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Beneficial and Pest Larval Species Common to Broccoli on the California Central Coast

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Common Beneficial Syrphid Larvae in Broccoli

Syrphid flies (Diptera: Syrphidae), which are also known as flower flies or hover flies, are widely considered to be the most economically important aphid predators in vegetable cropping systems (Hughes 1963, Colfer 2004, Smith *et al*. 2008). These bee-mimicking flies lay eggs that hatch into predacious larvae (or maggots), each of which can consume hundreds of aphids (Hopper *et al*. 2011). Nieto *et al*. (In Prep.) documented these predators reducing pest pressure in broccoli by 72-190 aphids/plant and increasing marketable (i.e. aphid-free) yield by 10-47%, when compared with broccoli that experimentally "excluded" syrphid larvae by using the larvicide Entrust® (Smith *et al*. 2008). Syrphid larvae similarly reduced lettuce aphid densities by 91%, relative to aphid densities on Entrust®-applied lettuce (Smith *et al*. 2008). Reliance on this naturally-occurring predation is especially relevant to organic vegetable production, where beneficial insectaries are often used to facilitate syrphid-driven aphid management (Hogg *et al*. 2011, Brennan 2013).

Growers have long observed, however, that the predation services offered by syrphid flies can be inconsistent or unpredictable; these predators may colonize a field either in insufficient densities or too late in a growing season to adequately control aphid densities in time for harvest. Subsequent research confirmed that the timing of aphid and syrphid establishment during a broccoli growing season strongly influences the likelihood of successful

(i.e. aphid-free) yields (Nieto *et al*. 2006, Ambrosino *et al*. 2007). While a wide array of factors (e.g. microclimate, landscape-level diversity, management practices, etc.) likely contributes to these unpredictable biological control outcomes, a limited understanding of how dynamic syrphid communities relate to, and interact with, agroecological systems only confound these inconsistent harvest outcomes. For instance, no fewer than 15 aphidophagous syrphid species have been recorded in California lettuce and cole crop systems (Oatman and Platner 1973, Smith and Cheney 2007, Chaplin-Kramer *et al*. 2013), and to further complicate matters, the composition of this generalist predator community often varies from region-to-region and year-to-year (Table 1).

In order to address these complexities, species-specific characterizations are required. Once syrphid communities have been robustly assessed, important species-specific descriptions and distinctions can then be made to help stabilize these predation services: e.g. source of field-level attraction (i.e. feeding vs. reproductive opportunities), seasonality, nectar source (i.e. beneficial insectary) preference, alternate prey species (i.e. non-pest aphids) compatibility, overwintering habitat suitability, and performance evaluations/comparisons of crop-specific species (e.g. Hogg *et al.* 2011).

The following broccoli-specific syrphid guide is intended to update and complement the previous work by Bugg *et al*. (2008).

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Table 1. Syrphid species distribution in California vegetable crops. Relative species rank (and percentage of total syrphids collected) provided per study column.

Syrphid Species	Monterey, Santa Cruz & San Benito Counties			Orange County
	broccoli[1] 2012-2014	broccoli[2] 2006-2008	lettuce[3] 2005	cabbage[4] 1967-1970
Allograpta exotica	-	7 (<1%)	-	2
Allograpta obliqua	1 (66%)	1 (67%)	4 (10%)	1
Eupeodes americanus	2 (12%)	-	8 (<1%)	-
Eupeodes fumipennis	-	3 (6%)	-	-
Eupeodes volucris	-	6 (1%)	7 (1%)	-
Metasyrphus meadii	-	-	-	6
Platycheirus stegnus	4 (9%)	5 (2%)	2 (27%)	-
Scaeva pyrastri	-	-	-	5
Syrphus opinator	3 (11%)	4 (4%)	5 (2%)	3
Sphaerophoria cylindrica	-	-	-	4
Sphaerophoria sulfuripes	5 (3%)	2 (18%)	3 (13%)	-
Toxomerus marginatus	-	-	1 (39%)	-
Toxomerus occidentalis	-	6 (1%)	6 (1%)	-

[1]Nieto *et al.* (In Prep.)

