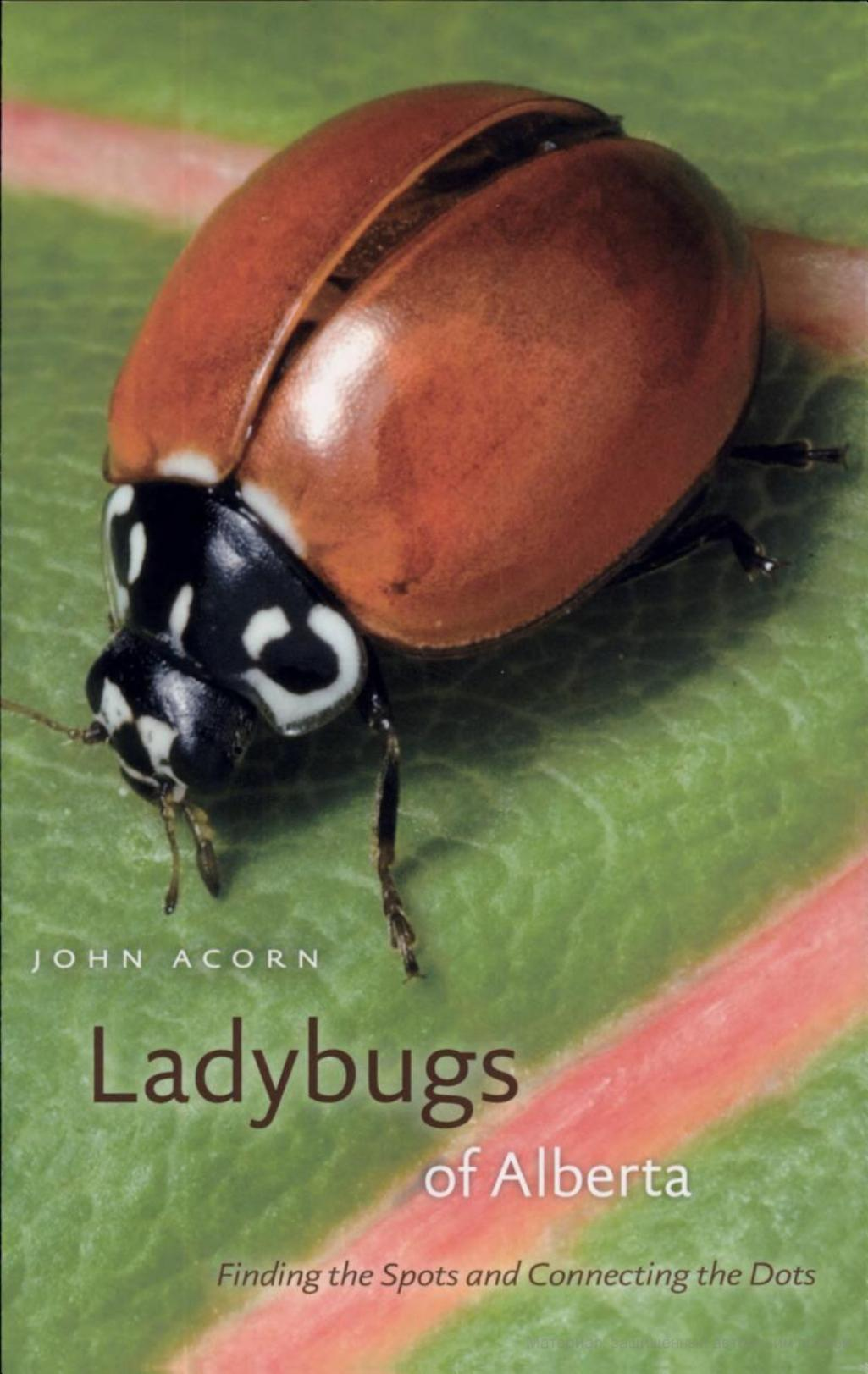

JOHN ACORN

Ladybugs of Alberta

Finding the Spots and Connecting the Dots

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Preface

When I began work on the Alberta Insect Series, it seemed to me that it should be possible to complete one book each year over a five-year period (treating tiger beetles, damselflies, ladybugs, the bigger moths, and dragonflies). That was 7 years ago, and this is only the third book in the series—proof that things become both more complex and more interesting as you start to work on them.

