FINAL PROJECT REPORT

Project Title: *Amblydromella caudiglans*: A new predatory mite for Washington apples

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Other funding sources

Agency Name: Washington State Commission on Pesticide Registration
Amt. awarded: Awarded $13,690 (2013), Awarded $11,750 (2014)

Total Project Funding: **Year 1:** 23,419 **Year 2:** 23,275

Budget History:

Item	2013	2014
Salaries	14,198	14,766
Benefits	2,029	2,110
Wages	4,733	4,922
Benefits	459	477
Equipment	0	0
Supplies	0	0
Travel	0	0
Miscellaneous	2,000	1,000
Plot Fees	0	0
Total	23,419	23,275

OBJECTIVES

1. Conduct a survey of predatory mite (Phytoseiidae) species in Washington apple orchards to determine species prevalence and biodiversity.

2. Assess the effects of various factors, including climate, landscape, available prey species, and type of pesticide regime (conventional or organic) on the species composition of predatory mites found at each site using Geographic Information Systems (GIS) analysis. This will allow us to form a model which can be used to predict the species composition of individual orchards. The ability to inform growers which predator species they are likely to find in their orchard will allow them to adapt their management strategy to best suit the needs of that particular predator to maximize biological control of spider mites.

3. Compare the biology, pesticide tolerance, and predatory ability of *A. caudiglans* and *G. occidentalis*. This will provide growers with the information needed to adapt current integrated mite management (IMM) practices to their dominant predator.

SIGNIFICANT FINDINGS

1. Predatory mite survey:

- 22% of identified mites were *Amblydromella caudiglans,*
- *Amblydromella caudiglans* was the dominant species in 20% of samples,
- Predatory mite species found in the survey include: *Amblydromella caudiglans*, *Amblyseius andersoni*, *Euseius finlandicus*, *Galendromus flumenis*, *Galendromus occidentalis*, *Neoseiulus fallacis*, and *Typhlodromus pyri,*

2. Factors effecting predatory mite populations:

- *Galendromus occidentalis* populations were higher in apple blocks where bifenazate was used, in conventional blocks (vs. organic), and where carbaryl was used as a fruit thinner
- *Amblydromella caudiglans* populations were higher in apple blocks where bifenazate was not used and in blocks with weedy herbicide strips
- The main variety planted in the block also affected *A. caudiglans* populations; fewer *A. caudiglans* were found in 'Golden Delicious' blocks

3. Biology, pesticide tolerance, and predatory ability of *A. caudiglans* and *G. occidentalis:*

- *Galendromus occidentalis* spent significantly more time in the egg and larval stage than *A. caudiglans*, but *A. caudiglans* spent significantly more time in both nymphal stages, thus *G. occidentalis* has an overall shorter development time.
- Survivorship for both species was similarly high at all life stages, except for the egg stage; fewer *G. occidentalis* eggs hatched.
- The sex ratio for both species was similar (74% female for *G. occidentalis*, 78% female for *A. caudiglans*).
- *Amblydromella caudiglans* had higher than 25% corrected mortality when treated with bifenazate, azinphosmethyl, imidacloprid, carbaryl, and spinetoram, whereas *G. occidentalis* had >25% mortality only when treated with imidacloprid and spinetoram.

- All pesticides tested reduced *A. caudiglans* fecundity by more than 25% relative to the untreated control.
- *Amblydromella caudiglans* consumed more *Tetranychus urticae* eggs than *G. occidentalis*, but consumed a similar number of protonymphs.
- However, on a diet consisting solely of *T. urticae* eggs, *A. caudiglans* laid fewer eggs than *G. occidentalis*. The predators laid similar numbers of eggs on the protonymph diet. This indicates that *T. urticae* eggs may be a poor source of nutrition for *A. caudiglans*.

