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Research Brief #13

Can Hedgerows Attract Beneficial Insects and Improve Pest Control? A Study of Hedgerows on Central Coast Farms

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Hedgerows began to appear on Central Coast farm edges in 2000, due largely to the efforts of the non-profit Community Alliance with Family Farmers (CAFF).[a] On the Central Coast, hedgerows consist of linear assemblages of trees, shrubs, herbs and grasses, many of them native species, which provide multiple services to farms.

When contour-planted on a sloped field, mature hedgerows with deep and fibrous root systems can reduce soil erosion as well as absorb mobile nutrients like nitrate (Kinama et al. 2007, Bu et al. 2008). Tall, dense hedgerows act as a windbreak, which can reduce crop field edge effects such as stunted growth or poor germination, as well as protect crops from physical and chemical contaminants. Hedgerows with dense canopies can also suppress weed populations in the field margin (often the source of field weeds) through competition for light, water, and nutrients (Boutin 2006). These ecosystem services from hedgerows have been observed and documented. Consequently, on California's Central Coast, hedgerows have become a recommended practice for irrigated agriculture, especially for the goals of biodiversity and water quality conservation (CAFF website, NRCS 2008).

Producers are also interested in hedgerows for their potential to support beneficial insect populations. However, compared with other functions they provide, the role that hedgerows play in enhancing biological control services is less understood. Generally, increasing the diversity of plants and providing undisturbed habitat in the field margin increases both the diversity and abundance of insects. Reducing tillage decreases insect mortality rates, allowing surviving insects to reproduce and contribute new individuals to the future generation. Furthermore, untilled land with permanent vegetation can increase the fitness of insects by providing them with critical resources such as pollen, nectar, host prey, and shelter.

From an invertebrate conservation standpoint, an increase in insect diversity is a positive result of hedgerows. However, from a biological control standpoint, we are also interested in increasing numbers of specific natural enemies that attack pests of economic importance, while not creating or exacerbating pest problems. It is often assumed that if natural enemies are attracted and retained in farms with added habitat, then their control of pests in crop fields will also increase. However, in order for biological control to take place, insect natural enemies must disperse from flowering habitat into the crop field to either parasitize (if a parasitoid) or consume (if a predator) their host prey. The results of studies that have tested the effects of added habitat on predation or parasitism rates in the field are often quite variable (Lee and Heimpel 2005, Pfiffner et al. 2009) or show no apparent effect (Rebek et al. 2006, Lee and Heimpel 2008).

The objectives of this study, conducted from 2005 to 2007, were (1) to assess the habitat quality of different hedgerow plants for insect natural enemies and pests, (2) to track the movement of insects from hedgerows into adjacent crop fields and (3) to test the effect of hedgerows on parasitism rates of an economically important pest, the cabbage looper (*Trichoplusia ni*).

Many conservation biological control studies are set up as greenhouse or field experiments where environmental factors, such as the host crop environment, herbivore populations, and climate are controlled, and the only varying factors are the habitat or resource treatments. This approach is extremely useful for screening plants for insectary qualities and determining fundamental behavior response of particular

Figure 1. Tara Pisani Gareau collects insects from a hedgerow shrub in San Juan Bautisita, CA.

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insect species. However, actual agro-ecosystems—where an array of factors influence insect interactions with plants and other insects—can be complex.

The question of whether or not hedgerows can enhance biological control services in Central Coast farm systems is best addressed with on-farm studies. Thus we assessed the hedgerows that growers planted in their fields, rather than manipulate hedgerow and crop field plantings. While this approach can add more variability or "noise" to results, detected patterns also better reflect the ecological reality of hedgerows planted in Central Coast farms.

METHODS

The attractiveness of hedgerow plants to key insect natural enemies and pests

This study took place at four farms with hedgerows on the Central Coast of California. Using a vacuum sampler (Figure 1), we monitored key insect natural enemies and pests at six hedgerow plants: common yarrow (*Achillea millefolium*), coyote brush (*Baccharis pilularis*), California lilac (*Ceanothus griseus* and *C.* 'Ray Hartman'), perennial buckwheat (*Eriogonum giganteum*), toyon (*Heteromeles arbutifolia*), and coffeeberry (*Rhamnus californica*). We chose to monitor these native California plants because they are commonly used as foundational plants in hedgerow design (Earnshaw 2004).

At each hedgerow site, we sampled insects from four to five replicates of each plant species eight times in 2005 and ten times in 2006 between the months of May and October. We also measured the availability of floral resources on each individual plant for each sampling period.

