Can we predict when SWD are active and begin egg-laying in the spring? Try using a Degree-Day Model!

SWD FLYer: Issue Four

Take a Closer Look at SWD!

Spotted wing Drosophila (SWD), a tiny fly that began to invade our fruit crops in 2008, originates from SE Asia. By now it has become widespread from east to west coast, and worldwide. While most other *Drosophila* species only attack rotting fruit, such as those placed in compost piles, SWD can infest ripening, ripe, and over-ripe strawberries, cherries, blueberries, raspberries and blackberries, and many other soft- or thin-skinned fruit hosts, depending on management practices and environmental conditions.

Interestingly, SWD are found in very low to no numbers in traps in the spring as compared to late summer and fall, when we can see extremely high populations build up. Researchers have been focusing on this delay in population increase that is influenced chiefly by winter mortality, and by spring and early summer 'heat units' (degree-days; amount of heat accumulated over time). What we find is that cold winters (and a lack of protective refuge locations), plus cool, (and probably wet) springs delay reproduction so that some early season fruit crops may not be at risk. Pinning down these conditions in a more predictable way can help fruit growers know the relative risk they are facing as the season progresses and when to begin treatments. Fly movement in the landscape, diverse vegetation and riparian habitat adjacent to fruiting crop, and the various crop hosts available for egg-laying is also likely to influence crop risk from SWD.

Why can a Degree-day Model help you?

This **SWD FLYer** is focused on the use of a degree-day tool and how to use one to manage SWD. Degree-day (DD) models, also known as phenology models, are one of many tools to help predict and report when SWD may become a problem. Models are not a replacement for monitoring, but should be used to strengthen our interpretation of monitoring results. The SWD DD model links temperature to specific needs for the fly's development, from egg to adult. As we know, year to year variation in weather and temperature in particular is a strong driver behind the differences we see in crop production, yields, and in pest damage. With models, we can begin to understand and predict this variability and to chart yearly activities.

Degree-days, as a measure of temperature over time, account for roughly 85% of the variation in development in insects and plants. The other 15% is usually due to moisture (rainfall and humidity), day-length, and food quality.

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Since these other factors are mostly seasonal and more regular, degree-days are helpful, and being used in the case of SWD, for signaling events such as to:

1. Predict the time when overwintering flies become active in seeking ripening fruit
2. Determine when overwintering females are ready to lay eggs
3. Show the best times to set up monitoring traps
4. Suggest when SWD risk levels increase and signals first treatment

Several things the model does NOT do at this time include:

1. Predict first egg-laying on non-crops such as early fruiting ornamental or wildland plants

2. Continue late into the fall or predict the beginning of overwintering behaviors

3. Provide precision about need for or timing of subsequent insecticide treatments

Some people associate the term “modeling” with something difficult to use and understand, but actually it can be quite easy and useful, once you see how a model is built and have computer access. Developing and refining a good useable model is a process and requires input, effort and time to create, and must be tested across regions, management types, and fruit types. These models provide a general outline of insect activities, but usually require supporting data from the field. Timing treatments with the use of a DD model will be more effective once we better understand how and when SWD wakes up from winter-resting and when they begin moving into a crop from protected areas. These events are currently being studied in great detail, so hopefully more precise predictions will be possible with future model updates.

The Modeling Team at OSU

Several folks at Oregon State University (Crop and Soil Science and Horticulture Dept.) have united with Len Coop and Paul Jepson (Integrated Plant Protection Center-IPPC) to develop a degree-day model for SWD. The tool will help to predict SWD spring activity from awakening overwintering adult populations and to forecast flight activity and egg-laying events. The SWD DD prediction model is based on W. Oregon lab and field data, along with data from three studies from Japan, where SWD is presumed native and has been a pest for many years. The model, if used together with solid monitoring data and an understanding of crop host vulnerabilities, can help growers and farm managers determine overall risk and help in timing of control measures. Models tend to improve over time when more data and feedback from users are incorporated, as we expect for this SWD-DD model.

A DD Model for SWD can be accessed on: OSU, Integrated Plant Protection Center Online Phenology and Degree-Day Models for agricultural and decision-making in the US at:

http://pnwpest.org/cgi-in/ddmodel.pl.