RESULTS & DISCUSSION

Survey. *Amblydromella caudiglans*, *Amblyseius andersoni*, *Euseius finlandicus, Galendromus flumenis, Galendromus occidentalis, Neoseiulus fallacis,* and *Typhlodromus pyri* have been identified from the locations surveyed (Fig. 1). The majority of identified individuals were *G. occidentalis* (Fig. 1), but *A. caudiglans* was also present in significant numbers. Although *G. occidentalis* was the dominant predator in the majority of orchards, *A. caudiglans* was dominant at 20% of the sites surveyed (Fig. 2). It was suggested by Downing and Moillet (1972) that a movement away from chemical control, especially organophosphates, could result in the replacement of *G. occidentalis* by *A. caudiglans*. *Galendromus occidentalis* has historically been considered to be highly resistant to pesticides compared to other phytoseiid species (Downing & Moillet 1972). Additionally, European red mite has replaced the McDaniel mite as the common outbreak pest mite species in Washington apple orchards (Beers and Hoyt 1993). While spider mites that spin copious webbing, like the McDaniel mite and twospotted spider mite, are the preferred prey of *G. occidentalis* (McMurtry and Croft 1997), *A. caudiglans* has difficulty moving through webbing and prefers spider mites like *P. ulmi* that produce little webbing (McMurtry and Croft 1997, Putman 1962). Therefore, the transition to a new predominant pest mite species

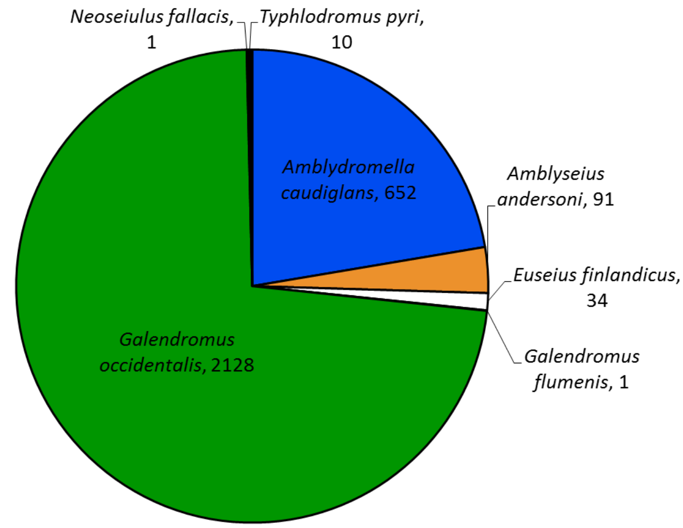

Figure 1. Number of female phytoseiids found in survey (total *n*=2917)

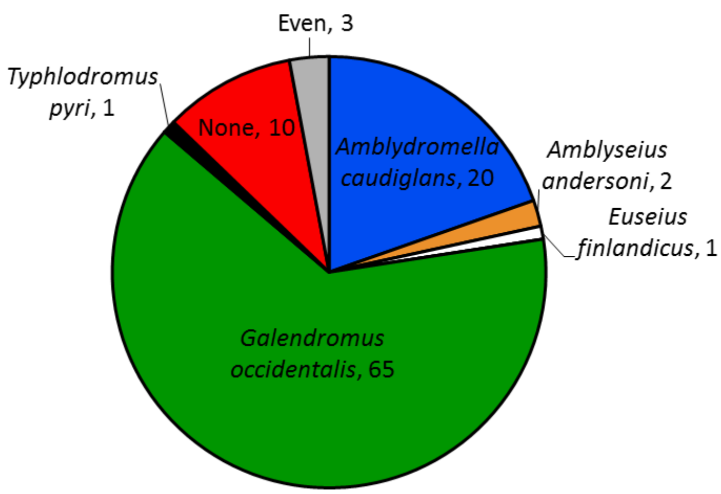

Figure 2. Number of sites where each species was dominant (n=102)

may have promoted the increase in *A. caudiglans* populations.