The first book in the series, *Tiger Beetles of Alberta: Killers on the Clay, Stalkers on the Sand* is one of a handful of tiger beetle books that have appeared in recent years. I was glad that it was well received here, that it has found an audience well beyond the boundaries of Alberta, and that the majority of the names I proposed were endorsed by the readers of the journal *Cicindela* for "official" use in more recent field guides, such as the fine book on the Canadian and US tiger beetles by David Pearson, Barry Knisely, and Charles Kazilek. My book also inspired research with students Cindy Sheppard and Randy Dzenkiw on the Alberta populations of the beautiful tiger beetle, which appear to constitute a distinct geographic race. Thus, they deserve their own subspecies name, and we are now championing the resurrection of the name *Cicindela formosa fletcheri* Criddle for these beetles. Make a note in the margin of your tiger beetle book and watch for a scientific paper sometime soon.

Damselflies of Alberta: Flying Neon Toothpicks in the Grass was also one of a number of damselfly guides to appear in recent years, and I was glad to provide an Alberta perspective on these insects. The reason it came second in the series is simple: I had all the photographs I needed for this group of insects, which was not yet the case for the other groups I am planning to feature. The most common feedback I have received on the damselfly book is the question: "When are you going to do the dragonflies, John?" The answer, of course, is "When I get around to it—these books take time!" In the meantime, there are good dragonfly guides available for North America in general and more in the works.

I am delighted to present to you a book on our province's ladybugs. Unlike the first two books in the Alberta Insect Series, the book you now hold is truly alone in its field. Amazingly, there are no other popular guides to the ladybugs of any part of North America! There are, of course, technical works on the subject, but the most important of these (Robert Gordon's monographic papers published in 1976 and 1985) are almost impossible to find unless you have access to a good university library, and difficult to read unless you are a trained entomologist. Another excellent but quite technical reference is Nat Vandenberg's ladybug chapter in the two-volume series "American Beetles." Britain has popular guides to the "ladybirds," but so far we have not been so lucky.

Another difference between this book and the two that preceded it is the number of species covered. There are 19 species of tiger beetles in Alberta, 22 species of damselflies, but a whopping 75 species of ladybugs. This may come as a surprise to most readers, and if so, I hope it is a happy one. To be honest, I'm often surprised by local ladybug diversity myself, and I deeply hope that readers of this book will find themselves inspired to get out and see as many species as possible, rather than being overwhelmed by the number of possibilities when it comes to making an identification.

The underlying theme of my tiger beetle book involves life in isolation, and the dynamics of patchy, highly eroded habitats—places like sand dunes, salt flats, and beaches—kept in existence by geological forces but continually under threat from colonization by pesky plants. Likewise, the damselfly book had a geographic thread running through it, about the appearance of new habitats, such as those created by water management on the prairies, and the warm-water outflows from power plants. The theme for this ladybug book is different—it has to do with the effects of introduced species on a native fauna. Most naturalists are aware that the seven-spot ladybug (*Coccinella septempunctata*) is a newcomer to Alberta, and that other European and Asian species are established elsewhere in North America, and might possibly find their way here as well. In fact, I have had a number of people ask why I would bother with a ladybug book, since "all I see now is that damned seven-spot."

This, to me, is a fascinating story. I too was deeply troubled by the arrival of the seven-spot, and by the decline of familiar native species, especially the transverse ladybug. I originally intended this book to be a call to arms against such alien invaders, and a sort of eulogy for the native ladybugs of our province. But as I became increasingly familiar with the situation, I started to find native species all around me, most of them right where I remembered them from my youth (I was a beetle collector as a school kid; a sort of person you just don't run into nowadays). It was clear that some of the old familiar ladybugs had become quite rare, but not all. Things have changed, but is change in itself a bad thing?

As a quasi-paleontologist (I have had a long working association with the Royal Tyrrell Museum), I am continually reminded that the one constant in nature is change. The history of Alberta since the end of the last ice age is a case in point. Most people assume that the "unusual" ice melted, and things became "normal," but in truth, the last 10,000 years have been characterized by fluc-

A winter ladybug climbs the leaf of a sage plant on the prairies.

tuations in climate, To believe that there was a stable, "original" state of nature that existed before the arrival of European people is simply a mistake. All evidence suggests continual change. It was slow gradual change for the most part, but still change. Therefore, much of our common sense view of the world, and especially the rather stabilist approach we take toward the conservation of nature, is based more on myth and nostalgia than on ecology and biogeography. Making peace with ecological change may be difficult, but to me, it makes sense as the only real option.

