Biological Invasions **2:** 81–85, 2000.

Invasion note

The effect of the Argentine ant on the threatened valley elderberry longhorn beetle

Gary R. Huxel
Department of Environmental Science and Policy, University of California, One Shields Avenue, Davis, CA 95616, USA (e-mail: grhuxel@ucdavis.edu)

Received 23 August 1999; accepted in revised form 2 June 2000

Key words: Central Valley, *Desmocerus californicus dimorphus*, extinction, invasive species, *Linepithema humile*

Introduction

The extinction of species from island and fragmented mainland ecosystems due to exotic species has resulted in a significant loss of species over the last 300 years (Courtenay and Meffe 1989; Diamond 1984; Minckley and Deacon 1991; Savidge, 1987; Simberloff 1981; Simberloff et al. 1997; Sinclair et al. 1998). Here, I present evidence suggesting an impact of an introduced species, the Argentine ant *Linepithema humile* Mayr (Hymenoptera: Formicidae) on the threatened valley elderberry longhorn beetle (VELB) *Desmocerus californicus dimorphus* (Coleoptera: Cerambycidae). Holway and others have shown that a loss of intraspecific aggression among nests in invaded areas has contributed to the success of Argentine ant (Holway 1998b; Holway et al. 1998). *L. humile* has been spreading in riparian woodlands adjacent to permanent streams since its introduction into California circa 1907 (Holway 1998; Ward 1987). These riparian woodlands are important habitat for blue elderberry *Sambucus mexicana* (Caprifoliacae), the host plant of the VELB. Because the VELB is an obligate specialist on elderberry, any further reduction in the amount or quality of suitable riparian woodland habitat could significantly impact the VELB. Riparian woodland habitat has been largely reduced and severely fragmented (from a pre-Gold Rush 775,000 acres to approximately 12,000) by flood control, intensive agricultural production, and urbanization (Barbour et al. 1993; Kucera and Barrett 1995; Smith 1980).

The potential interaction between VELB and *L. humile* may be most important in fragmented riparian woodland habitat, such as along Putah Creek and American River watersheds. Where it has spread, the Argentine ant has impacted native ants and other ground-dwelling arthropods (Cole et al. 1992; Holway 1998a, b; Human and Gordon, 1997; Ward 1987). For example, Suarez et al. (1998) found that the Argentine ant had a greater impact on native ant species in fragmented habitats than in more continuous habitat.

The extreme rarity and threatened status of the VELB does not allow for manipulative experimentation. Therefore, using the 'natural experiment' of *L. humile* invasions, I explored whether the presence of *L. humile* was correlated with the absence of VELB. Specifically, I use a comparative approach to determine whether the invasion of *L. humile* has impacted the distribution of *D. californicus dimorphus* along the Putah Creek and the American River watersheds.

Methods

Sites along the Putah Creek and the American River watersheds encompass two of the three critical habitat areas listed in the VELB recovery plan (USFWS 1984). Putah Creek has been extensively and intensively sampled for the Argentine ant since 1986 and these studies have demonstrated that the ant is spreading towards its headwaters (Holway 1995, 1998b; Ward 1987). The spread of *L. humile* along Putah Creek provides a natural experiment to examine the impact of an invasive species on a threatened species in critical habitat. However, the Argentine ant has not been reported along the American River, and its potential impact along this river is unknown.

This study was carried out in Yolo, Solano, and Sacramento counties. The surveys occurred in an area bounded by latitudes 38°30′ N and 38°32′ N and by longitudes 122°04′ W and 121°45′ W for Putah Creek and by latitudes 38°33′ N and 38°39′ N and by longitudes 121°31′ W and 121°15′ W for the American River. Sampling was conducted in valley riparian woodland habitat (Sawyer and Keeler-Wolf 1995), which is favorable habitat for both the Argentine ant and elderberry. The sites included essential habitat (habitats that have localized large populations) within critical habitat area for the VELB along both streams (USFWS 1984).