Survey Analysis. Seventy-nine surveys regarding grower practices have been completed. The answers to these surveys, as well as the latitude, elevation, surrounding landscape, and prey species present at each site were modelled separately against the abundance of *G. occidentalis* and *A. caudiglans*. For each model, degree days were used as a covariate to account for effect of sampling date. The use of bifenazate positively affected *G. occidentalis* abundance, but negatively affected *A. caudiglans* abundance. *Galendromus occidentalis* populations were higher in conventional blocks than organic blocks and in blocks where carbaryl was used for fruit thinning. *Amblydromella caudiglans* populations were higher in blocks with weedier herbicide strips. The main variety of apple planted in the block was also found to effect *A. caudiglans* populations; fewer *A. caudiglans* were found in 'Golden Delicious' blocks than other varieties (Fig. 3). These findings indicate that *G. occidentalis* populations thrive in environments with higher levels of agricultural disturbance, whereas, *A. caudiglans* can increase in abundance where agricultural inputs are less intense. Organic or "soft" conventional programs should take into consideration that the dominant mite predator that they find in their orchards may be *A. caudiglans* instead of *G. occidentalis* and take measures to conserve this predator. This may include preserving habitat (weeds) in herbicide strips and avoiding the use of certain pesticides. Additionally, these findings support previous research that indicated that generalist predators (like *A. caudiglans*) are more effected by the surrounding environment (dominant apple variety and weediness) than specialist predators (*G. occidentalis*) (Camporese and Duso 1996; McMurtry and Croft 1997). The identification of pesticides that may affect phytoseiid populations (bifenazate, carbaryl) is also a useful tool for determining future bioassay targets.

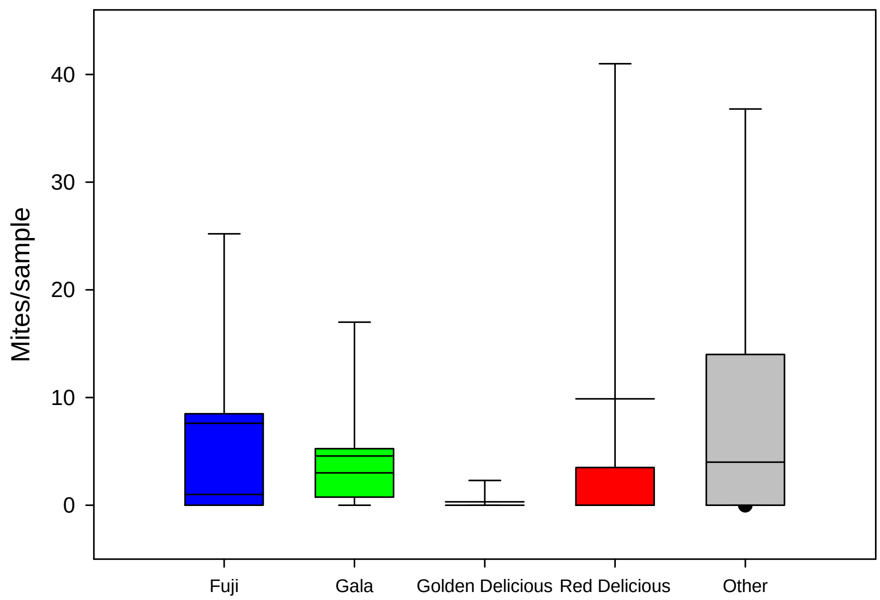

Figure 3. Box plots of *A. caudiglans*/sample for each variety.

