
Chadron State Park
Hiking, cabin stays & trout fishing
Sioux City
Madison
Rockford
Cedar Rapids
Iowa City
IOWA
Des Moines
NEBRASKA
Omaha
Google
Map data ©2022 Goo

The Mobile Fruit Fly Lab

Being able to image specimens at high resolution on a field trip is very important because many species cannot be kept alive or reared before coming back to the home lab. My mobile lab was equipped with everything needed to collect, identify, preserve, breed, and image fruit flies and all of their body parts at high resolution for our next book. The lab was made of an easy-setup tent by Clam that I put over the picnic table of the campsite. Picnic tables make surprisingly comfortable lab benches even when working with microscopes of different sizes. For wind and rain protection, brown side panels with closable windows were put over the tent sides if needed. Electricity was produced by two 100-W solar panels that charged my collection of three solar generators. I had a total energy storage capacity of 3.5 kWh, which, even without sunlight, would have allowed me to run the lab for about two or three weeks. The lab contained three microscopes, among which were one regular dissection scope for identifying and dissecting flies, one inverted microscope to image genitals at 400X magnification, and one big dissection scope with a 4K digital camera attached that was operated by a laptop to capture images. Fly pictures were taken at about 50 focal layers throughout the fly body, and the individual raw images were then Z-stacked with Helicon Focus to produce one sharp image, as also described and illustrated in our first book. Working in this lab was perhaps the most fun experience I have had in my entire career. The following pictures show the lab tent with the equipment.






OLYMPUS


Jackery
Jackery



Collection Methods

Generally, in wooded areas, a bottle with fermenting banana was hung from a tree branch. Nearby, a pile of watermelon rind and a pile of water-soaked mushrooms were placed about 1-2 meters apart, preferably next to a fallen log. This assembly of three bait types is referred to as a "site" in this report. The following picture shows a typical site with a banana bottle (upper right), a pile of watermelon rind (lower left), and a pile of mushrooms (bottom center).



The following two pictures show what a bait looks like when flies were attracted to it and after the flies were captured with a net and moved into collection vials.





The following pictures show stacked images of two species from this trip, *Drosophila flavopinicola* (top) and *Leucophenga montana* (bottom), taken with the field equipment.





I recorded the flies in a paper field notebook by species and number, sometimes by sex, and noted from what bait type they were collected. For simplicity, I will in this report only comment on the bait types for species of special interest. Except for Montana, (where I had to attend the baits all day and take them away at night), I established 5 sites in each state and left the baits out until three consecutive days of collection were performed. After that, the baits were removed from the sites. The flies were caught with an insect net and brought back alive to the field lab for identifying, recording, imaging, and preserving the specimens.

In the field lab, all flies were anesthetized with ether and examined under a dissection microscope. Flies that needed to be imaged for the next book were either imaged directly and/or put into food vials for rearing. All other flies were counted, identified, and stored in ethanol or, in some special cases, in RNA Later. The preserved flies will be sequenced for further species identification, as some species in the Northwest are very challenging or impossible to identify based on morphological characters alone. These species are *D. athabasca, D. subobscura, D. persimilis, D. pseudoobscura, D. miranda*, *D. borealis*, and *D. montana*. Dr. Bernard Kim from Stanford University is my new collaborator, who has received many collected samples from me to carry out the DNA and RNA sequencing analysis. Although this is a last-minute modification of the originally proposed strategy to handle the preserved samples, the opportunity to have the collected specimens sequenced right away instead of having them sit in a drawer in a museum for perhaps decades was too tempting to not accept.

Results Summary

On the entire trip, I collected a total of 3452 drosophilid flies belonging to up to 21 different species:

1) *Leucophenga montana*
2) *Chymomyza amoena*
3) *Drosophila melanogaster*
4) *Drosophila suzukii*
5) *Drosophila athabasca*
6) *Drosophila subobscura*
7) *Drosophila pseudoobscura?*
8) *Drosophila miranda?*
9) *Drosophila persimilis?*
10) *Drosophila busckii*
11) *Drosophila borealis?*
12) *Drosophila montana?*
13) *Drosophila immigrans*
14) *Drosophila funebris*
15) *Drosophila flavopinicola*
16) *Drosophila neotestacea*
17) *Drosophila falleni*
18) *Drosophila rellima*
19) *Drosophila suboccidentalis*
20) *Drosophila subquinaria*
21) *Scaptomyza pallida*

Collection Results for Montana

The collection results will be given for all three days and three bait types lumped together. I collected on three consecutive days (starting on the day after setting up the baits) in the morning at around 8 AM. I collected at only one site, as I had to sit next to the baits to prevent them from being eaten by bears. The GPS coordinates for this site are: N45°27.817’ W110°57.312′. The following pictures show the collection site at the Upper Hyalite Road above the Hyalite Reservoir.