I selected 30 sites where elderberry occurred, 15 each on Putah Creek and the American River, and performed surveys for both VELB and the Argentine ant (Table 1; Figure 1). Sites along Putah Creek were chosen to span sites of known Argentine ant infestation, while sites along the American River were chosen to span a similar distance and habitat as those sites on Putah Creek because of the lack of information concerning *L. humile* along the river. VELB were sampled by searching for current year exit (emergence) holes on all elderberry within 10 m × 10 m plots. Current year exit holes are distinguished from older holes by coloration and the presence of frass. The VELB is the only insect known to inhabit live elderberry wood and to make exit holes of a similar size and shape in the Central Valley (Barr 1991). At each site two sampling methods were used to determine the presence of *L. humile*. First, ant workers were collected from elderberry bushes. Second, foraging worker ants were collected in petri dish lids using tuna, in oil, as bait (Ward 1987). These baited traps were within 5 cm of an elderberry bush and observed for a 2-hour period

Table 1. List of surveyed sites and the occurrence of the VELB, Argentine ant, and native ant species at 30 sites in Yolo and Solano Counties along Putah Creek (sites 1–15) and in Sacramento County along the American River (sites 16–30). Presence is indicated by plus (+) sign; absence is indicated by minus (−) sign.

Site no.	County/Location	VELB	Argentine ant	Native ants
1	Solano: Lake Solano Park, East End	+	+	+
2	Solano: Lake Solano Park, South End	+	−	+
3	Solano: Lake Solano Park, West End	+	−	+
4	Solano: Putah Creek Road, East	+	−	+
5	Solano: Putah Creek Road, Middle	−	+	−
6	Solano: Putah Creek Road, West	−	−	+
7	Yolo: Main Street, Winters	−	+	−
8	Yolo: Rte. 128, Fishing Access #3	+	−	+
9	Yolo: Rte. 128, Fishing Access #4	+	+	−
10	Yolo: Russell Ranch, East End	−	+	−
11	Yolo: Russell Ranch, Middle	−	+	−
12	Yolo: Russell Ranch, West End	−	+	−
13	Yolo: Putah Creek Reserve, East End	−	−	−
14	Yolo: Putah Creek Reserve, Middle	+	−	−
15	Yolo: Putah Creek Reserve, West End	−	+	−
16	Sacramento: Discovery Park, East End	−	−	+
17	Sacramento: Discovery Park, Middle	−	−	+
18	Sacramento: Discovery Park, West End	−	+	+
19	Sacramento: Howe Access, East End	−	−	−
20	Sacramento: Howe Access, Middle	+	−	+
21	Sacramento: Howe Access, West End	+	+	+
22	Sacramento: Waterton Access, East End	−	−	+
23	Sacramento: Waterton Access, Middle	−	−	+
24	Sacramento: Waterton Access, West End	−	−	+
25	Sacramento: Goethe Park, East End	−	−	+
26	Sacramento: Goethe Park, Middle	+	−	−
27	Sacramento: Goethe Park, West End	−	−	+
28	Sacramento: Sunrise Access, East End	−	−	−
29	Sacramento: Sunrise Access, Middle	−	+	−
30	Sacramento: Sunrise Aceess, West End	+	−	+