Pesticide Bioassays. Eight pesticides were tested for nontarget effects on *A. caudiglans* and *G. occidentalis*. Due to previous difficulties establishing a colony of *A. caudiglans*, individuals of both species were collected from two experimental orchards where each species was previously found to be dominant. These field collected individuals were used in the assays. After the completion of an assay, individual mites were identified to species to ensure that the correct species was used. Corrected mortality (percent difference from check) for both species was calculated (Table 1). More pesticides were found to be toxic to *A. caudiglans* than *G. occidentalis,* including the two pesticides flagged by the survey data (bifenazate and carbaryl). Spinetoram and imidacloprid were toxic to both species, but azinphosmethyl, bifenazate, and carbaryl caused >25% correct mortality to only *A. caudiglans*. As previously mentioned, resistance to organophosphates like azinphosmethyl is well-known in *G. occidentalis* and its use may be a driving factor in the abundance of these two phytoseiid species. Some carbaryl resistance in *G. occidentalis* has also been reported (Babcock and Croft 1988), so its use may tip any competition in favor of *G. occidentalis* over *A. caudiglans*. The negative effects of bifenazate on *A. caudiglans* are surprising, as this pesticide is specifically marketed as safe for beneficial mites. However, *A. caudiglans* is not one of the phytoseiids specifically mentioned on the label (*Amblyseius fallacis, Phytoseiulus persimilis, Galendromus occidentalis, Typhlodromus pyri*). This indicates that this species may differ

	Abbott's Corrected Mortality (%)	
Pesticide	*A. caudiglans*	*G. occidentalis*
Bifenazate	43.29	0.00
Novaluron	18.48	-9.09
Azinphosmethyl	81.88	21.21
Chlorantraniliprole	-8.70	-0.36
Imidacloprid	83.70	76.28
Carbaryl	100.00	9.88
Spinetoram	95.06	90.08
Spirotetramat	13.04	1.30

Table 1. Abbott’s corrected morality for each pesticide tested. Negative numbers indicate a lower mortality than the check. Box shading represents the relative strength of the effect, where dark gray is the most harmful (>75%), white is the least harmful (<25%), and light gray is intermediate (≥25 and ≤75).

	Eggs/female		Live larvae	
	A. caudiglans	*G. occidentalis*	*A. caudiglans*	*G. occidentalis*
Bifenazate	47		60	
Novaluron	64	39	81	94
Azinphosmethyl	77	49	91	46
Chlorantraniliprole	56	13	46	24
Imidacloprid	70	68	87	83
Carbaryl		52	100	97
Spinetoram	100	100	89	100
Spirotetramat	77	87	65	100

Table 2. Percent reduction from check in fecundity and live larvae for each pesticide tested. Values for *G. occidentalis* were taken from Beers and Schmidt 2014. Box shading represents the relative strength of the effect, where dark gray is the most harmful (>75%), white is the least harmful (<25%), and light gray is intermediate (≥25 and ≤75). Black boxes indicate data was not collected (no females survived treatment by carbaryl to lay eggs).

significantly in pesticide resistance and tolerance when compared to current model organisms.

The field collected *G. occidentalis* used in these pesticide trials had an unusually low rate of oviposition (even in the check), so these data are not reported. A recently published study (Beers and Schmidt 2014) can be consulted for the effects of the pesticides tested here (except for bifenazate) on a Washington population of *G. occidentalis*. All pesticides reduced *A. caudiglans* fecundity by >25% and resulted in reduced live larvae in the second generation (Table 2). Compared to data for *G. occidentalis* (Beers and Schmidt 2014, shown in Table 2), azinphosmethyl and chlorantraniliprole seem to negatively affect *A. caudiglans* more than *G. occidentalis*, whereas spirotetramat reduced live larvae less in *A. caudiglans* than *G. occidentalis* (although live larvae were substantially reduced in both). Because these sublethal effects assays were conducted in separate experiments, comparisons between species may not be valid. However, the negative effects of bifenazate and chlorantraniliprole on *A. caudiglans* (vs. *G. occidentalis*) were also seen in the mortality data.