SWD Life Cycle and Development

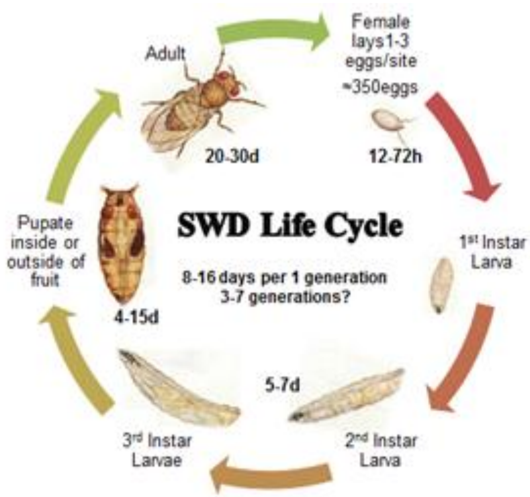

Figure 1. Life cycle of SWD.
Created by Tanya Telshow, OSU 2010

SWD has 4 stages of development which include: egg, larva, pupa (cocoon-like), and adult. (**Figure 1**-above). Adult flies spend the winter in protected places. Cold winters (hard freezes) affect the survival of SWD. Females appear to have a higher survival rate than males. When looking for SWD in the winter landscape, it has been difficult locating them. However, on warm days, traps will continue to capture adults at any time of the year including Dec-Feb, at least in protected locations where populations had built-up the previous fall. These adults are thought to be seeking moisture and nourishment, and are not at all ready for egg-laying, which the model currently predicts to begin around mid-May based on 30-year temperature averages in Corvallis, OR (**Table 1**-page 4). This event occurs about 2 weeks earlier in the Willamette Valley, Oregon compared to Olympia, WA and about 1 week earlier than Northwest WA (e.g. Bellingham).

On warm winter and spring days, SWD adults respond to warming temperatures (approximately 55°F and higher) and will mostly feed on tree saps, nectars and yeasts to gain energy and to increase egg longevity and viability. When ready, female SWD look for fruit hosts to lay eggs in, which they are able to do using their saw-like ovipositor. Larvae hatch from eggs after only 1 to 3 days, and feed inside the fruit for from about 5-12 days. When finished, they most often pupate in the fruit, which takes around 4-10 days, and, after that, new adults emerge. Depending upon the temperature, the whole cycle can take from only a couple of weeks, to about a month, and much longer in locations with cooler weather.

What is a Degree Day Model?

Insect development depends on the temperature in their environment. On warm days, insects develop faster than they do on cold days. But excessively warm temperatures will either slow down development, or can be lethal in some cases. Research has indicated that SWD does not develop below about 50°F or above 86°F, which means the cool Pacific Northwest winter weather slows development to almost nil, while our occasional hot dry summers can also temporarily suppress populations (as is known to occur in California). It is believed that this have happened in the PNW during the late Summer/early Fall of 2012, when SWD numbers were greatly reduced compared to the same interval in 2010 and 2011, rather than continued to build. Our typical mild summers, however, are nearly ideal for SWD. In 2011, spring and early summer temperatures were cooler than normal in the PNW, and it took longer for SWD to become active, which lowered the early season risk of infestation (**Table 1**- below). A degree-day model allows us to track temperatures over time so that we can predict to what extent populations may be ahead or behind normal.

SWD EVENT (50F; single sine; Jan1)	2004 (warm year)	30-year Average	2011 (cool year)
1. 1st egg laying by OverWintering (OW) flies	April 27	May 17	June 4
2. Peak egg laying OW	May 30	June 14	June 28
3. 1st egg laying 1st generation	June 4	June 19	July 3
4. Peak adult emergence 1st gen.	June 20	July 4	July 17
5. Peak egg laying 1st generation	July 6	July 19	Aug 1
6. Peak adult emergence 2nd gen.	July 21	Aug 2	Aug 17
7. Peak egg laying 2nd generation	Aug 1	Aug 15	Aug 28

Table 1. Some estimated SWD event DATES based on the warmest and coolest years (last 10 years) and 30-year historical temperature averages for a selected location (CRVO Agrimet Corvallis, Oregon; elevation: 230 ft). Note: event number 5, peak egg-laying 1st generation, may be the time when it is likely that populations have had sufficient heat to cause infestations and risk to fruiting crop, if fruit in susceptible ripe stage.

How are Degree- Days Calculated?

The simplest way to think about calculating degrees days (DD) is as follows: One DD accumulates for every degree that the average daily temperature is above the lower threshold (50°F for SWD).

So, for example, if the average daily temperature is 70°F, then 70 minus 50 equals 20 DDs calculated for that day. This process is repeated each day and a running total number of DDs is added up to compare to the established model. We tend to use a slightly more accurate formula than the daily average method, known as the single sine curve method. This formula fits a sine curve to the daily maximum and minimum temperatures and then calculates the area between the upper and lower thresholds, as shown in idealized form in **Figure 2.**

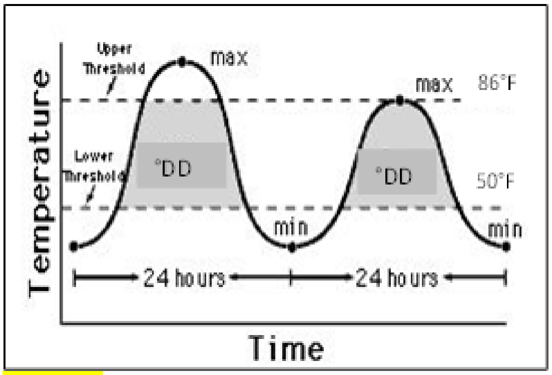

Figure 2. Accumulation of degree-days within upper and lower development thresholds of SWD using the single sine method. Modified from: http://www.ipm.ucdavis.edu/WEATHER/ddconcepts.html

Temperatures (and other parameters) are obtained from a nearby weather station that follow the standards established by the National Weather Service, rather than attempting to follow the micro-weather conditions experienced by the insect or plant we are modeling. This use of standards is one key to successful use of models for pest and crop management.