The dispersal of indicator insects from hedgerows into adjacent crop fields

We conducted an insect tracing experiment three times during the summer of 2006. Insects foraging on hedgerow plants were marked with a yellow fluorescent pigment, which was sprayed on hedgerow vegetation twice during each trial according to methods described by Schellhorn et al (2004).

We did this experiment at four different vegetable fields with bordering hedgerows and placed 10 traps immediately following the second spray at 25 m and 100 m from the hedgerows (20 traps/field). The mark is distinguished on insects under magnification with a UV lamp.

The effect of hedgerows on parasitism rates of a sentinel pest

In 2006 and 2007 we set out first and second instar cabbage looper larvae on 20 potted collard plants in eight vegetable fields. We used the vegetable fields adjacent to the hedgerows where we monitored indicator insects and paired those fields with a nearby vegetable field that lacked a hedgerow in the field margin.

In 2006, five sentinel collard pots were placed in each field at 10, 25, 50 and 100 m from the field margin. Since the rotations of the vegetables often led to sentinel pots being placed in different crop environments, in 2007 we tried to better standardize the surrounding crop by placing ten sentinel pots within a near distance of 10–25 m and far distance (50–100 m) in crops known to host cabbage looper or if not available, on bare ground. Larvae were collected from the potted collard plants after seven days and brought back to the laboratory where they were raised on an artificial diet in a growth chamber. Percentage parasitism was calculated for each distance by totaling the number of collected larvae from the pots at the distance, dividing that number by the total number of parasitized larvae and multiplying by 100. This experiment was conducted three times in each year.

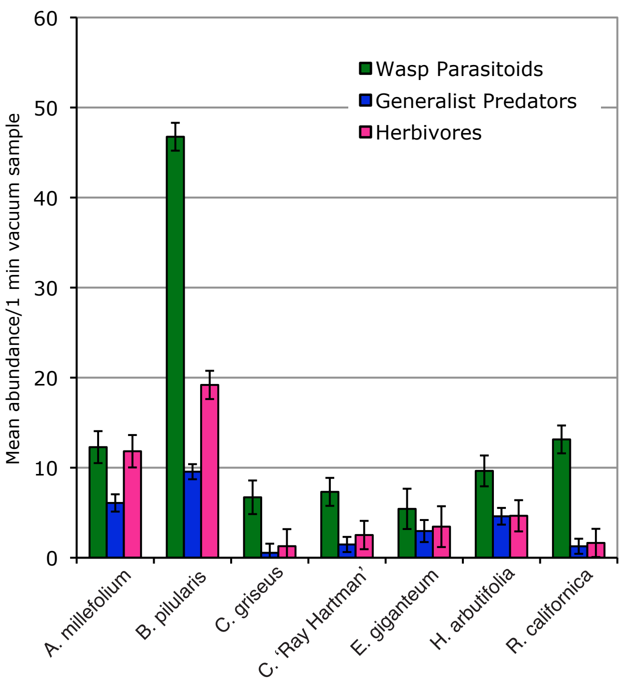

Figure 2. Mean number of wasp parasitoids, generalist predators and herbivores collected in 1 minute vacuum samples from May through October 2006.

Wasp parasitoids included hymenopterans from the families: Ichneumonidae, Braconidae, and Chalcidoidea. Generalist predators include the following insect taxa: lady beetles (Coleoptera: Coccinellidae), syrphid flies (Diptera: Syrphidae), green lacewings (Neuroptera: Chrysopidae), brown lacewings (Neuroptera: Hemerobiidae), minute pirate bugs (Orius spp., Hemiptera: Anthocoridae), big-eyed bugs (*Geocoris* spp., Hemiptera: Lygaeidae), and damsel bugs (Nabis spp., Hemiptera: Nabidae). Herbivores included the western spotted cucumber beetle (*Diabrotica undecimpunctata undecimpunctata*, Coleoptera: Chrysomelidae), the western striped cucumber beetle (*Acalymma trivittatum*, Coleoptera: Chrysomelidae), flea beetles (*Phylotretta* spp., Coleoptera: Chrysomelidae), the western tarnished plant bug (*Lygus hesperus*, Hemiptera: Miridae) and aphids (Homoptera: Aphidae).

RESULTS

Key insect natural enemies and pests attracted to hedgerow plants

We found a number of natural enemy taxa important in the biological control of crop pests in Central Coast hedgerows. Parasitic wasps, minute pirate bugs, lacewings, lady beetles, and syrphid flies were commonly found on hedgerow plants.

The minute pirate bug (*Orius* spp.) was the most abundant predator sampled on hedgerow vegetation, followed by lady beetles (Coccinellidae), big-eyed bugs (*Geocoris* spp.), green lacewings (Chrysopidae) and brown lacewings (Hemerobiidae), respectively. Overall, wasp parasitoids were consistently more abundant on hedgerow plants than generalist predators or herbivore pests (Figure 2). Indeed, Chalcidoidea, a super family of minute parasitic wasps, was the most abundant insect group overall, comprising 54% of the total indicator insects collected in 2006.