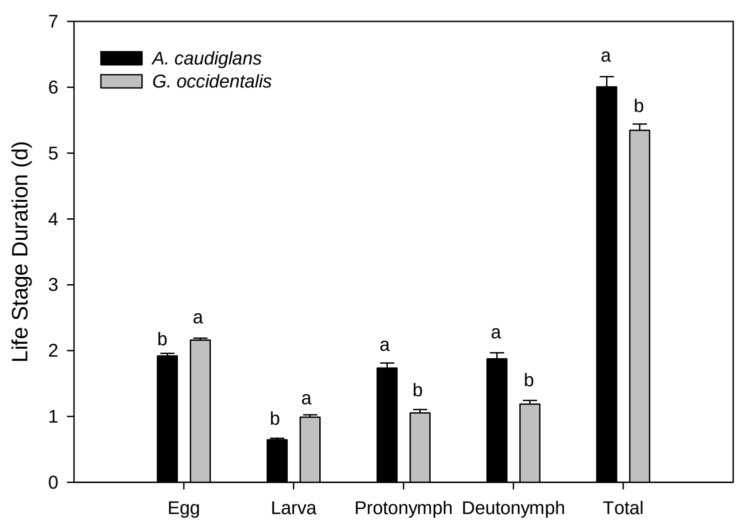

Figure 4. Life stage duration of predatory mite species.

Life table studies. *Galendromus occidentalis* has a shorter egg to adult development time than *A. caudiglans* at 75-89° F and 16 h day length (Fig. 4). Although *A. caudiglans* has shorter egg and larval stages, *G. occidentalis* has shorter nymphal stages. Unlike *G. occidentalis*, *A. caudiglans* larvae do not feed, thus rapid progression more quickly through its early life stages is advantageous. One implication of this life history trait is that *G. occidentalis* is capable of providing biological control earlier in its life cycle than *A. caudiglans*. This makes it less detrimental that it spends a greater amount of time as a larva. Both species develop quickly, allowing for their success as predators of rapidly growing pest populations. Both predators also had similar proportions of individuals survive through each life stage, except as eggs (Fig. 5). At the specified conditions, *G. occidentalis* has lower percentage egg hatch. This could indicate that *A. caudiglans* eggs are more likely to remain viable in the warmer climates found in central Washington. Therefore, like *G.*

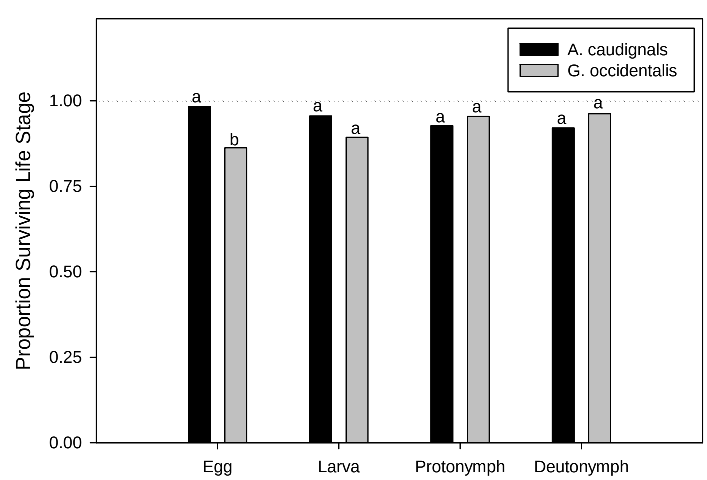

Figure 5. Survivorship at each life stage for predatory mites.

occidentalis, this predator matures quickly, increasing its ability to control pest mite populations. Both species have similar sex ratios (74% female for *A. caudiglans*, 78% female for *G. occidentalis*).