There are two common responses to ecological change: you can resent it and fight against it or find it interesting and worthy of study. You may think the second option odd, but let me remind you that many modern ecologists believe that the arrival of new species is best viewed as a series of accidental experiments that test and clarify our views about ecology and evolution (especially when nature has rearranged itself without any extinctions taking place). To see it this way, one must also agree that dispersal is a normal part of the history of life, humans are a part of nature, human-assisted dispersal is not really different in kind from so-called natural dispersal, human-assisted dispersal is a predictable result of human dispersal itself, the term "native" has no real meaning in biology, there never was an original state of nature, there is no such thing as the balance of nature, and there is no such thing as "the way nature intended." These things may not be readily apparent to everyone reading applied ecology driven by the need to control nature), they make perfect sense. In contrast, those who instantly label any and all introduced species as "alien invaders" or "threats to biodiversity" may be missing the real lessons that these newcomers can teach us about the way nature works.

Some people will no doubt accuse me of undermining the conservationists' cause (and perhaps coming across as an Alberta redneck) by my reluctance to demonize introduced species of ladybugs, but undermining conservation is the furthest thing from my mind. Instead, I am trying very hard to follow my conscience and remain as scientifically self-honest as I can. Conservation, to me, is about sustaining the living world around us—people included—not about returning to a mythical golden era when we, or our ancestors, or someone else's ancestors, were "in harmony with nature." The biggest threat to conservation I see is the loss of credibility that comes from "crying wolf," and I think that ladybugs provide a case in point. The second biggest threat to conservation is loss of habitat, not introduced species.

I dislike industrial development, urban sprawl, and the conversion of natural or semi-natural landscapes into cropland as much as the next naturalist, but my point here has nothing to do with these things—it is about the nature of the living world, and the need to make peace with inevitable change. The new ladybugs are here, more are likely on the way, and my job is to lay out for you a detailed picture of what we know, what we don't know, and what kind of sense we can make of these patterns from the perspective of biology.

It was a ladybug specialist, Theodozius Dobzhansky, who gave us one of science's most famous quotes: "Nothing in biology makes sense except in the light of evolution." Ladybugs are the dynamic products of evolution by natural selection, not off-the-shelf cogs in an environmental machine. What this means takes time and patience to unravel. Conservation biologists will tell you that their field is now in its "ecological–evolutionary" phase, in step with modern science, having outlived its so-called "romantic–transcendental" phase, tied as it was to religious and cultural biases, and rather outdated notions about the nature of the living world. I personally think that this announcement is premature and that many, if not most, people in the conservation arena are engaged in a hopeless struggle against change and toward a stabilist goal for the environment, loosely based on naïve notions of what things were like here some 300 years ago. However, as philosopher Daniel Dennett wrote, the evolutionary view bears "an unmistakable likeness to universal acid: it eats through just about every traditional concept and leaves in its wake a revolutionized world views, with most of the old landmarks still recognizable but transformed in fundamental ways." If evolution is about change (and it is), then change, in and of itself, cannot be the enemy in an evolutionary version of conservation biology. We are not living among the finished products of the evolutionary process—we are living within the currents of the process itself, but that is a much bigger topic for discussion and perhaps not one to hide in the preface of a ladybug book.

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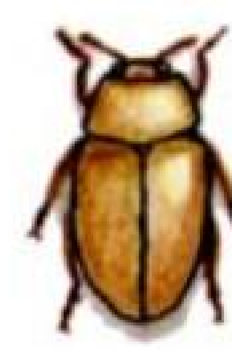