The decision of when to begin accumulating DDs is generally derived by lowest error methods, with January 1 (as for SWD) as the default starting date. Some models will be primed by an actual event such as flowering dates or first trapping results. We call this type of model start date a "biofix" date, but we have not found such an event in the case of SWD. So, for SWD we begin accumulating DDs on Jan. 1 and use the model to predict when adult flies become active and when egg-laying begins in the late spring or early summer. Following initial egg-laying in late Spring, the model estimates development of eggs, larvae, and pupae and when this first generation emerges and begins laying eggs, which can range from about 3-6 weeks later. The model continues to estimate additional generations and focuses on peak adult emergence and egg-laying times. However, by the late second or early third generation, the populations overlap such that "peak" events are no longer precise, and will tend to vary locally according to the availability of hosts and any insecticides that may have been used in the area. The model should, however, be useful in showing how many total generations have developed, which can help indicate the potential population buildup: populations would be expected to be much higher by the fourth generation than during the first or second generation, for example.

No more than four or five complete generations are expected in the Pacific Northwest (and only three on average in NW Washington), whereas as many as 8 or 9 generations may be completed in locations such as S. California near the coast. SWD females are fairly long-lived; so the first eggs laid can **develop** into adults while the same female is still laying eggs, if conditions are favorable. This is one reason why the SWD model is specified for peak events (using average development times and the mid-point of egg-laying) as well as for maximum generations, which assumes that first eggs develop into adults which also produce first eggs that develop into adults and so on.

We have observed that late harvested fruit generally produce higher levels of damage than late spring-summer harvested fruit with lower populations of SWD. After fruit harvest in the fall, SWD greatly increases, but egg-laying probably is reduced as females prepare to overwinter.

Table 3 is provided (on last page) as an easy-to-read reference showing expected degree-day totals for specific events. As we continue to improve the model we will adjust the degree-day totals.

Access the DD Model for SWD accessed at:

http://pnwpest.org/cgi-in/ddmodel.pl.

You should see something like the online modeling interface shown in **Figure 3** (below). To begin, use the Google map to select a nearby weather station. Note that many weather stations have data quality problems and should not be used.

Figure 3. An image of the online phenology screen and data needed to enter to obtain current degree-days is displayed.

Choose weather station, insects, spotted wing Drosophila model category, start and end dates, then click "Calc".

Click the "Calc" button to get model output (**Table 2**). By comparing the model results to the discussion in this FLYer, you can begin to gain confidence in the delayed Spring activities that researchers have been studying. In running the model for the current year, a 7-day forecast and 30-year average data forecast are used for future predictions. **Table 1** (page 4) includes several estimated SWD event dates based on temperatures from the warmest and coolest years (from 2004 and 2011), and on 30-year historical temperature averages using the location CRVO Agrimet Corvallis, OR. As the season progresses, you can see several generations developing and get a sense of the population buildup that will occur if conditions are good for this fly. Again, the model is not precise about "peak" times but provides examples of how long each generation takes to develop. Remember, the model is subject to change as new data is incorporated.

Table 2. An output table is generated of daily degree-day cumulative totals for SWD from January 1 to May 4, 2013 taken from the CRVO Agrimet CORVALLIS OR weather station. Note: only selected dates were included in table below.