[2]Chaplin-Kramer *et al.* 2013

[3]Oatman and Platner 1973

[4]Smith and Cheney 2007

Distinguishing pest and beneficial larvae in broccoli

Pest caterpillars and beneficial maggots commonly found in cole crops are easily distinguishable (Fig. 1). These caterpillars have three pairs of true legs and 3-5 pairs of prolegs, whereas maggots are legless. While caterpillars have hard sclerotised heads with chewing mouthparts, maggots have nondescript heads with internal hook-like mouthparts. Finally, cole crop-associated caterpillars are larger (½ to 1½ inches) than comparable maggots ($^1/_3$ to ½ inches).

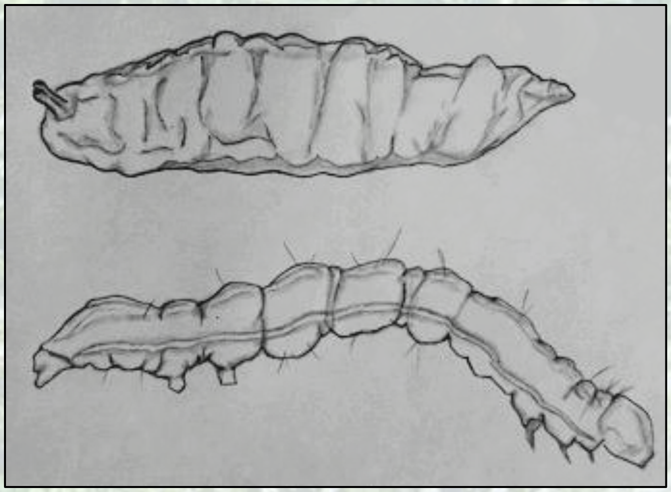

Figure 1. Maggot (above) and caterpillar (below). Anterior ends of both larvae are on the right.

Allograpta obliqua

Alloqrapia obliqua has been widely recorded throughout North America, including most of the continental United States, along with parts of Canada and Mexico (Weems 2014). This syrphid species is found in a diverse array of cropping systems, such as citrus, corn, alfalfa, cotton, vegetables and ornamentals; correspondingly, it feeds on numerous aphid species (e.g. pea aphid, cowpea aphid, melon aphid, apple aphid, lettuce aphid, etc.) (Weems 2014). In California, *A. obliqua* is consistently the most commonly encountered syrphid species in cole crops (Table 1).

The life cycle of *Allograpta obliqua* averages three weeks and nine weeks during summer and winter, respectively (Weems 2014). Using temperature settings that mimicked an average summer in Hollister, CA, laboratory-reared *A. obliqua* averaged roughly 22 days from egg to adult, which was shorter than three other syrphid species tested (including *Sphaerophoria sulphuripes*) (Hopper *et al*. 2011).

Allograpta obliqua is considered especially well-suited for lettuce aphid biological control. *Allograpta obliqua* larvae consumed an average of 22 lettuce aphids per day and 228 such aphids over a lifetime, which was greater than predation rates provided by smaller syrphid species, such as *Sphaerophoria sulphuripes* and *Toxomerus marginatus* (Hopper *et al*. 2011).

Given the prominence and predation potential of *A. obliqua* in organic vegetable production, targeted efforts towards this predator's conservation may be warranted. For instance, selecting beneficial insectary plantings that are compatible with *A. obliqua* feeding may improve aphid control. These efforts may be particularly

Adults: 6-7mm. Body primarily yellow and black, narrow, cylindrical and parallel-sided. Abdomen with yellow transverse banding; two posterior-most abdominal segments have four apparent yellow longitudinal bands. Photo by Ted Eubanks.

useful, as 1) syrphid flies can be quite selective when choosing a type of flower to feed upon (Colley and Luna 2000) and 2) *A. obliqua* populations are enhanced when sources of natural habitat are present in large scale broccoli production (Chaplin-Kramer *et al*. 2013). *Allograpta obliqua* has been observed feeding on (among other flowers) sweet alyssum, fennel, buckwheat and phacelia (Bugg *et al*. 2008, Hogg *et al*. 2011).