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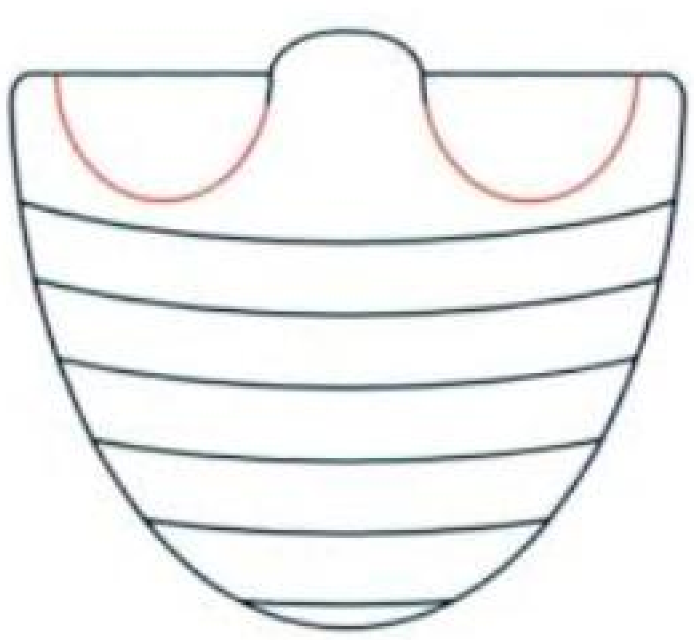
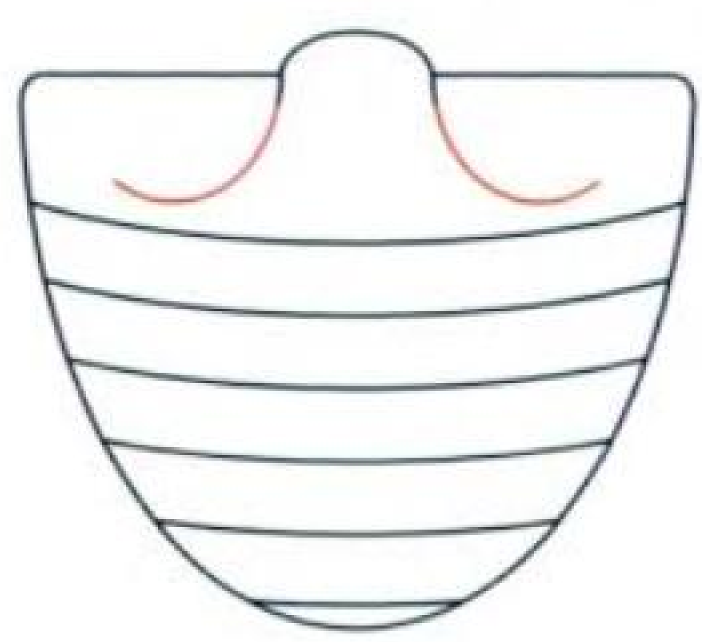


Underside of abdomen showing complete postcoxal arcs.



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1

What is a Ladybug?

Ladybugs are some of our most familiar insects, to be sure. Just about everyone loves them, at least here in Alberta, and I am delighted to say that this is the first ladybug field guide for any part of the Western Hemisphere. It would be nice if there were only a few different types of ladybugs in Alberta, but the truth is that there are 75 or more different species, some of which are quite variable in their appearance. If you are up to the challenge, ladybug identification is reasonably easy and fun, and I'm delighted to help Albertans pioneer this aspect of nature appreciation.

So let's begin with the simple question: What is a ladybug? Technically, ladybugs are members of a single family of beetles, the Coccinellidae. Since they are beetles, some people dislike the name "ladybug;" the so-called "true bugs" belong in the insect order Hemiptera, and beetles are members of the Coleoptera. For this reason, you will often see them called "ladybirds," "ladybird beetles," or "lady beetles." To me, it is silly to try to re-educate Albertans, who almost universally call them ladybugs. It's about as hopeless as getting people to say "Richardson's ground squirrel" instead of "gopher." Besides, I wrote an entire book on damselflies knowing perfectly well that they were not flies, so I don't feel bad about writing on ladybugs knowing they are not bugs.

The "lady" part of their name, by the way, refers to the Virgin Mary, and they are in that sense actually "Our Lady's Bugs." The red colour of many ladybugs reminded some early Europeans of the red robes of the Virgin Mary, and this is said to be the origin of the name. "Coccineous" is a term meaning "berry red" and is of course the Greek source from which the name Coccinellidae is derived. One prominent entomologist, Willis S. Blatchley, attempted to promote the name "plant louse beetles" alongside "lady bugs" and "lady beetles," but, thankfully, that idea never caught on.

What should we call ourselves, those of us who study ladybugs? I made the mistake, not long ago, of asking a man standing next to me in the poster section of a scientific meeting, if he was "a ladybug guy." He looked at me quizzically, and I rephrased it—"Oh, I mean… are you a coccinellidologist?" At this point, his eyes lit up, and he turned toward me ready to chat. It was John Sloggett, a well-known British ladybird man, and I was pleased to meet him. Personally, I like the term "ladybugster," but I'm not sure it will catch on. How about "ladybug enthusiast" or "ladybug lover?" They all have their shortcomings, but as long as we can recognize each other as kindred spirits, we'll be all right.

As beetles, ladybugs have forewings that are hardened into wing covers, or "elytra," that meet in a straight line down the back of the beetle, and cover the folded hind wings, which are used for flight. Most ladybugs are less than 10 mm long, and some are less than 2 mm in total length. Ladybugs generally have rounded or oval bodies, relatively short legs, and relatively short antennae with small but obvious clubs at their tips. Entomology texts will tell you to count the segments of the tarsus or "foot" of a ladybug, and look for the hidden third segment at the base of the fourth segment in order to confirm that you do indeed have a ladybug in front of you. I find this difficult to see at times, even with a microscope, since it is indeed hidden, and the fact that some ladybugs (in the genus *Nephus*) have only three tarsal segments has convinced me to look for their other distinguishing features in times of confusion. If you know your beetles reasonably well, you will find that all ladybugs do indeed possess "the ladybug look."