Prey Consumption. Predation of *T. urticae* eggs was much higher for *A. caudiglans* than *G. occidentalis* (Fig. 6a). However, this diet resulted in decreased oviposition in *A. caudiglans* compared to *G. occidentalis* and to *A. caudiglans* fed on a diet of *T. urticae* protonymphs (Fig. 6b). This supports previous findings that indicated that *A. caudiglans* may not derive adequate nutrition from *T. urticae* eggs, resulting in compensatory feeding (Putman 1962). Both species consumed a similar number of protonymphs and oviposited at similar rates on this diet (Fig. 6). Unfortunately, prey consumption studies comparing both species feeding on European red mite could not be performed, as we were unable to establish this species in a laboratory colony. However, these data indicate that *A. caudiglans* does not perform as well as *G. occidentalis* on one stage of the former breakout spider mite pest (*T. urticae*). Reduced fecundity on this prey may be another contributing factor to previous findings that *G. occidentalis* is the sole predator in Washington apple orchards.

This study highlights potential factors that may have limited *A. caudiglans* populations in the past. This species is more sensitive to agricultural disturbances, including pesticides, than *G. occidentalis*. Additionally, it is also less capable of reproducing on one stage (eggs) of *T. urticae*, which may have limited its ability to reach high abundances when *Tetranychus* spp. were more common pests of orchards than they are at present. However, the discovery that it is presently the dominant phytoseiid species in many apple orchards warrants its conservation in these systems. It is more likely to be found in organic or “soft” conventional programs where key pesticides (like carbaryl and bifenazate) are avoided. Additionally, we are likely to see more of this predator in the coming years as organophosphate use is phased out.

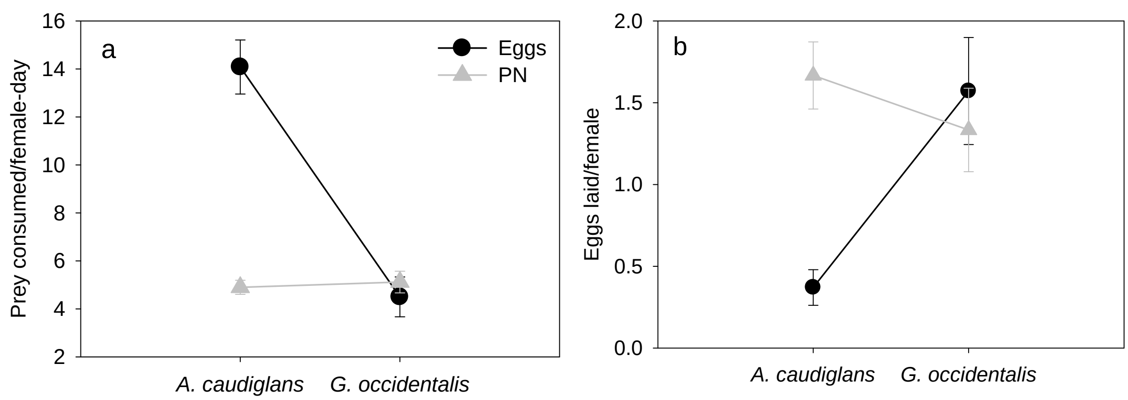

Figure 6. a) Average number of prey consumed by females per day in a two day evaluation period, b) average number of eggs laid per female on each diet four days after starting diet.

References Cited

Babcock J.M. and Tanigoshi L.K. 1988. Resistance levels of *Typhlodromus occidentalis* (Acari: Phytoseiidae) from Washington apple orchards to ten pesticides. Experimental and Applied Acarology 4: 151-157.

Beers E.H. and Schmidt R.A. 2014. Impacts of orchard pesticides on *Galendromus occidentalis*: lethal and sublethal effects. Crop Protection 56: 16-24.

Camporese P. and Duso C. 1996. Different colonization patterns of phytophagous and predatory mites (Acari: Tetranychidae, Phytoseiidae) on three grape varieties: a case study. Experimental and Applied Acarology 20: 1-22.

Downing R.S. and Moilliet T.K. 1972. Replacement of *Typhlodromus occidentalis* by *T. caudiglans* and *T. pyri* (Acarina: Phytoseiidae) after cessation of sprays on apple trees. Canadian Entomologist 104: 937-940.