Key pests of vegetable and fruit crops were also present on hedgerow plants and cumulatively represented 10% and 14% of the indicator insects sampled in 2005 and 2006. The most abundant key pests found were the western spotted cucumber beetle (*Diabrotica undecimpunctata undecimpuntacta*), followed by the western striped cucumber beetle (*Acalymma trivittatum*), the flea beetles (*Phylotretta* spp.) and the western tarnished plant bug or lygus (*Lygus hesperus*).

The western spotted cucumber beetle represented 8.5% and 10% of the indicator insects collected across the sampling periods in 2005 and 2006 respectively. However, most of the cucumber beetles collected came from one study site, and were found mainly on toyon and coyote brush.

We also found aphids in hedgerows, although the majority appeared to be species other than cabbage and lettuce aphids and most likely species related to woody vegetation. Thus it is possible that aphids on hedgerow plants may be alternate prey or host for natural enemies or provide them with added sugar resources in the form of honeydew.

Other key pests of vegetables such as the silverleaf whitefly (*Bemisia argentifolli*), the cabbage looper (*Trichoplusia ni*) and the imported cabbageworm (*Pieris rapae*) were either not collected or extremely rare.

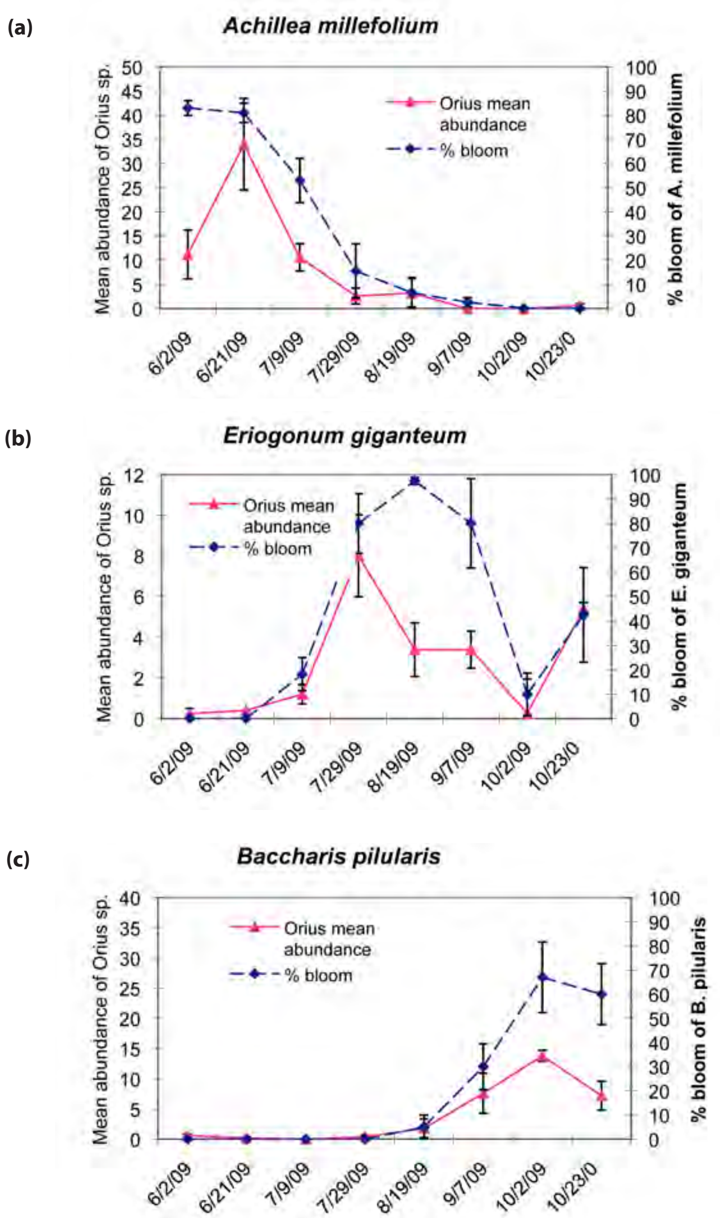

Figure 3. Mean abundance of *Orius* spp. at yarrow (a), perennial buckwheat (b), and coyote brush (c) within a hedgerow in San Juan Bautista, CA. The dashed blue line represents percentage bloom of the plant.