The evolutionary place of ladybugs among the beetles is fairly well understood, and the ladybugs comprise one family among many in a large group of quite obscure small beetles called the "Cucujoidea." Their closest relatives include the families Latridiidae (the minute brown scavenger beetles), and Endomychidae (the handsome fungus beetles)—creatures that only specialists recognize, for the most part. Surely, on this branch ("the cerylonid series") of the massive family tree of beetles, the ladybugs are the most famous, most obvious, and best-loved members.

Plenty of red and black, or orange and black creatures look like ladybugs, so don't be fooled! (As well, please be sure that what you are looking at is a ladybug, before you write to me and tell me disdainfully that I "missed" a species!) Be especially wary of some leaf beetles (in the family Chrysomelidae), which generally have longer antennae and a different look in their eye. There are also red and black stink bugs, most of which are ladybug-like only when they are young and lack wings. Another true bug, the superb plant bug (*Adelphocoris superbus*) is quite ladybuggish as a winged adult. When searching for the tiniest of ladybugs, even careful beetlers often pick up large numbers of "shining flower beetles," in the family Phalacridae, small smooth beetles with clubbed, elongate antennae. (Despite my having sorted through hundreds of phalacrids in search of tiny ladybugs, the official checklist of Alberta shining flower beetles includes a grand total of zero species, so this is obviously a place where discoveries might be made, if ladybugs themselves seem too mainstream for you.)

[illegible] *beetle* (Phalacrus *sp.*), *bottom left: black-footed tortoise beetle* (Jonthonota nigripes), *bottom right: immature two-spotted stink bug* (Perillus bioculatus).

In this book, I have tried to make ladybug identification both easy and accurate. Most species can be identified simply by examining the colour pattern on the wing covers and the pronotum (the shield on the top of the beetle, between the head and the elytra). Most of the important features are on the dorsal (top) side of the beetle, but on occasion you will need to look at the ventral (under) side as well. Perhaps the most important features to see are the so-called post-coxal arcs on some of the lesser ladybugs: thin lines on the first segment of the abdomen behind the base of the hind legs. For this, you will need a "dissecting" or "stereo" microscope (or perhaps a hand lens and a steady hand) that magnifies at least 20 times. This is also the only instance where you might need dead specimens. Most ladybugs can be identified while still alive or from good macro photographs.

The colouration of typical ladybugs—black with yellow, orange, or red—is a warning to predators that they taste bad (and I should add here that I performed some quick-and-dirty tests for ultraviolet reflections using a digital camera and a UV-cutoff filter, but found nothing that looked like ultraviolet patterning in ladybug specimens). Ladybugs protect themselves with compounds in their blood called alkaloids. When they are threatened, as for example in a bird bill or between the tips of human fingers, they perform "reflex-bleeding" in which the blood (or "haemolymph") escapes from joints in the legs, causing no long-term harm to the ladybugs but causing the predator to release the beetle. This is why you see orange liquid on your fingers when you pick up a ladybug too firmly. Many of these alkaloids have been named for the ladybugs from which they were derived, with names such as coccineline, hippodamine, and adaline, named for the genera *Coccinella*, *Hippodamia*, and *Adalia* respectively.

Not all ladybugs taste equally bad. Since the sense of taste in birds is immensely difficult to investigate (involving careful experiments with naïve captive reared birds, among other things), I often taste the reflex blood of ladybugs myself. This is not nearly as weird as it sounds, but I'll admit it does sound weird. If there were any diseases or parasites I could catch, I wouldn't do it, believe me. The procedure is simple: I place the ladybug on my tongue, press them gently against the roof of my mouth, remove them unharmed, and swirl the saliva around my mouth. I then take notes. I have determined that, to my taste at least, the worst ladybugs are the seven-spot, the transverse, the twice-stabbed, the Halloween, and the ash-gray (*Olla v-nigrum*). All of these are bitter tasting and put me off my appetite. By contrast, most of the *Hippodamia*, as well as the two-spot taste mildly musty, something like the smell of two-week-old salad, or dirty socks. The only lesser ladybug I have tasted is the lateral ladybug—my field notes read "subtle, bitter, metallic, and recognizably a ladybug alkyloid." The absolute worst is a relative of the twice-stabbed ladybug, *Chilocorus cacti*, which I tasted in Florida—it nauseated me for a full eleven hours.