Larvae: 8-11mm. Color variable, but often green with two white lateral lines extending almost the entire length of the body dorsally. Body is elongate, smooth and slightly transparent. Breathing tubes long and fused at base, diverging sharply to create a Y-shaped structure (Fig. 2).

Figure 2. Breathing tubes of *Allograpta obliqua* (top) and *Sphaerophoria sulphuripes* (bottom)

Eupeodes americanus

Eupeodes americanus has been widely documented throughout the continental United States, with particular focus paid to these predator populations in the Great Lakes Region, the Virginias and the West Coast (Short and Bergh 2005, Brown and Mathews 2007, Noma *et al*. 2010, Smith and Chaney 2007, Gontijo *et al.* 2012). *Eupeodes americanus* has also been recorded throughout Canada (Vockeroth 1992) and in Sonora, Mexico (IB-UNAM 2015). This syrphid is a commonly encountered predator of woolly apple aphid and rosy apple aphid in apple orchards (Brown and Mathews 2007, Gontijol *et al.* 2012). *Eupeodes americanus* is also (although much less commonly) encountered preying upon soybean aphid and lettuce aphid in soy and lettuce, respectively (Smith and Chaney 2007, Noma *et al*. 2010).

The inconsistent and unpredictable presence of *E. americanus* in cole crops makes

Adults: 9-12mm. Large fly that is easily confused with *Syrphus opinator*. Thorax is often a metallic yellow-bronze. Abdomen is flat with prominent yellow transverse banding. Unlike *S. opinator*, front of face has a dark stripe or stippling (Fig. 3). Photo by Kim Phillips.

Figure 3. Faces of *Eupeodes americanus* (top) and *Syrphus opinator* (bottom).

Eupeodes americanus

this a somewhat enigmatic predator. For instance, despite being completely absent from all multi-county broccoli collections in 2013, *E. americanus* was nonetheless ranked 2nd in overall species composition (Table 1), largely as a result of very high densities recorded in 2014 (Nieto *et al*. In. Prep). Other studies provide similar contradictions: On the California Central Coast, *E. americanus* densities were moderate-to-high in Brussels sprouts from 2010-2011, but were completely lacking in broccoli from 2006-2008 (Nieto *et al*. unpublished data, Chaplin-Kramer *et al*. 2013). A similar pattern was described in Washington apples, as *E. americanus* and *E. fumipennis* were abundant one season and absent the next (Gontijol *et al*. 2012).

Larvae: 11-12mm. Opaque tortoiseshell pattern with tan, brown and black markings. Dorsal heartline is black and interrupted by six white-to-tan-colored transverse bars on posterior half of body. Ridges and relatively pronounced spines are also present. Very inconspicuous tubercles also present and are easily contrasted with apparent *S. opinator* breathing tubes. Larvae display very active behavior by using its anterior end to constantly probe in front of it's body while moving along a leaf’s surface.

Syrphus opinator

Syrphus opinator has been observed primarily on the West Coast. In California, *S. opinator* has been documented in Southern California, the Central Valley and the Central Coast (Kamal 1926, Oatman and Platner 1973, Neuensch *et al*. 1975, Smith and Chaney 2007). *Syrphus opinator* has also been documented in Oregon, Washington and Southwestern Canada (Vockeroth 1992, Colley and Luna 2000, Gontijo *et al* 2012).