Association between floral resource availability and insect abundance

Out of all the insects monitored in the study, the minute pirate bug was the most influenced by floral resources. In 2005 and 2006, *Orius* spp. abundance was positively correlated with the floral resource availability of all hedgerow plants, except for *C. griseus*. The abundance of *Orius* spp. generally overlapped at hedgerow plants tracking the plants' bloom periods. For example at the San Juan Bautista site in 2005 *Orius* had the highest abundance on yarrow in the spring, on perennial buckwheat in the summer and on coyote brush in the late summer (Figure 3).

Attractiveness of hedgerow plants

To assess the attractiveness of hedgerow plants to insect natural enemies and pests, we relativized or "scaled" the data equally so that we could compare the distribution across plants of insect taxa that may have different abundances due

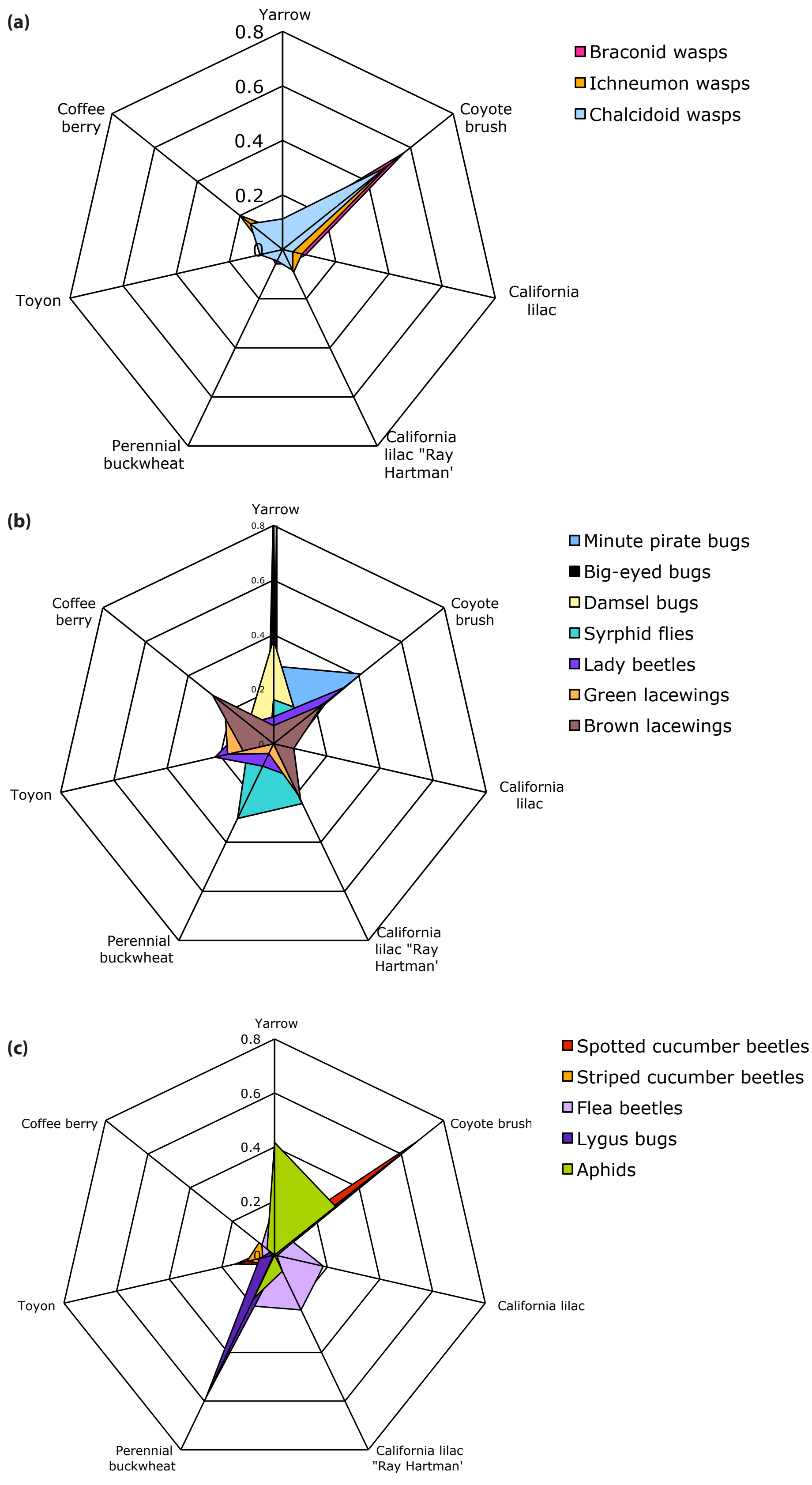

Figure 4. Spider plots of the relative abundance of (a) wasp parasitoids, (b) generalist predators, and (c) herbivore groups collected on hedgerow plants in 2006. The sum of the data for each insect taxa equals 1.0.

to the natural abundance of the group in the environment or to the sampling method used. Relativized data were then summed by plant and plotted in "spider" charts to visually represent the overall distribution of each insect taxa across plants in hedgerows (Figure 4).