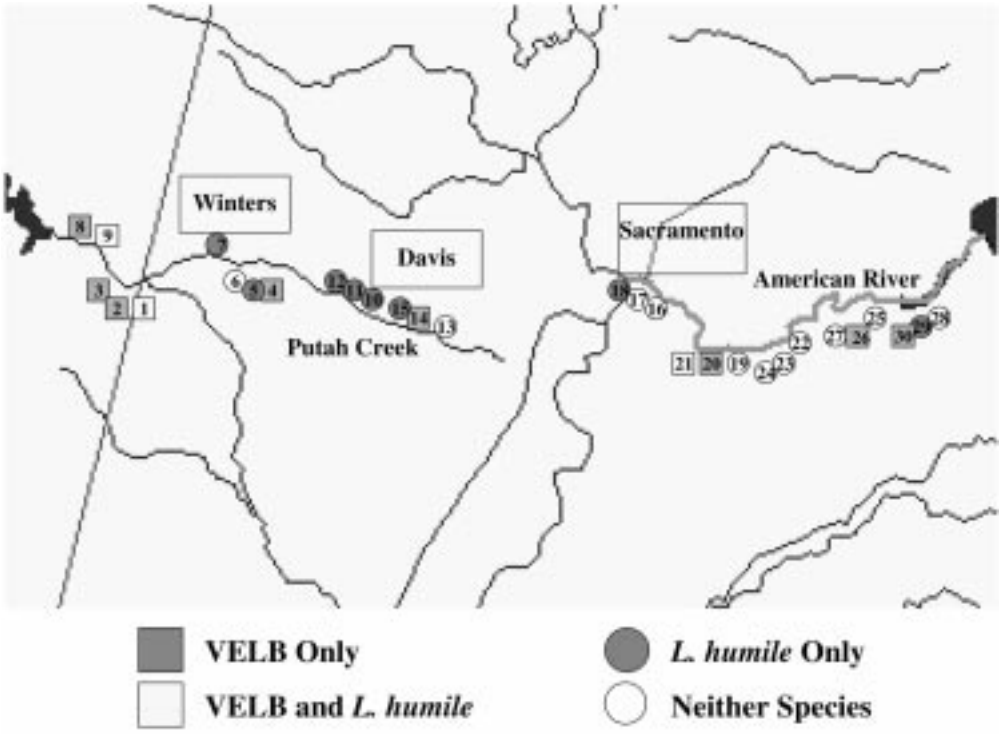

Figure 1. This figure shows the 30 sites; 1–15 are along Putah Creek and 16–30 are along the American River (see along Table 1).

and then collected. Surveys were performed prior to or concurrently with flowering of the elderberry (March to May 1999) to insure that only those ants that were active during the VELB emergence and oviposition period (which is synchronous with elderberry flowering) were sampled.

Results

The survey results from the 30 sites for the Argentine ant, VELB and native ants are given in Table 1 (see also Figure 1). A Pearson's chi-square test was performed separately for each stream to determine whether the distribution of the two species was independent (Sokal and Rohlf 1981). The null hypothesis is that the spatial distributions of the two species were independent.

Of the 15 sites along Putah Creek, VELB were present in seven sites, *L. humile* were found in eight sites, and both were found in two sites. Along Putah Creek the *L. humile* had a negative, but not significant relationship with the VELB ($p = 0.072$; Table 2). However, one can justifiably omit the two sites (1 and 9) where *L. humile* and VELB were found to co-occur, because both of these are sites newly colonized by *L. humile* and one would expect a period of time for extirpation of the VELB. Omitting these two sites then one rejects the null hypothesis for independence between the VELB and Argentine ant ($p = 0.002$; Table 2). Previous sampling efforts in 1986 (Ward 1987) and 1995 (Holway 1995) near Site 1 had not found *L. humile* near this site suggesting that this invasion occurred within the last three years. Similar evidence for Site 9 indicates that this site has been colonized within the last five years (Holway 1995, 1998b; Ward 1987). Additionally, the data for the Putah Creek sites suggest that this negative effect can be reasonably attributed to the Argentine ant because native ants

Table 2. Pearson's chi-square test for independence.

	Taxon pairs	Pearson's chi-square test (p)
Putah Creek	VELB–Argentine ant	0.072
	VELB–Native ants	0.003
	Argentine ant–Native ants	0.005
American River	VELB–Argentine ant	0.770
	VELB–Native ants	0.680
	Argentine ant–Native ants	0.770

occurred at only one site in which *L. humile* was present ($p = 0.005$) and native ants were positively associated with the VELB ($p = 0.003$).

Of the 15 sites along the American River, VELB was present in four sites, Argentine ants were found in three sites, and they co-occurred in one site. No significant result was found along the American River ($p = 0.770$). Additionally, unlike along Putah Creek, there was no significant negative relationship between *L. humile* and native ants ($p = 0.770$) or between the VELB and native ants ($p = 0.680$). The co-occurrence of the Argentine ant and native ant species suggests that the invasion of the Argentine ant into the riparian woodland of the American River may be recent (Ward, pers. comm.). The one species that was found to co-occur with *L. humile* on Putah Creek was *Prenolepis imparis* it is known to be able to co-exist with *L. humile* (Holway 1998b; Ward 1987). However, along the American River, species that are not typically found co-occurring with *L. humile* such as *Formica aerata*, *Dorymyrmex bicolor*, *Pogonomyrmex subdentatus*, *Tapinoma sessile*, *Crematogaster hespera*, and *Lasius alienus*, where found co-existing with *L. humile* (Holway 1998b; Ward 1987).