It may be that less-distasteful ladybugs mimic the more distasteful species. In Britain there is evidence for two "mimicry rings," both of which involve a number of species. There are light-coloured beetles in one ring and dark-coloured beetles in another, and some polymorphic species (species with more than one colour form among their members) participate in both. This has not been studied here in North America, but it seems likely that mimicry is involved here too. It is also likely that some of the leaf beetles and stink bugs that are often mistaken for ladybugs are involved in these mimicry associations as well.

One of the great mysteries of ladybug colouration is simply this: why, if ladybugs are warningly coloured, do some species occur in a variety of colour patterns? Why not show the predators just one pattern, so the predators can learn more effectively? Apparently, there are two aspects of mimicry theory that might help here. First, it might be that predators don't distinguish among the colour morphs and easily learn to avoid all ladybugs regardless of pattern. I'll let you look at the illustrations and decide for yourself if this is reasonable, but to me it seems unlikely, especially when you consider the diversity of other small colourful insects out there. Second, there may be mimicry involved, and the polymorphism may be a distasteful species' way of evolving away from its less distasteful mimics (which reduce the effectiveness of the defence). Since some individuals die while the predator is being educated by the distasteful ladybug, perhaps evolution favours those who look less like the mimics. When there are mimics around, educating the predators is not as efficient, and the warning colouration is not as effective at saving ladybug lives. Do I believe this? Well, sort of— but it sounds improbable to me.

Colour polymorphism may not have much to do with mimicry at all. For polymorphic species, it has also been suggested that dark colour ("melanism") is related to increased humidity, aridity, industrial pollution, and the like, but in a complex and poorly understood way. In warmer areas where ladybugs are out and about year-round, dark forms of some species do best in summer, whereas lighter beetles do best in winter. One good example is the two-spot ladybug, and this species includes both light (red) and dark (mostly black) individuals both here and in Europe. As well, the genetics of the two-spot are quite well understood, making this a popular subject for this sort of research.

In some studies, females preferred one colour of male to the other, and it seems that females also seem to prefer larger and more active males and to recognize them in part by their smell. When the characteristics of living things come from the effects of the opposite sex choosing some sorts of mates over others, we speak in terms of "sexual selection," and in my conversations with other ladybugsters this is the explanation that seems to make most sense when explaining polymorphism.

There is another pattern here that makes little sense to me so far. All of our polymorphic ladybugs live in trees (the two-spot, polkadot, and Halloween), and all of the low-vegetation species are generally uniform in their appearance. Perhaps this has to do with greater threat from bird predators in trees. Perhaps

Two very dusty, but still lusty, two-spot ladybugs—note that the female is larger, and that neither of these individuals has only two spots.

it is related to the presence of the extremely bad-tasting twice-stabbed ladybug in trees but not in low vegetation. Or perhaps there is an even more subtle explanation. Among mimicry biologists, it has become increasingly important to look at the background context of colour patterns, and perhaps there is something about the "look" of a ladybug in a tree, as opposed to on a herb, that promotes the origin of more than one colour pattern within a species. Who knows, but I do hope that some patient, well-funded person is able to pursue this as part of their research sometime soon.

Speaking of which, it is sometimes relatively easy to tell male and female ladybugs apart. Males are generally smaller, while females are generally larger—the usual pattern in most insects. As well, the males may have a broader indentation on the trailing edge of the last or second-last abdominal segment. Among the lesser ladybugs, it is common for males to have more yellow on their face than the females. However, in most common species of ladybugs I can't see any obvious sexual differences, and I doubt it is easy to tell them apart.

Of course, ladybugs are also prominent in Western culture, and other human cultures as well. We have all heard the poem "Ladybug, ladybug, fly away home..." and we have all been told that the ladybug is our friend. Gardeners, especially, like to think of ladybugs as just the right sort of bugs for the garden, since ladybugs are small, cute, and eat pestiferous aphids. I am absolutely amazed at home many gardening shops use ladybugs (and typically the seven-spot ladybug) in their advertising logos. How odd, considering that the object of gardening is to grow plants, not insects! Add the sheer number of ladybug decorations and toys for sale in garden shops and nature centres, and the message is clear: we love ladybugs and they can do no wrong.