Fly collecting was, on two out of three days, interrupted by thunderstorms that started at around noon. The temperature was at or slightly above 13°C in the early morning when it was sunny with a relative humidity of around 80%. Afternoon temperatures increased to 26°C, when the relative humidity fell to approximately 45% later in the day (if it was not raining). I collected only a total of 20 drosophilid flies over three days, usually after 11 AM when the temperature was above 20°C. Twenty flies in three days are a very low number. During three days of collecting, I only found 2 or 3 species:

***Drosophila suboccidentalis* (17 flies).** Only males of this species can be reliably identified based on morphological characters. All wild-collected males belonged to *D. suboccidentalis*. Five wild males were imaged for the book, and their dissected remains were stored in ethanol and RNA Later. The females were kept alive for breeding. The male F1 offspring of two stocks revealed that they too belonged to *D. suboccidentalis*. The remaining stocks were given to Dr. Bernard Kim for sequencing. Five females of the F1 offspring were imaged for the book after their species identity was revealed. Note: The other species that looks very similar is *Drosophila occidentalis*. The difference lays in the males' foreleg hairs.

Drosophila persimilis and/or ***Drosophila pseudoobscura* (3 male flies).** Morphological characters are variable and insufficient to separate these two species. The flies will be sequenced for final identification and were preserved in 95% ethanol for this purpose.

Lessons learned from collecting in Montana: All flies that I collected were first encounters with these species in the wild for me, which was very exciting. I also learned that the lab tent could withstand 65 mph winds that came blowing from the lake (see cover image of the report, taken when it was not windy), but that it is better to support the sides with extra strings and stakes to prevent a partial collapse of the tent, which has happened during the storm with about $20,000 of equipment inside. Fortunately, nothing got wet or damaged. I also need to note that packing up the baits before dark and whenever a storm is coming in drastically reduces the effectiveness of fruit fly collecting, as many species are active during dusk and dawn, and the best collection is usually done in the morning when flies had a full day to settle on the baits.

Collection Results for Idaho

I established 5 sites in Farragut State Park with the following GPS coordinates:

Site 1: N47°58.124’ W116°32.489'

Site 2: N47°58.230’ W116°32.433'

Site 3: N47°58.071’ W116°33.678'

Site 4: N47°57.894’ W116°34.009'

Site 5: N47°57.608’ W116°33.929'

The following pictures show the locations of Sites 1 through 5, in that order:






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The collection results will be given for all three days, five sites, and three bait types lumped together, except for the most interesting findings. I collected on three consecutive days (starting on the day after setting up the baits) in the morning at around 9 AM, when the temperature was on each day between 18 – 20°C, and the relative humidity was around 60%, with sunshine and no wind.

I collected a total of 775 flies, among which were between 7 and 9 species:

Chymomyza amoena **(one fly)**: I got a good look at the only specimen that I saw in my net at Site 2 collected from the banana bottle, but the fly escaped. There is no previous record of this species in the Northwest, but it is common in the Northeast and is about to widen its distribution range both in America and in Europe.

Drosophila melanogaster **(two flies).** This is a cosmopolitan species that everyone complains about invading their kitchen in late summer.

Drosophila athabasca **(the majority of collected flies).** This is a wide-spread and very common species in many locations. Only the males can be identified to the species using morphological features.

Drosophila subobscura **(very few flies).** This is an invader from Europe that established itself in the early 1980s in western North America.

Drosophila pseudoobscura/persimilis/miranda **(a few dozen flies).** The males of these three species cannot be distinguished from each other reliably by morphological features and need to be sequenced to come to a sure conclusion. They were all preserved in 95% ethanol for this purpose. Some females were allowed to lay eggs for culturing. *D. miranda* is usually bigger and darker than the other two species, and I have reason to believe that *D. miranda* was among the collected flies.

Drosophila suboccidentalis **(a few flies).** Only males of this species can be reliably identified based on morphological characters. The flies will be sequenced for final species identification, and some females were kept alive for egg-laying to establish cultures. The cultures were handed to Dr. Bernard Kim, who joined me in Oregon later during this trip, when a heat wave threatened to destroy my culture collection.

Drosophila neotestacea **(a few dozen flies).** This is a common and wide-spread species. The flies were stored in 95% ethanol.

Lessons learned from collecting in Idaho: *Drosophila miranda* was a possible first encounter for me in the wild. It was also nice to see *Chymomyza amoena*, which added a new entry in my Table of Contents for my next book. Collecting nearly 800 flies was very good, considering that I only found 20 flies in Montana just before collecting in Idaho.