Discussion

Because *L. humile* is spreading along permanent streams, I expect it to have a significant impact on the long-term persistence of the VELB. The Argentine ant has been shown to be spreading up to 200 m ($\sim$ 16 m on average, Holway 1998a) per year along riparian woodland habitat along permanent streams (Holway 1998a; Ward 1987). Along invasion fronts, *L. humile* spreads mainly by colony budding; however occasional long dispersal jumps can occur due to human-mediated transport. This is evidenced by the patchy distribution of *L. humile* along the American River and to a lesser extent along Putah Creek (Figure 1).

An important factor in this study is the time to extinction of the VELB and native ants due to the interaction with *L. humile*. The time to extinction for native ants due to effects by *L. humile* is not precisely known, however given *L. humile*'s superior exploitative and interference competition ability (Holway et al. 1998a; Human and Gordon 1996; Mallis 1938; Michener 1942; Shapley 1920; Ward 1987; Woodworth 1910), local extinction of most native epigeic ants probably occurs within a few years. This may be especially true near elderberry as Argentine ants are attracted to the nectaries of the elderberry.

Studies examining the effects of the Argentine ant on other arthropods may have missed any potential impacts on rare, ground-dwelling arthropods (Holway, 1998a; Human and Gordon 1996). In addition, the effects of *L. humile* on arboreal arthropods also were not addressed in similar studies with the exception of one study in which Way et al. (1992) found that *L. humile* was a significant egg predator on the arboreal eucalyptus borer *Phoracantha semipunctata* (Coleoptera: Cerambycidae). Way et al. (1992) further suggested that the Argentine ant might be used as a biological control agent against this stem borer. Two native ant species (*Liometopum occidentale* and *Formica aerata* (Huxel, pers. obs.) and Argentine ants commonly foraged on, and some nested, in elderberry bushes. The difference between the native ants and *L. humile* in their ability to extirpate the VELB may be due to the greater intensity of aggression and the greater foraging efficiency of *L. humile* (Holway 1998a, b; Holway et al. 1998; Human and Gordon 1996; Ward 1987). While the mechanism of interaction between the VELB and the Argentine ant could be egg predation (as with *L. humile* on the eucalyptus borer), the exact mechanism needs to be identified and studied. Also, predation on adult VELB may be limited due to accumulation (and potential use for defense; VELB have aposematic coloration) of cyanogenic glucosides produced by elderberry (USFWS 1984).

The results suggest that the threatened valley elderberry longhorn beetle may be at great risk due to combined effects of loss ($> 97\%$) and fragmentation of riparian woodland habitat (Barbour et al. 1993; Kucera and Barrett 1995; Smith 1980) and the invasion of the Argentine ant. In a study of demographic and environmental factors on the population dynamics of the VELB, model results suggested that habitat loss and juvenile mortality play a significant role in the probability of extinction of the VELB (Huxel and Collinge, unpublished manuscript). Thus, the long-term survival of the VELB may require control, and perhaps reversal, of the spread of the Argentine ant and migration of the effects of habitat loss and fragmentation.

Acknowledgements

This work was supported by a NSF Research Training Grant (BIR-960226) to the Institute of Theoretical

Dynamics at the University of California, Davis. I am grateful to Phil Ward who saved me many hours and from many errors by identifying the ants and to Francisco Sanchez Piñero, Kevin McCann, James Umbanhowar, Ted Grosholz, Sharon Collinge, Marcel Holyoak, and two anonymous reviewers for helpful comments.