These graphs do not reflect the variation in abundance over time, nor across sites; rather, they provide a summary picture of the attractiveness of hedgerow plants to the indicator insects. Long, thin polygons "pointing" towards the tip of an axis represent a strong association with the plant on the axis; short, round polygons represent a more even distribution across hedgerow plants.

Parasitic wasps were highly attracted to coyote brush, as indicated by the one directional polygon on the coyote brush axis (Figure 4a). In contrast, predators showed a more even distribution across hedgerow plants, with the exception of big-eyed bugs, which were exclusively found on yarrow (Figure 4b). Syrphid flies were also more attracted to perennial buckwheat and California lilac 'Ray Hartman' in comparison to the other plants.

Herbivore groups exhibited strong attraction to particular plant species (Figure 4c). Aphids were attracted to yarrow and coyote brush. Lygus bugs were highly attracted to perennial buckwheat. Flea beetles were more commonly collected at the California lilac varieties as well as the buckwheat. Finally, cucumber beetles were highly attracted to coyote brush, although this relationship occurred only in 2006 and primarily at one site. Coffeeberry and toyon were not attractive to key pests nor to aphids.

The dispersal of indicator insects from hedgerows into adjacent crop fields

The fluorescent mark placed on both natural enemies and pest species was found on all insect taxa at 25 m and 100 m, except for lady beetles and flea beetles, which were only found marked at 25 m (Figure 5). The mean proportion of marked individuals, however, was significantly higher at 25 m and dispersal rates varied across taxa. Minute pirate bugs showed low movement rates into adjacent crop fields (<10% at 25 m and 100 m).

However, when distances are combined to get an overall mean rate of movement into fields, predators as a functional group had a higher rate of movement (17.3m ± 2.9 SE) than both parasitoids (5.4m ± 1.5 SE) and pests (6.5m ± 1.3 SE). In particular, syrphid flies and green lacewings, showed the greatest dispersal capacity, followed by brown lacewings. Of the wasp parasitoids, ichneumonid wasps showed the highest rates of movement into crop fields at both distances.

The effect of hedgerows on parasitism rates

In 2006, parasitism of "sentinel" cabbage looper larvae placed in fields was detected mostly in the June trial and at only two sites, a field with a hedgerow and a control field without a hedgerow. However, these fields were not paired (i.e., not within the same geographic location) and thus not comparable in terms of detecting a hedgerow effect.

Results from this trial suggested that the surrounding crop may strongly influence parasitism rates. In the San Juan Bautista field, percentage parasitism ranged from 70% in the brassica stand to 0% where there was bare ground (Figure 6). In contrast, in the control field planted entirely in a brassica crop, parasitism rates ranged from 20% to over 80%. Parasitism rates also declined with distance from the field margin in the comparison field, indicating that parasitoids may be more abundant on the edges of fields.

In 2007, parasitism was detected in all three trials, however, rates never reached as high as those seen in the June 20006 trial, and generally there was a high variation in rates within and between fields across the trials (Figure 7). On average, percent parasitism was significantly higher at 100 m in the comparison fields than at 25 m in those same fields as well as at 25 and 100 m in hedgerow fields. There was no significant difference in parasitism at 25 m between hedgerow and comparison fields.

Seven parasitoids were reared from sentinel cabbage looper (*T. ni*) larvae in 2007. The majority of parasitism (77.5%) was by a *Hyposoter* wasp (Hymenoptera: Ichneumonidae)