This syrphid feeds on cabbage aphid in cole crops, lettuce aphid in lettuce, pea aphid and spotted alfalfa aphid in alfalfa and woolly apple aphid in apples (Neuensch *et al*. 1975, Colley and Luna 2000, Smith and Chaney 2007, Gontijo *et al* 2012). While *S. opinator* occupies intermediate species rankings (3rd – 5th) in California vegetable production (Table 1), it's a particularly prominent woolly apple aphid predator in Washington orchards (Gontijol *et al* 2012), where the use of sweet alyssum as a beneficial insectary improved aphid biological control (Gontijol *et al.* 2013). In addition to alyssum, *S. opinator* has also been recorded on fennel, phacelia and yarrow (Colley and Luna 2000, Bugg *et al*. 2008, Hogg *et al*. 2011).

Adults: 7-12mm. Large fly with convex abdomen and prominent yellow transverse banding. Thorax typically a dull greenish-bronze color. Face yellow-to-brown and without markings (Fig. 3). Photo by Gary Mcdonald.

Syrphus opinator

Larvae: 12-14mm. Lemon-yellow to brown-yellow in color with ridges and spines. Banding pattern forms distinct chevrons in older larval stages and extends as a narrow line completely to the anterior end. The heartline is dark brown to black and is conspicuous. Breathing tubes are also brown and conspicuous.

Sphaerophoria sulphuripes

Sphaerophoria sulphuripes has been documented on the West Coast, specifically California (e.g. Orange County and Central Coast) and Oregon (Oatman and Platner 1969, Colfer 2004, Ambrosino *et al*. 2007). On California's Central Coast and in Oregon's Willamette Valley, *S. sulphuripes* is one of the most prevalent aphid predators in lettuce and cole crops (Colfer 2004, Ambrosino *et al*. 2007, Smith and Cheney 2007, Chaplin-Kramer *et al*. 2013). In both of these regions, *S. sulphuripes* was recorded feeding on alyssum and yarrow (Colley and Luna 2000, Bugg *et al*. 2008).

Sphaerophoria sulphuripes has an anticipatory oviposition (i.e. egg-laying) strategy that distinguishes it from other sryphids. Smith and Chaney (2007) report that *S. sulphuripes* was 1) most commonly collected in a field with low aphid densities, when compared with fields possessing moderate-to-high aphid densities, 2) more likely than other syrphid species to deposit eggs on plants that lacked aphids (e.g., almost half of *S. sulphuripes* were collected from such prey-free plants, and 3) oviposition rates (1.19 eggs/plant) were relatively low.

Adults: 8-9mm. Body very narrow and cylindrical. Abdomen has uniform yellow and black transverse banding. Males have conspicuous bulbous genitalia; females with most-posterior abdominal segments showing prominent black spots against yellow background. Photo by Linda Dahlberg (DiscoverLife.org).

Within a life cycle of approximately 27 days, *S. sulphuripes* consumed 194 lettuce aphids (Hopper *et al*. 2011). Based on high-risk oviposition strategies and relatively low predation rates, it therefore may not be surprising that 1) *S. sulphuripes* larvae are smaller than either *Allograpta obliqua* or *Eupeodes fumipennis* larvae and 2) *S. sulphuripes* was estimated to have a

Sphaerophoria sulphuripes

lesser capacity for lettuce aphid control, when compared with these larger species (Hopper *et al*. 2011). However, the potential of *S. sulphuripes* to prevent aphid colonies from establishing may mitigate these limitations and provide complimentarity within the syrphid community.

Larvae: 9-10mm. Green in color with two white lateral lines extending the length dorsally. Body is somewhat stout, smooth and slightly transparent. Breathing tubes are shorter than those belonging to *A. obliqua*, fused at base, and are not divergent (Fig.2).

Platycheirus stegnus

Platycheirus stegnus has been documented in Southwestern Canada, the Western United States and Mexico (Vockeroth 1992, Young 2012). In California and Oregon, *P. stegnus* is an important aphid predator in cole crops and lettuce (Ambrosino *et al*. 2007, Smith and Chaney 2007, Chaplin-Kramer *et al*. 2013).