References

Barbour MB, Drysdale PF and Linstrom S (1993) California's Changing Landscapes. California Native Plant Society, Sacramento, CA, USA, 244 pp

Barr CB (1991) The Distribution, Habitat, and Status of the Valley Elderberry Longhorn Beetle *Desmocerus californicus dimorphus*. US Fish and Wildlife Service, Sacramento, CA, USA, 134 pp

Cole FR, Medeiros AC, Loope LL and Zuehlke WW (1992) Effects of the Argentine ant on arthropod fauna of Hawaiian high-elevation shrubland. Ecology 73: 1313–1322

Courtenay Jr WR, and Meffe GK (1989) Small fishes in strange places: A review of introduced poecilids. In: Meffe GK and Snelson Jr FF, (ed) Ecology and Evolution of Livebearing Fishes (Poecilidae), pp 319–331. Prentice Hall, Englewood Cliffs, New Jersey

Holway DA (1995) Distribution of the Argentine ant (*Linepithema humile*) in northern California. Conservation Biology 9: 1634–1637

Holway DA (1998a) Effect of Argentine ant invasions on ground-dwelling arthropods in northern California riparian woodlands. Oecologia 116: 252–258

Holway DA (1998b) Factors governing rate of invasion: A natural experiment using Argentine ants. Oecologia 115: 206–212

Holway DA, Suarez AV and Case TJ (1998) Loss of intraspecific aggression in the success of a widespread invasive social insect. Science 282: 949–952

Human KG and Gordon DM (1997) Effects of Argentine ants on invertebrate biodiversity in northern California. Conservation Biology 11: 1242–1248

Kucera TE and Barrett RH (1995) California wildlife faces uncertain future. California Agriculture 49: 23–27

Mallis A (1938) Army ants in California. Science Monthly 47: 220–226

Michener CD (1942) The history and behavior of a colony of harvester ants. Science Monthly 55: 248–258

Minckley WL and Deacon JE (eds) (1991) Battle Against Extinction: Fish Management in the American West. University of Arizona Press, Tucson, AZ, USA, 517 pp

Savidge JA (1987) Extinction of an island avifauna by an introduced snake. Ecology 68: 660–668

Sawyer JO and Keeler-Wolf T (1995) A Manual of California Vegetation. California Native Plant Society, Sacramento, California, 471 pp

Shapley H (1920) Notes on pterergates in the California harvester any. Psyche 27: 72–74

Simberloff D (1981) Community effects of introduced species. In: Nitecki H (ed) Biotic Crises in Ecological and Evolutionary Time, pp 53–81. Academic Press, New York

Simberloff D, Schmitz C and Brown TC (eds) (1997) Strangers in Paradise: Impact and Management of Nonindigenous Species in Florida. Island Press, Washington, DC, 467 pp

Sinclair ARE, Pech RP, Dickman CR, Hik D, Mahon P and Newsome AE (1998) Predicting effects of predation on conservation of endangered prey. Conservation Biology 12: 564–575

Smith F (1980) A short review of the status of riparian forests in California. In: Sands A (ed) Riparian Forests in California, pp 1–2. University of California Press, Berkeley, California

Sokal RR and Rohlf FJ (1981) Biometry. 2nd edition. WH Freeman and Company, San Francisco, California, 859 pp

Suarez AV, Bolger DT and Case TJ (1998) Effects of fragmentation and invasion of native ant communities in coastal southern California. Ecology 79: 2041–2056

US Fish and Wildlife Service (1984) Valley Elderberry Longhorn Beetle Recovery Plan. US Fish and Wildlife Service, Portland, Oregon, 62 pp

Ward PS (1987) Distribution of the introduced Argentine ant (*Iridomyrmex humilis*) in natural habitats of the lower Sacramento Valley and its effects on the indigenous ant fauna. Hilgardia 55: 1–16

Way MJ, Cammell ME and Paiva MR (1992) Studies on egg predation by ants (Hymenoptera: Formicidae) especially on the eucalyptus borer *Phoracantha semipunctata* (Coleoptera: Cerambycidae) in Portugal. Bulletin of Entomological Research 82: 425–432

Woodworth CW (1908) The Argentine ant in California. University of California Agricultural Experiment Station Circular 38: 1–11