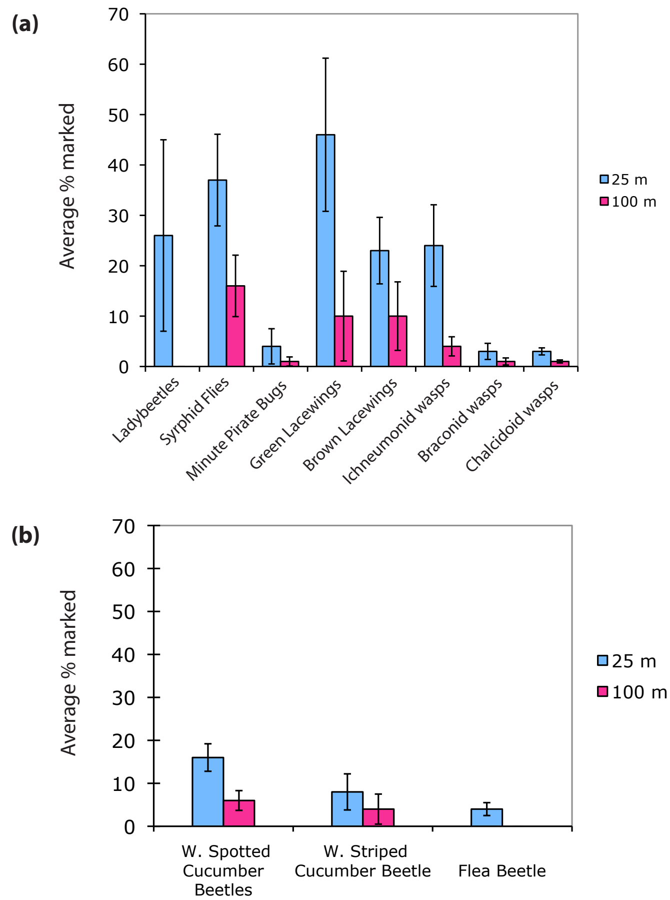

Figure 5. Average percentage of marked natural enemies (a) and pest species (b) found 25 m (blue bars) and 100 m (red bars) from hedgerows.

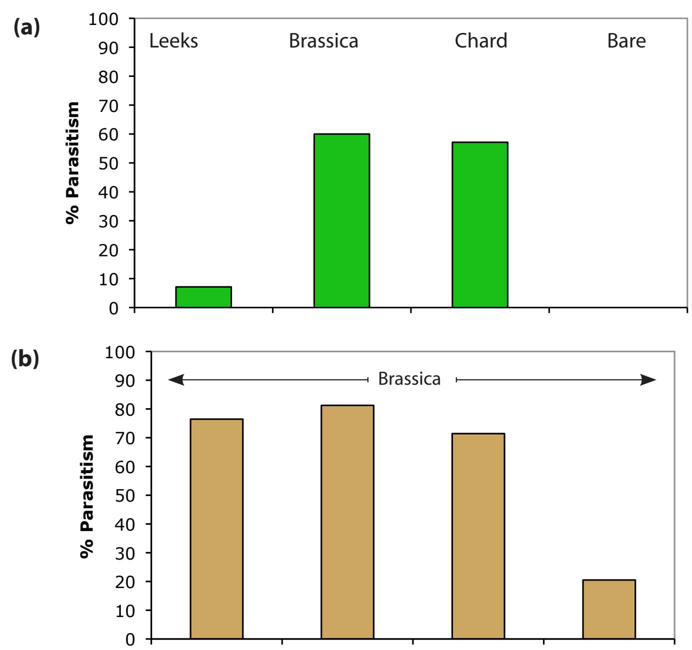

Figure 6. Percentage parasitism in a field with a bordering hedgerow (a) in San Juan Bautista; and in a field with an unmanaged field margin (b) in Watsonville. Trial occurred in June 2006.

(Figure 8). Tachinid flies (Dipetera: Tachinidae) contributed 16% to the total parasitism.

DISCUSSION

Results from this study support the hypothesis that hedgerows provide beneficial insect habitat. Over the course of the study and across sites, we typically found that insect natural enemies were more frequent and abundant in hedgerow samples than key insect pests. This is an important finding, because our farm sites varied in geographic location (from Watsonville to Hollister), cropping patterns, and to some extent hedgerow characteristics such as plant density, cover, and composition. Thus we believe that hedgerows can play an important role in the conservation of insect natural enemies in vegetable systems.

However, hedgerow plants are not created equal in terms of quality and accessibility of resources for insect natural enemies. We found strong patterns of insect-plant associations in both years of the study. Particularly striking was that wasp parasitoids were generally four times more abundant on coyote brush than other plants. Yarrow was also a highly attractive plant, especially to hemipteran predators, including big-eyed bugs.

We expected floral resources to drive insect abundances on all plants, but found this association to be strongly positive for only the minute pirate bugs. There was no correlation between the abundance of wasp parasitoids and floral resources of coyote brush. While our observations suggest that insect natural enemies forage on hedgerow plants, clearly other mechanisms also influence their presence and abundance on plants. Insects use hedgerows as refuges to rest and reproduce and very likely as a site to feed on or parasitize alternate prey.