Platycheirus stegnus has a high prey density oviposition (i.e. egg-laying) strategy that distinguishes it from other syrphids within this community. Smith and Chaney (2007) report that *P. stegnus* was 1) most commonly collected in fields with high aphid density fields, 2) the most well represented species (e.g. 71%) in these aphid-infested crops, 3) more likely than most other syrphid species to deposit eggs on plants with high aphid densities (e.g. 86 lettuce aphids/plant), and 4) was likely to deposit multiple eggs per plant (e.g. 7.5 eggs/plant). *Platycheirus stegnus* demonstrated similar responses to very high cabbage aphid densities on the Central Coast, in which these late-arriving predators quickly reduced pest populations in Brussels sprouts and broccoli (Nieto *et al*. unpublished data). Consequently, *P. stegnus* often constitutes the “syrphid of last resort” with respect to aphid management.

Adults: 7-10mm. Gray body with dark metallic blue/black thorax. Distinct black transverse banding is present on abdomen. Photo by Aaron Schusteff.

Platycheirus stegnus

Larvae: 10-11mm. Uniformly orange to rust-orange in color, with two white lateral lines visible in older larvae that originate from the breathing tubes and extend dorsally, converging into one narrow anterior line. Body is lightly transparent with somewhat short and stubby breathing tubes. Multiple immature larvae are bright orange and surprisingly conspicuous given their small size and often-partially obstructed position within dense aphid colonies.

Common caterpillar pests in broccoli

The caterpillar community in cole crops on the Central Coast is comprised primarily of the diamondback moth (*Plutella xylostella*), cabbage looper (*Trichoplusia ni*) and imported cabbageworm (*Pieris rapae*) (Fig. 4). The susceptibility of cole crops to economically-relevant caterpillar feeding damage depends partially on crop type; i.e. when florets, rather than leaves, are harvested (e.g. broccoli or cauliflower), a crop can sustain fairly high caterpillar densities without compromising yield. However, if leaves are harvested (e.g. cabbage or collards), moderate feeding alone may significantly limit yields. Frass (i.e. caterpillar excrement) can also create a contamination issue when larger caterpillar species (e.g. cabbage looper) are abundant.

Figure 4. Caterpillars commonly found in cole crops: **Diamondback moth (left)** possesses distinct black bristles, forked posterior prolegs, and displays "squirmish" behavior when disturbed; **Cabbage looper (center)** is largely smooth, demonstrates looping (i.e. arched body position) behavior while walking, and is the largest of the three caterpillars; **Imported cabbageworm (right)** is hairy, providing a velvet-green appearance, with yellow stripes (solid dorsally and broken laterally) and demonstrates a relatively lethargic behavior (McCalley *et al.*1992).

Commonly-applied organically-compliant materials for caterpillar management are generally safe, affordable, targeted (i.e. rather than broad spectrum) and effective. However, prior to applying larvicides, the following considerations should be weighed: First, a crop's susceptibility to yield-compromising caterpillar feeding varies tremendously (as described above). Second, a robust community of egg, larval and pupal parasitoids commonly maintains these pests below economic thresholds. For example, the diamondback moth (DBM) parasitoid *Diadegma insulare* (Fig. 5) is very effective at reducing DBM populations on the central coast (Fox *et al.* 1990), but is vulnerable to insecticide exposure (Idris and Grafius 1993). Third, these pest caterpillars, and DBM in particular, are adept at developing resistance. Various DBM populations are resistant to many commonly used insecticides, including *Bacillus thuringiensis* (Bt) and spinosad (Sayyed *et al.* 2004, Baxter *et al.* 2005, Zago *et al.* 2014). Fourth, larvicide use may also detrimentally affect syrphid larvae, which would of course compromise cabbage aphid management. For instance, the organically-compliant spinosad larvicide Entrust® induced high mortality rates among these predacious larvae (Smith *et al.* 2008, Nieto *et al.* In Prep.). Consequently, pest management decisions should attempt to incorporate comprehensive assessments of both pest and beneficial insect communities prior to chemical applications to best promote positive harvest outcomes.

Figure 5. Dianmondback moth parasitoid *Diadegma insulare*.
Photo by David Wahl.

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