

other hosts in the southwestern U.S.

This research demonstrates the value of detailed and long-term records on host distribution and abundance as well as parasitism rates that have been collected by MLMP volunteers. A study of this magnitude would have been impossible without their contributions.

Acknowledgments

I thank the hundreds of MLMP volunteers who have contributed to this project, especially Deb Marcinski, Emily Toriani-Moura, Alan Williams, Donna Kemp, Brian Bockhahn, Sondra Cabell, Ilse Gebhard, Sharon Duerkop, Darlene Pinchot, Susan Payant, Suzanne Oberhauser, Diane Rock, and Charlie Cameron; and Monarch Lab students and staff for their help in developing protocols and communicating with volunteers. This research was supported by the National Science Foundation (ESI 9731429, ESI 0104600), the National Center for Ecological Analysis and Synthesis, and the Monarchs in the Classroom program at the University of Minnesota.

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The Lost Ladybug Project: Citizen Spotting Surpasses Scientist's Surveys

John Losey, Leslie Allee, and Rebecca Smyth

Coccinellids, known as ladybugs, ladybeetles, or ladybird beetles, are among the most common and easily recognizable invertebrate components of almost every terrestrial ecosystem in the U.S. and Canada (Gordon 1985). Species in this family are so ubiquitous and yet so sensitive to environmental conditions that they have been proposed as indicator species (Iperti 1999). In addition to their ubiquity, the bright coloration and gentle nature of this group make them a favorite wild creature of adults and youth alike. Like honeybees, ladybugs are revered for their industriousness and their important ecological role as well as their beauty.

This respect is well deserved, as ladybugs contribute to the control of many pest insect species (reviewed in Hodek and Honěk 1996). Given their potential to control pest species, many programs have tried to supplement extant populations or introduce new species.

Ladybugs have been the subject of many scientific studies, and from these studies we know that ladybug species vary greatly in their ability to suppress pest populations (reviewed in Hodek and Honěk 1996) and their response to changing environmental conditions (Iperti 1999; Bazzocchi et al. 2004). Thus, long-term regional shifts in species composition may have important implications for the functioning of this complex and its response to environmental changes.

Over the past twenty years, several native ladybug species that were once very common have become extremely rare (Harmon et al. 2006). During this same time, several species of ladybugs from other places have greatly increased both their numbers and range (Harmon et al. 2006). This has occurred very quickly, and we don't know how this shift happened, what impact it will have (e.g., whether the exotic species will be able to control pests as well as our familiar native ones have),

or how we can prevent more native species from becoming so rare.

These rapid ongoing changes in the North American complex of ladybug species are clearly a cause for concern. As applied scientists, we need data on the current status and future trends in the ladybug complex in order to most effectively utilize ladybug populations so that they continue to suppress pests, and to prevent the extinction of native species. These shifts in the ladybug complex also afford us a rare opportunity to address some major issues in basic ecology regarding the distribution and abundance of rare species and pattern of invasion and spread of invasive species (Strayer et al. 2006). Thus, both from a basic and an applied perspective, it is vital that we obtain more data on the distribution and abundance of ladybugs over time. While scientists studying these issues have historically relied on scientific surveys, more recently, citizen scientists are contributing to this database. The focus of this paper is to compare how scientific surveys and citizen science have contributed to our knowledge of ladybug populations.

Materials and Methods

After years of planning and trial runs, The Lost Ladybug Project was formally initiated in 2008 to document changing distributions of ladybugs across North America. Now, after four years of operation, the Lost Ladybug Project has over 12,000 verified records of ladybugs from all 50 states in the U.S., four Mexican states, and seven Canadian provinces. The Lost Ladybug Project collects volunteer-submitted photographs of ladybugs via a program Web site (<http://lostladybug.org>). To report a ladybug sighting, citizen scientists (a.k.a. “spotters”) provide their contact information, a digital photograph, suggested species identification, location details, habitat information, and comments within an online form. Only images identified to species by Lost Ladybug Project staff were used for this study. Submissions from entomologists to the Lost Ladybug Project were not included in the data used for this study. Observations made by the same individuals in the same general location were considered statistically independent provided they occurred at least 24 hours apart. Images of groups of aestivating coccinellids are counted as single observations of that species because they may not be functionally equivalent to a similar number of active individuals in the field.

Data from scientist surveys from 1991–2006 were based on the data set reviewed by Harmon et al. (2007). That publication broadly reviewed published literature for surveys of adult aphidophagous coccinellids in natural and managed ecosystems throughout the United States and Canada. To be included in Harmon et al. (2007), studies needed to meet the following criteria: 1) at least 20 naturally occurring individuals had been collected; 2) the proportion of native and adventive species was easily determined from the paper; and 3) >95% of individuals were identified to species (see reference for detailed methods). Data from published coccinellid surveys from 2006 to the present were reviewed for this study. The studies we found in our wide search of the literature all conformed to the criteria set out by Harmon et al. (2007). All comparisons were made using Fisher’s exact chi-square test, except for the mean number of observations per sample, which was compared using a 2-tailed t-test.