Collection Results for Washington

I established 5 sites in the non-wilderness area outside Olympic National Park south of Mora Campground with the following GPS coordinates:

Site 1: N47°53.958' W124°35.148'

Site 2: N47°54.013' W124°35.170'

Site 3: N47°54.047' W124°35.168'

Site 4: N47°54.030' W124°35.311'

Site 5: N47°54.097' W124°35.369'

The following picture shows the non-wilderness trail, along which the 5 research sites were established:



The following pictures show the 5 research sites, from Site 1 through Site 5, in that order:











The results will be given for all five sites, three collection days, and three bait types lumped together, except for the most interesting findings. I usually collected in the morning from around 9 to 10 AM, when the temperature was surprisingly cold, between 13 and 18°C with sunshine and no wind. The relative humidity was then around 80%. The fly activity was great despite the chilly temperatures. I collected a total of 1026 flies over the three consecutive days, starting the day after putting the baits out, among which were between 7 and 9 species:

***Drosophila flavopinicola* (three female flies)**: I collected two females from Site 4 and one from Site 5. They came to watermelon rind and banana baits. I imaged all three females for the book and preserved the remains in 95% ethanol as well as RNA Later for sequencing and species confirmation. This species is very uncommon and prefers cold habitats. It is virtually impossible to rear in the lab.

***Drosophila borealis* (one male and two females):** I collected a male and a female from the banana bottles at Sites 3 and 4, as well as a female from watermelon rind at Site 5. I tried to establish two cultures, but only one female produced offspring. The flies will need to be sequenced because they look extremely similar to *Drosophila montana*. Furthermore, the western *D. borealis* may be a different species (yet undescribed) from *D. borealis* in the East; thus, sequencing their genomes may allow us to learn more about the phylogeny of this group of closely related species and possibly describe a new species.

***Drosophila athabasca* (the majority of flies):** This is a wide-spread and very common species in many locations. Only the males can be identified to the species using morphological features.

***Drosophila subobscura* (very few flies):** This is an invader from Europe that established itself in the early 1980s in western North America.

***Drosophila pseudoobscura*/*persimilis*/*miranda* (a few dozen flies):** The males of these three species cannot be distinguished from each other reliably by visual features and need to be sequenced to come to a sure conclusion. They were all preserved in ethanol for this purpose. Some females were allowed to lay eggs for culturing. *D. miranda* is usually bigger and darker than the other two species, and I have some reason to believe that some *D. miranda* flies were among the collected specimens.

***Drosophila suboccidentalis* (a few flies):** Only males of this species can be reliably identified based on morphological characters. The flies will be sequenced for final species identification, and some females were kept alive for egg-laying to establish cultures.

***Drosophila neotestacea* (a few dozen flies):** This is a common and wide-spread species.

***Drosophila subquinaria* (a few flies):** This is a fungus-feeding fly species of the West. It is replaced by *Drosophila recens* in the East.

Lessons learned from collecting in Washington: Finding the rare *Drosophila flavopinicola* as well as *Drosophila borealis* was exciting. The campground was like a rainforest, and the picnic table (made of concrete) was so wet and overgrown with algae and mosses that it needed to be covered with a waterproof picnic blanket to protect the research equipment. Also, the cold and wet seat of the bench was only useable with a towel on top. Other than that, it is a very nice fly collection place worth another visit next year.

Collection Results for Oregon

I established 5 sites in the L.L. Stub Stewart State Park with the following GPS coordinates:

Site 1: N45°44.481’ W123°11.415'

Site 2: N45°44.500’ W123°11.460'

Site 3: N45°44.502’ W123°11.529'

Site 4: N45°44.501’ W123°11.598'

Site 5: N45°44.438’ W123°11.652'

The following pictures show Sites 1 through 5, in that order:











The following picture gives an impression of what the forest looks like:



The results will be given for all five sites, three collection days, and three bait types lumped together, except for the most interesting findings. I usually collected in the morning from around 9 to 10 AM, when the temperature was around 22°C and the relative humidity around 60% with sunshine and no wind. The Oregon sites provided the biggest diversity and largest fly number of all five states. I collected a total of 1514 flies over the three consecutive days, starting on the day after putting the baits out, among which were between 14 and 16 species:

***Drosophila borealis* (one female):** I collected a female from watermelon rind at Site 5. She died, and I preserved the fly in 95% ethanol for sequencing. *D. borealis* looks extremely similar to *Drosophila montana*. Furthermore, the western *D. borealis* may be a different species (yet undescribed) from *D. borealis* in the East; thus, sequencing the genome of this fly may allow us to learn more about the phylogeny of this group of closely related species and possibly describe a new species.

***Drosophila rellima* (a few dozen flies):** I imaged 5 males and 5 females for the new book, as I have never seen this species in nature before. I tried to establish a live culture, but this species seems to be hard to maintain in captivity. Most specimens were preserved in 95% ethanol and a few males and females also in RNA Later.