In Central Coast vegetable systems, hedgerows may also provide resources to pest species as well as insect natural enemies. Pest presence in a hedgerow, however, may not be a bad thing. In addition to pollen and nectar, predators need to consume prey species and may take advantage of the honeydew produced by aphids. In fact, the combination of both floral resources and prey presence results in increased egg laying by green lacewings (Jonsson et al. 2009). If host prey species are not present in the fields due to the delayed planting or absence of the crop, the availability of alternate prey in field margins may help the farm system retain natural enemies. The same principle applies to parasitoids, which can parasitize alternate prey found in extra field vegetation early in the season when host prey are not available (Doutt and Nakata 1973). Of course the presence of pests in hedgerows should not exacerbate crop damage; thus we recommend regular monitoring of hedgerows for pests.

While we assume that hedgerows are not the source habitat for cucumber beetles, it was apparent that cucumber beetles use hedgerow resources. We collected and observed an abundance of cucumber beetles at one site where large stands of cucurbit crops (melons and squash) were grown. In October 2006 the beetle numbers spiked within the hedgerow, and specifically in coyote brush when the plant was blooming and field cultivation was occurring. It is unclear whether the hedgerow provided an overwintering location for the cucumber beetles, although this scenario is possible since research has shown that cucumber beetles hibernate in protected areas and tend to aggregate close to field borders (Luna and Xue 2009). If that is the case, hedgerow management for

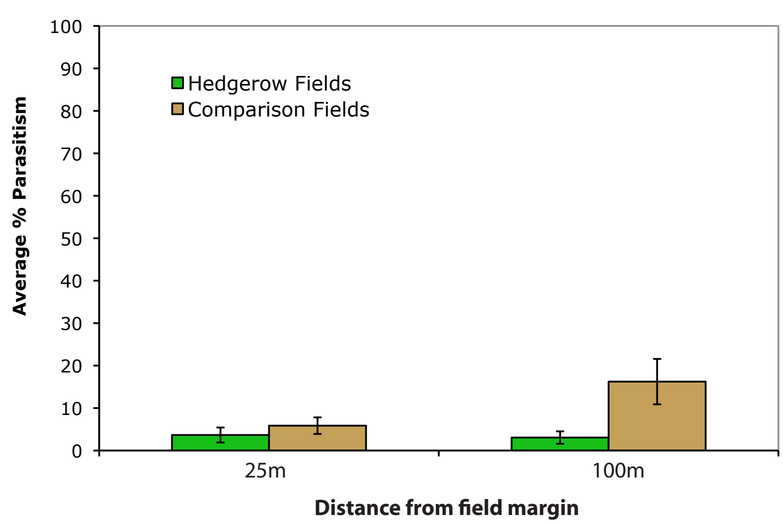

Figure 7. Average percentage parasitism in fields with a bordering hedgerow and fields without a hedgerow (N=4 paired fields). Data collected in 2007.

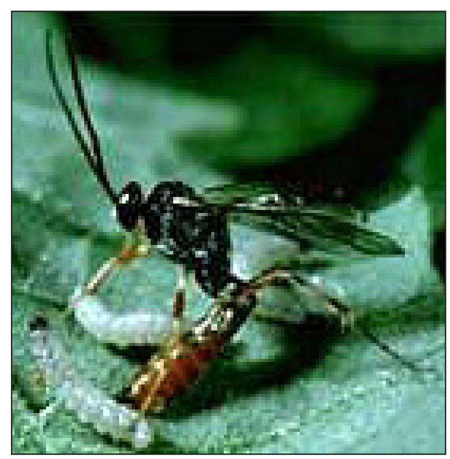

Figure 8. ***Top:*** **a Hyposoter wasp is shown parasitizing a young cabbage looper larva. Hyposoter's white speckled pupa about ¼ inch long (*bottom*) can be found attached to the underside of leaves.**
UC Statewide IPM Project.

vegetable systems that naturally host high populations of cucumber beetles might include early season traps to catch dispersing beetles. Kairomone traps that could lure pest species out of the hedgerow (Hoffman et al. 1996, Jackson et al. 2005) may be a sound approach to controlling pest species without harming the insect predators and parasitoids that are also using hedgerow resources.

Key insect natural enemies were present on hedgerow plants and these insects dispersed into adjacent crop fields. The majority of insects dispersed up to 100 m from the margin within a week of visiting the hedgerow. For many organic vegetable fields, 100 m from the border may represent the middle or far end of the field, indicating good coverage of crops by natural enemies. Since we only marked insects foraging on hedgerows, we don't know whether or not insects would disperse at higher rates from non-flowering edge habitat or surrounding fields. The prey search behavior of parasitoids and predators may decline directly after nectar feeding (Lee and Heimpel 2007), which can explain why natural enemy abundance and biological control rates tend to increase along field edges that are close to floral resources (van Emden 1965, Pollard 1971, Lavandero et al. 2005).