Hoyt S.C. and Beers E.H. 1993. Western predatory mite: Orchard Pest Management: A Resource Book for the Pacific Northwest (ed. by EH Beers, JF Brunner, MJ Willett & GM Warner) The Good Fruit Grower, Yakima, WA.

McMurtry J.A. and Croft B.A. 1997. Life-styles of phytoseiid mites and their roles in biological control. Annual Review of Entomology 42: 291-321.

Putman, W. L. 1962. Life-history and behaviour of the predacious mite *Typhlodromus* (T.) *caudiglans* Schuster (Acarina: Phytoseiidae) in Ontario, with notes on the prey of related species. Canadian Entomologist 94: 163-177.

EXECUTIVE SUMMARY

This two year project focused on increasing current knowledge of predatory mite populations in Washington apple orchards. The integrated mite management program in Washington is based on the assumption that *Galendromus occidentalis* is the only predatory mite in orchards, but this idea has not been tested. To improve our understanding of predatory mite diversity, three objectives were addressed: 1) a survey of predatory mites to determine the available diversity within orchards, 2) analysis of the effects of various factors, including location, landscape, pesticide use, and other agricultural inputs on predatory mite abundance, and 3) a comparison of the biology, prey consumption, and pesticide tolerance of the two most commonly found species of predatory mite in the survey.

Although it was found in high abundance (73% of collected individuals), *G. occidentalis* was not the only predatory mite found in apple orchards. *Amblydromella caudiglans*, *Amblyseius andersoni*, *Euseius finlandicus, Galendromus flumenis*, *Neoseiulus fallacis*, and *Typhlodromus pyri* were also present. *Amblydromella caudiglans* was the second most abundant species and was dominant at 20% of sites.

Galendromus occidentalis populations were higher at sites that used bifenazate and carbaryl, and in conventional (vs. organic) orchards. *Amblydromella caudiglans* populations were higher at locations where bifenazate was not used and in blocks with weedy herbicide strips. The counts of this species were also lower in 'Golden Delicious' blocks as compared to other varieties. These results indicate that increased agricultural inputs may favor *G. occidentalis* and that changing management practices may promote *A. caudiglans* populations.

Galendromus occidentalis was also more tolerant of most of the pesticides tested in bioassays than *A. caudiglans*. Bifenazate, azinphosmethyl, imidacloprid, carbaryl, and spinetoram caused >25% corrected mortality in *A. caudiglans*, whereas, only imidacloprid and spinetoram reached these levels of toxicity in *G. occidentalis*. Chlorantraniliprole, which did not have significant sublethal effects on *G. occidentalis* in previous studies, reduced fecundity in *A. caudiglans*. These results support previous findings that *G. occidentalis* is much more resistant to broad-spectrum insecticides (especially organophosphates) than *A. caudiglans*.

The duration of life stages for both species is fairly similar. The egg and larval stage were slightly longer for *G. occidentalis*, while the nymphal stages were longer for *A. caudiglans*. This resulted in *G. occidentalis* having a slightly shorter development time. The prey consumption of these two predators significantly differed. *Amblydromella caudiglans* consumed more *Tetranychus urticae* eggs than *G. occidentalis*. However, when fed exclusively on this life stage, *A. caudiglans* laid relatively few eggs. Both predators consumed similar numbers of *T. urticae* protonymphs and feeding on this prey did not depress the fecundity of either species. This indicates that *T. urticae* eggs are nutritionally poor host for *A. caudiglans*; although it eats more prey items, it is unable to adequately reproduce.

These findings indicate that there are two key factors that may have influenced historically unnoticed populations of *A. caudiglans* in apple orchards. Previous pesticide regimes, involving frequent sprays of broad-spectrum insecticides were not conducive to conserving this predator. Additionally, the fairly recent switch from a less suitable prey (*T. urticae*) to European red mite may also have allowed for *A. caudiglans* populations to flourish. As this predator is more likely to be dominant in organic or "soft" conventional programs, measures should be taken to conserve its populations for the purposes of biological control