***Drosophila athabasca* (the majority of flies):** This is a wide-spread and very common species in many locations. Only the males can be identified to the species using morphological features.

***Drosophila subobscura* (very few flies):** This is an invader from Europe that established itself in the early 1980s in western North America.

***Drosophila pseudoobscura*/*persimilis*/*miranda* (a few dozen flies):** The males of these three species cannot be distinguished from each other reliably by visual features and need to be sequenced to come to a sure conclusion. They were all preserved in ethanol for this purpose. Some females were allowed to lay eggs for culturing. *D. miranda* is usually bigger and darker than the other two species, and I have reason to believe that some *D. miranda* flies were among the collected specimens.

***Drosophila suboccidentalis* (a few flies):** Only males of this species can be reliably identified based on morphological characters. The flies will be sequenced for final species identification, and some females were kept alive for egg-laying to establish cultures.

***Drosophila neotestacea* (a few dozen flies):** This is a common and wide-spread species.

***Drosophila subquinaria* (a few dozen flies):** This is a fungus-feeding fly species of the West. It is replaced by *Drosophila recens* in the East. I performed a male genital prep to confirm the species.

***Drosophila funebris* (one male):** This fly was expected to be found in the Northwest and was the only specimen of this species on the entire trip.

***Drosophila immigrans* (a few dozen flies):** This is a pretty common species in many places.

***Drosophila busckii* (a few flies):** This is a pretty common species in many places, often found associated with human activity.

***Drosophila melanogaster* (two flies):** This is a cosmopolitan species that everyone complains about invading their kitchen in late summer. I discarded these flies as they were of no scientific use.

***Scaptomyza pallida* (one male and one female):** There are about 20 species of the genus *Scaptomyza* in the Northwest, *S. pallida* being the most wide-spread and common one. Unfortunately, I did not see any of the other species of this genus on this trip.

***Drosophila suzukii* (a few flies):** This is an invasive agricultural pest species from Southeast Asia that has invaded the north American mainland in 2008.

Lessons learned from collecting in Oregon: The species diversity in Oregon was the best of all five states. Especially exciting was seeing *Drosophila rellima* for the first time.

Collection Results for Colorado

I established 5 sites in the Roosewelt National Forest (the Viestenz-Smith Mountain Park) with the following GPS coordinates:

Site 1: N40°25.138’ W105°16.962'

Site 2: N40°25.140’ W105°16.011'

Site 3: N40°25.121’ W105°16.925'

Site 4: N40°25.109’ W105°16.922'

Site 5: N40°25.095’ W105°16.919'

The following pictures show the Sites 1 through 5, in that order:











The following pictures give an impression of what the forest looks like:





The results will be given for all five sites, three collection days, and three bait types lumped together, except for the most interesting findings. I usually collected in the morning at around 7-8 AM, when the temperature was around 20°C and the relative humidity around 50% with sunshine and no wind. I collected a total of 117 flies over the three consecutive days, starting the day after putting the baits out, among which were between 9 and 10 species:

***Leucophenga montana* (five females):** All flies were dissected, imaged, and preserved (two in RNA Later and three in 95% ethanol). I found two flies on banana, two on watermelon rind, and one on mushrooms at Sites 2, 4, and 5.

***Drosophila montana* (one male):** I collected a male from banana at Site 2. I preserved the fly in 95% ethanol for sequencing. *D. montana* looks extremely similar to *Drosophila borealis*. Sequencing this fly will reveal its real identity.

***Drosophila athabasca* (a few flies):** This is a wide-spread and very common species in many locations. Only the males can be identified to the species using morphological features.

***Drosophila pseudoobscura*/*persimilis* (the majority of flies):** The males of these two species cannot be distinguished from each other reliably by visual features and need to be sequenced to come to a sure conclusion. They were all preserved in ethanol for this purpose. Some females were allowed to lay eggs for culturing.

***Drosophila suboccidentalis* (a few flies):** Only males of this species can be reliably identified based on morphological characters. The flies will be sequenced for final species identification, and some females were kept alive for egg-laying to establish cultures.

***Drosophila subquinaria* (one male):** This is a fungus-feeding fly species of the West. It is replaced by *Drosophila recens* in the East.

***Drosophila immigrans* (one fly):** This is a common species in many places.

***Drosophila melanogaster* (a few flies):** This is a cosmopolitan species that everyone complains about invading their kitchen in late summer. I preserved these flies in 95% ethanol.

***Drosophila suzukii* (a few flies):** This is an invasive agricultural pest species from Southeast Asia that has invaded the north American mainland in 2008.

Lessons learned from collecting in Colorado: Finding *Leucophenga montana* for the first time was the most exciting part of the Colorado collection. *Leucophenga montana* looks at first sight like *Drosophila flavopinicola*, just a bit bigger.