With the exception of lady beetles, we found that large-bodied insect natural enemies (lacewings, syrphid flies, and ichneumonid wasps) had higher rates of dispersal than small-bodied insects (minute pirate bugs, braconid and chacidoid wasps). This finding is congruent with the general consensus on insect dispersal. Thus, the area of influence of hedgerows on caterpillar and aphid pest densities may be greater than on minute pests like mites or leaf miners, whose small natural parasitoids may have limited dispersal capacity. Combining hedgerows with in-field floral plantings (in strips or randomly throughout) may increase dispersal of small-bodied insects through the fields.

Results from the 2006 and 2007 parasitism trials were not conclusive because the crop environment was not adequately controlled within and across fields. We believe that the crop environment affected the background population of cabbage loopers, which in turn affected the diversity and abundance of parasitoids present in the systems. Keep in mind that we did not release a standardized amount of parasitic wasps in each field, as was done in other studies that have demonstrated positive effects of floral resources (Begum et al. 2006, Araj et al. 2009), but rather we relied on the naturally occurring parasitoid populations. Further variability in the stage of development of the crop, which influenced the exposure of the sentinel potted plants, may have also affected wasp foraging behavior. Being able to place sentinel larvae in a standardized crop matrix is essential for detecting the effects of added floral resources. The diversity of Central Coast organic mixed vegetable systems may swamp any effect of hedgerows or other habitat enhancement. The effects of on-farm habitat on ecosystem services may be more detectable in simplified landscapes.

Despite the lack of a clear field margin effect, it was apparent that the *Hyposoter* wasp plays a primary role in the parasitism of early instars of cabbage looper in mixed vegetable systems. Several other studies have also found *Hyposoter* species to be dominant parasitoids of noctuid larvae such as cabbage loopers (Henneberry et al. 1991, Ehler 2007, Haines et al. 2009).

To enhance natural biological control services of cabbage loopers and perhaps other caterpillar pests, it is important to determine the habitat requirements of this key parasitoid. We know that *B. pilularis* supports a high abundance of ichneumonid wasps, but we did not determine if *Hyposoter* was among the ichneumonid wasps present on *B. pilularis*. Nor do we understand the mechanisms that explain the attraction of ichneumonid wasps to the shrub. Further research to fill in these knowledge gaps would be useful, particularly the role alternate prey might play in either supporting parasitoids when host prey are not available or deterring the parasitoids from control of the key agricultural pests.

RECOMMENDATIONS AND CONCLUSION

Our research shows that the overall design of most Central Coast hedgerows—a mix of perennial flowering plants with different architectures and overlapping bloom periods—is accomplishing the goal of providing beneficial insect habitat. Each plant appears to be especially attractive to different insect natural enemies: coyote brush to parasitic wasps, common yarrow to hemipteran predators, coffeeberry to lacewings and perennial buckwheat and California lilac to syrphid flies. Even toyon, which did not attract a higher proportion of any one group of insect, was used by several different insect groups during the middle of the summer when other flower resources were scarce. Planting a diversity of plants that have different floral architectures should increase the likelihood of conserving a diverse community of insect natural enemies. Coyote brush and yarrow would be especially important foundational plants in hedgerows. In addition, as noted above, combining hedgerows with in-field floral plantings (in strips or randomly throughout) may increase the dispersal of small-bodied insect natural enemies through the fields.

Results from our study show that hedgerows provide habitat for insect natural enemies; however, although our dispersal and sentinel studies showed beneficial species dispersing from hedgerows and parasitism occurring, we could not definitively answer the question of whether the presence of hedgerows translates to improved pest control at the field level. This may in part reflect a limitation of our study design, which looked only at parasitism of one pest organism and did not assess the rate of predation by the many generalist predators that we found dispersing from hedgerows.

A variety of factors determine the rate at which a natural enemy population will attack an agricultural pest, including its nutritional status; host prey density in the field (Costamanga et al. 2004, Vollhardt et al. 2010);

alternate prey density; crop matrix diversity (which affects the ability of the natural enemy to locate its prey (Andow 1991); the proximity of the floral resource to the host prey (Vollhardt et al. 2010); and the habitat complexity and composition of the surrounding landscape (Thomson and Hoffman 2010).

To better manipulate these variables, more controlled experiments among different landscapes would be an important next step. Additionally, for a more holistic assessment, future hedgerow research on biological control should include monitoring a greater diversity of pest organisms and their associated predators, parasitoids and pathogens. Since natural enemy, host prey, and alternate host populations naturally oscillate from one year to the next, long-term studies that fully evaluate hedgerows' contribution to pest management would provide valuable information to farmers.

FOOTNOTE

[a]Among its many activities, CAFF sponsors a Biological Farming Program that promotes hedgerow plantings and provides support such as consultants, information resources, and grants.

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