Results

The observations recorded by the Lost Ladybug Project come primarily from small samples, while the observations reported in scientist surveys come primarily from larger samples (see Fig. 1). Sixty-five percent of the observations recorded by the Lost Ladybug Project are samples comprised of a single beetle from that time and

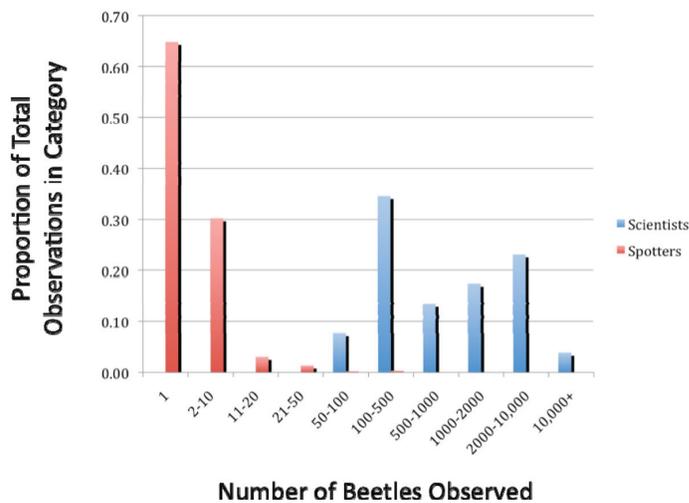


Fig. 1. Number of observations per sample for scientific surveys and spotter submissions.

place, while 44% of the samples from scientist surveys contain over 1,000 beetles. The mean number of beetle observations per sample from the Lost Ladybug Project (3) is significantly smaller than the number from scientist surveys (1,659) ($p=0.0001$; see Table 1).

Even though the set of observations from scientist surveys is eight times greater over the 20 years reviewed (1991–2011) than the set of observations from the Lost Ladybug Project’s four years of operation (2008–2011), the Lost Ladybug Project has data from over sixty times as many samples (Table 1). Corresponding to the larger number of samples, the Lost Ladybug Project had more recorded species of coccinellids (95) and a significantly higher ($p<0.0001$) number of species recorded per 1,000 observations (8.5) than the scientist surveys (55 and 0.6 respectively; see Table 1).

The same trend holds true for at least two rare coccinellid species that are of special interest: *Coccinella novemnotata* and *C. transversoguttata*. For *C. novemnotata*, the Lost Ladybug project has more records (68) than scientist surveys (17) and a significantly higher number of records per 1,000 observations (6.1 and 0.2 respectively; $p<0.0001$; see Table 1). For *C. transversoguttata*, the Lost Ladybug project has fewer records (169) than scientist surveys (210), but a significantly higher number of records per 1,000 observations (15.1 and 2.4 respectively; $p<0.0001$; see Table 1).

Discussion

Why has the Lost Ladybug Project proven more efficient in making observations of rare species of coccinellids than scientific surveys? We suspect that the greater number of samples alone is not the cause. Rather, we propose that it is the wider sampling in space that is the main reason (see Fig. 2). Although the total number of coccinellid observations represented is smaller, the Lost Ladybug

	Spotter Submissions	Scientist Surveys
Total Observations	11,162	86,281
Number of Sample	3,208	52
Mean Observations/Sample (\pm SEM)	3 \pm 1.9*	1,659 \pm 374
Total Species Observed	95	55
Species per 1,000 Observations	8.5*	0.6
Number <i>C. novemnotata</i> Observed	68	17
<i>C. novemnotata</i> per 1,000 Observations	6.1*	0.2
Number of <i>C. transversoguttata</i> Observed	169	210
<i>C. transversoguttata</i> per 1,000 Observations	15.1*	2.4

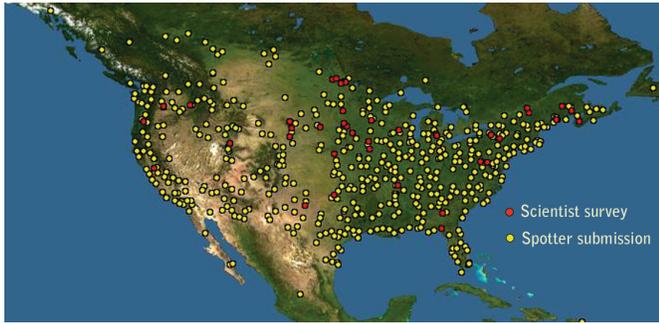


Fig. 2. Lady beetle observations in North America recorded in scientific surveys and spotter submissions.

Project observations are spread much more widely in space (Fig. 2).