================MODEL OUTPUT=====================

Weather station:
Lat- 44.6342 | Long-123.1897 | Elev:230

Month	day	max (°F)	min (°F)	precip (in.)	DD50F	CUMDD50F	Event
1	1	39.01	28.93	0.00	0.00	0.0	* START *
1	2	41.63	27.56	0.00	0.00	0.0	
1	3	38.31	26.42	0.00	0.00	0.0	
1	4	48.34	35.34	0.00	0.00	0.0	
1	5	41.01	36.55	0.00	0.00	0.0	
1	6	46.17	36.72	0.01	0.00	0.0	
1	7	54.71	44.77	0.16	1.45	1.5	
1	8	54.00	45.86	0.02	1.26	2.7	
1	9	52.35	35.70	0.19	0.38	3.1	
vvv							
2	5	51.33	41.43	0.27	0.21	5.4	
2	6	50.82	41.34	0.08	0.10	5.5	
2	7	46.52	34.49	0.02	0.00	5.5	
2	8	45.93	33.30	0.00	0.00	5.5	
2	9	44.96	35.80	0.03	0.00	5.5	
2	10	45.64	42.05	0.04	0.00	5.5	
2	11	48.06	40.71	0.00	0.00	5.5	
2	12	54.83	44.56	0.00	1.48	7.0	
2	13	53.03	46.30	0.00	0.91	7.9	
2	14	56.69	34.62	0.00	1.62	9.5	
2	15	55.30	40.17	0.00	1.38	10.9	
vvv							
3	1	61.09	47.61	0.00	4.78	19.3	
3	2	54.66	45.58	0.00	1.51	20.8	
3	3	49.61	32.74	0.00	0.00	20.8	
3	4	54.92	33.59	0.00	1.03	21.8	
3	5	47.67	34.59	0.40	0.00	21.8	
3	6	47.96	41.00	0.35	0.00	21.8	
3	7	55.09	30.41	0.00	1.00	22.8	
vvv							
4	1	61.12	49.15	0.00	5.23	96.5	
4	2	67.63	44.92	0.00	7.32	103.9	
4	3	62.97	40.14	0.00	4.44	108.3	
4	4	62.00	52.43	0.12	7.22	115.5	
vvv							
5	1	67.11	38.68	0.00	6.07	226.3	
5	2	75.90	46.83	0.00	11.81	238.1	
5	3	77.60	47.33	0.00	12.80	250.9	
5	4	82.00	55.07	0.00	18.53	269.5	1st EGG-LAYING BY OW FEMALES

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==============================MODEL INPUTS================================
 Model species/general links:        spotted wing Drosophila [fruit]
 Type:                               insect
 Model source/other links:           OSU vers. 2.0
 Calculation method:                 single sine
 Lower threshold:                    50 degrees Fahrenheit
 Upper threshold:                    86 degrees Fahrenheit
 Directions for starting/BIOFIX:     Calendar date Jan 1
 No starting/BIOFIX date, set to:    default date  1  1
 No ending date, set to:             default date  12 31
 Model validation status:            partly validated-has been compared to 2
                                       years of field data in PNW
 Region of known use:                potential for use in US
 ==============================EVENTS TABLE================================
 1.   261 DDs after Jan 1: 1st EGG LAYING BY OverWintering (OW) FEMALES
 2.   510 DDs after Jan 1: PEAK (ca. 50%) EGG LAYING BY OW FEMALES;
                         1st ADULT  EMERGE 1st GEN
 3.   565 DDs after Jan 1: 1st EGG LAYING BY 1st GEN FEMALES
 4.   755 DDs after Jan 1: PEAK ADULT EMERGE 1st GEN
 5.   995 DDs after Jan 1: PEAK EGG LAYING BY 1st GEN FEMALES; MAX 2+ GENS.
 6. 1249 DDs after Jan 1: PEAK ADULT EMERGE 2nd GEN; MAX 3+ GENS.
 7. 1489 DDs after Jan 1: PEAK EGG LAYING BY 2nd GEN FEMALES; MAX 4+ GENS.
 8. 1743 DDs after Jan 1: PEAK ADULT EMERGE 3rd GEN; MAX 5 GENS.
 9. 1983 DDs after Jan 1: PEAK EGG LAYING BY 3rd GEN FEMALES; MAX 6+ GENS.
10. 2237 DDs after Jan 1: PEAK ADULT EMERGE 4th GEN; MAX 6+ GENS.
11. 2477 DDs after Jan 1: PEAK EGG LAYING BY 4th GEN FEMALES; MAX 7+ GENS.
```

Table 2. An easy-to-read reference showing expected degree-day totals for specific SWD events. As we validate the model we will adjust the degree-day totals.

Spotted Wing Drosophila (SWD) degree-days (DDs) for selected western locations are updated daily, hosted by OSU IPPC-ipmPIPE at http://uspest.org/swd/. (**Table 4**, right-->).

The numbers in the right-hand column are DDs as of the date (e.g., July 16, 2013).

Click on values on **Table 4** to get detailed output. We also report how this year compares to the previous two and to 1981-2010 normals (nearest location).

Table 4. SWD location forecasts.

Station Location (S to N)	SWD DDs July 16, 2013
Mtn View Moffett Fld CA	2048 DDs 12 days ahead of 2012 22 days ahead of 2011 9 days ahead of normal
Medford OR	1511 DDs 11 days ahead of 2012 26 days ahead of 2011 14 days ahead of normal
Corvallis OR	1164 DDs 16 days ahead of 2012 26 days ahead of 2011 12 days ahead of normal

Stay posted for further SWD developments!

spottedwing.org

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