In other parts of North America where the Halloween ladybug is abundant, people have lost much of their affection for these beetles, since this newly arrived species often congregates in houses and causes a noticeable odour, an unmistakable insect presence through the winter, and the occasional bite. In these areas, it is as if the ladybugs have "gone bad," and entomologists are called upon often to explain how our favourite beetles could betray their human friends so badly. I have also heard people mistakenly refer to Haloween ladybugs as "those things that look like ladybugs but really aren't."

Of course, there are plenty of oddball beliefs about ladybugs out there as well. It should be clear to you that at least two popular beliefs about ladybugs are not true. First, the number of spots on a ladybug does not tell you how old it is, or how harsh the coming winter will be. Second, small ladybugs do not grow into big ladybugs. Instead, all ladybugs are adult beetles. Each individual ladybug was originally an egg, then a larva, then a pupa, and finally an adult beetle, and next I will describe the life of a ladybug in more detail.

2

The Life of a Ladybug

All ladybugs begin life as eggs, and the eggs of ladybugs are small, usually yellow or orange, and typically laid in clumps on a plant where the food of the larvae can be found. Interestingly, most ladybug egg clusters include a number of infertile eggs, and this is not an accident. The newly hatched larvae eat the infertile or "trophic" eggs, and for many baby ladybugs this is their first meal. Jennifer Perry, a graduate student at Simon Fraser University in British Columbia, found that when there were few aphids present the mothers laid more trophic eggs, presumably helping the new larvae along through tough times. Also, like many newly hatched insects, newly hatched ladybug larvae also eat their own eggshells.

The larvae of ladybugs are elongate, six-legged creatures with clearly defined body segments. Most people find them far less cute than the adults. As the larvae grow, they pass through four "instars" between which they shed their skins. At warmer temperatures and with more food, they grow more quickly, and their rate of growth can be remarkably fast. For example, Cesar Rodriguez-Saona and Jeffrey Miller found that the time it took convergent ladybugs to develop from egg to adult was a mere 14 days at 30 °C but a full 51 days at 18 °C. Moderation is the key, however, and adult weight and wing size was greatest among beetles that developed at an optimum temperature of 22 °C. J.Y. Xia and colleagues found that seven-spots also developed most quickly at high temperature but that egg to adult survival was highest at a more reasonable 25 °C, as was the number of eggs produced by adult females.

These sorts of studies allow entomologists to calculate the number of "degree-days" needed for development from egg to adulthood. To calculate degree-days, you take the average temperature each day, and subtract from it the minimum temperature at which the ladybugs can grow, the so-called "developmental threshold" (which is generally somewhere between 12 °C and 14 °C). For the convergent ladybug, the study by Rodriguez-Saona and Miller estimated that 231 degree-days are required for complete development, above a threshold of 13.6 °C. To increase their accumulation of degree-days, ladybugs often forage most heavily on the sunlit side of trees and bushes. I have noticed this with two-spot and seven-spot ladybugs feeding on aphids on caragana.

Because many ladybug larvae eat economically important pest aphids and scale insects, the feeding habits of ladybug larvae have been well studied. Aphids also attract other predators, such as lacewing larvae and the larvae of some hover flies, so aphid-rich plants can be dangerous places and not just for aphids. Ladybug larvae can also be cannibalistic, eating larvae and eggs of their own species or others.

Cannibalistic Halloween ladybug larvae are more likely to survive and develop quickly than their non-cannibalistic kinfolk. At least that's what William Snyder and his colleagues found, as well as determining that, if the larvae fed on other larvae that in turn fed on high-quality aphids (those without many toxic chemicals in their bodies), the benefits to the cannibals were even greater. If the larvae were fed only on poor- and intermediate-quality aphids, only those that fed on intermediate aphids (and/or larvae that themselves fed on intermediate quality aphids) survived to become adults. It seems likely that the cannibal larvae take advantage of the fact that their victims have already detoxified the lower quality aphids, but there are clearly still things here to be learned.

Other sorts of insect eggs can also serve as ladybug food. For example, one study found that twelve-spot ladybugs (*Coleomegilla maculata*) could develop on Colorado potato beetle (*Leptinotarsa decemlineata*) eggs, but not all the larvae made it to adulthood. This was the work of Joseph Munyaneza and John Obrycki. Mpho Phoofolo (the man with the best name in ladybug science, in my opinion) and John Obrycki found that twelve-spot and Halloween ladybugs could develop to adulthood eating nothing but lacewing eggs, but that seven-spot larvae could not. In turn, lacewing larvae (*Chrysoperla carnea*) could develop on nothing but twelve-spot eggs. As well, both the lacewing and ladybug larvae eat each other, although mostly this means the lacewings eat the ladybugs.