There is a similar trend for observations of rare species (see Fig. 3). Observations of both *C. novemnotata* (Fig. 3A) and *C. transversoguttata* (Fig. 3B) show a much wider spread of records than was found in scientist surveys. For *C. novemnotata*, all scientist survey data indicated that this species had been relegated to areas west of the Mississippi River, until it was discovered by the Lost Ladybug Project in Washington D.C. in 2006 (Losey et al. 2007) and in even greater numbers on Long Island, New York in July 2011. Similarly, for *C. transversoguttata*, the discovery of a single adult near Traverse City, Michigan in 2011 proved that the species was extant in the Great Lakes region. For both these rare species, citizen scientist observations recorded by the Lost Ladybug Project have greatly influenced our estimate of the current range. Since we make inferences regarding factors causing decline and conditions that allow continued existence based on our best estimates of current range, these changes will have a major impact on our current understanding of the status of these species.

Beyond having a wider geographic range of samples, the Lost Ladybug Project may also be more effective at finding species in general and specifically rare species because of the wider range of habitats the samples come from. Scientific surveys for coccinellids are undertaken primarily by agricultural scientists and are predominantly focused on agricultural habitats. In contrast, less than 8% of the records from the Lost Ladybug Project came from agricultural habitats. This is especially important because it has been hypothesized that rare native species may have suffered “habitat compression,” in which they have been relegated to suboptimal non-agricultural habitats (Evans 2010).

Even though the Lost Ladybug Project has been successful in finding these and some other rare species of coccinellids, we cannot conclude that “broad” sampling will always be more effective than “deep” sampling for rare species. If a species started with a broad range and has now declined to the point where it probably has a disjunct metapopulation structure, then broad sampling will almost certainly be more effective. Alternatively, if a species is still extant but very rare across a wide geographic range, or if we have some specific idea of where it is likely to be found (due to habitat restrictions), then deep sampling is likely to be more effective.

Acknowledgements

We greatly appreciate support from the Informal Science Education Program of the National Science Foundation, and from all the citizen scientists who have contributed to the Lost Ladybug Project. We thank Dr. John Pickering for assistance in creating maps of ladybug observations.

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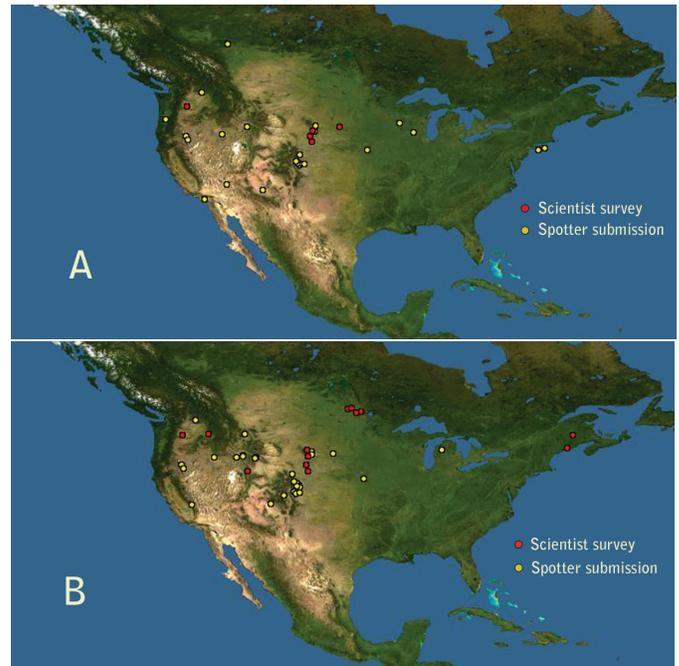


Fig. 3. Observations of *C. novemnotata* (A) and *C. transversoguttata* (B) recorded in scientist surveys and spotter submissions.

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John Losey an associate professor in the entomology department at Cornell University, is the founder and director of the Lost Ladybug Project. Dr. Losey has published technical papers on the decline of native ladybugs in America, the rediscovery of the 9-spotted ladybug, the ecological role of ladybugs as predators and the economic value of ladybugs and other beneficial insects. He is a firm believer that citizen science is the best way to educate and enthuse volunteers about the process of science and the best way to shed light on major environmental issues. Leslie Ladd Allee is the director of outreach and curriculum development for the Lost Ladybug Project and specializes in outreach to youth in underserved communities. Dr. Allee joined the development of the Lost Ladybug Project in 2005 and manages the administration of the project. She holds a Ph.D. in Entomology from Cornell University (2001) and has focused her research on alternatives to insecticides, primarily in corn. The Lost Ladybug Project gives her a way to combine her beetle expertise with her passion for outdoor play. Rebecca Rice Smyth handles data management and website development for the Lost Ladybug Project and contributes to outreach and curriculum. Her background includes bilingual studies and research in Latin America as well as inquiry-based curriculum development for middle school biology students and she combines these skills to promote participation among children from migrant worker families in New York State. She holds a Ph.D. in Entomology from Cornell University (2002) and has been studying chrysomelid leaf beetle ecology since 1998.