The influence of plant defence chemicals on the development of two-spot ladybug larvae feeding on peach-potato aphids (*Myzus persicae*) was the subject of a study by Frederick Francis and his colleagues. They reared aphids on canola (a plant with low levels of "glucosinolate" defence chemicals), mustard (which produces high levels of "GSL"), and beans (which have no GSL). In general, oddly enough, the aphids did best on canola and mustard and less well on beans. The canola and mustard-fed aphids produced faster growing larvae and larger ladybugs. However, mustard-fed aphids resulted in smaller ladybug eggs, fewer eggs, and fewer viable eggs. Like so much of ladybug ecology, I'm sorry to report, it makes no obvious intuitive sense at all—nature is so wonderfully but frustratingly complicated. Keep this in mind when we come back to the task of unraveling the effects of introduced species.

In this book, I have not attempted to provide a guide to ladybug larva identification, but it is likely that all of our species could eventually be told apart as larvae. There is a key to the larvae that takes them to the genus level, written by B.E. Rees and colleagues. Bob Gordon and Natalia Vandenberg have also produced a fine paper on the larvae of *Coccinella* ladybugs and for now that is our best guide. In general terms, the common larvae of *Coccinella* ladybugs can be separated from *Hippodamia* by the dark markings on the pronotal shield behind the head, which are connected at the hind edge in *Hippodamia*, and around the middle in *Coccinella*. Two-spot larvae have shorter legs and a more oval body. *Calvia* and *Myzia* larvae have a point or "appendix" on the top of the ninth abdominal segment. "Other genera," according to Gordon and Vandenberg, "differ conspicuously in the form of the body armature, particularly the dorsal setose processes, and are unlikely to be confused with *Coccinella*."

When a ladybug larva finishes its development, it generally leaves the plant on which it was hunting, and searches for a place to become a pupa. Ladybug pupae are usually formed in the open, attached to a surface by the tip of the abdomen. They are generally warningly coloured, in orange or yellow and black or brown, and they can wiggle a bit, presumably to scare off potential parasites. Colour may vary among pupae of a single species, and as with adults, darker pupae are apparently the result of increased humidity or lower temperatures, at least in part. Among the lesser ladybugs, the last larval skin covers the pupa, but this is not the case among the larger ladybugs.

After relatively short period (days or weeks, but not months), the pupa "ecloses" to become the adult ladybug. At first, the beetle is soft with pale colours. This is the teneral phase of the life history, during which chemical changes in the cuticle (the outer surface or exoskeleton) of the beetle both harden and darken the body. Within a single species, there can be quite a bit of variation in final body size, but males are generally smaller than the egg-bearing females.

Once ladybugs are past their teneral phase, they proceed with the business of feeding and finding mates. Males can mate more-or-less right away, since the production of sperm begins while they are in the pupa. Females can also mate immediately and store sperm for later use in a structure called the spermatheca. One mating is all that a female needs to fertilize all of her eggs for life, but most females mate multiple times nonetheless. In some species, including our most familiar ladybugs such as the seven-spot, the female can lay hundreds of eggs if she survives long enough to do so.

Unless indicated otherwise in the text that follows, it is generally the case that ladybugs eat aphids. Aphids are small sucking bugs in a number of families that in turn fall into a broader group called the Aphidomorpha. I wish I could recognize different species of aphids in the field, but I'm having enough trouble learning the ladybugs. Most aphids sit on the stems or leaves of plants, and suck the sugary juices from the phloem of the plant. In order to eat an aphid, a ladybug or ladybug larva simply walks up to it, and devours it. Aphids will kick to fight back, and they do produce defence chemicals; however, in most instances this is of little help in when confronted with a hungry ladybug.

Most aphids over-winter as pregnant adult females that emerge in spring and start colonies on plants (although many also overwinter as eggs). They go through a number of largely wingless parthenogenetic generations (females giving live birth to more females, in the absence of males) and then in the fall produce both winged females and winged males. Thus, aphid numbers increase very quickly over the course of the growing season, and ladybugs have in part synchronized their own life cycles to the annual waves of aphids, in an evolutionary sense. This also means that aphid numbers can almost always stay ahead of ladybug numbers, which is why ladybugs never manage to eat all the aphids.

Ladybugs that feed on aphids will also take a variety of alternative foods, especially during times when aphids are scarce. These alternative foods include other sorts of insects, insect eggs, sap, and even pollen. Thus, it is perfectly normal to find ladybugs in dandelions in the spring, or at sap-flow wounds on trees such as birch and maple. When I put out a bait of beer, rum, molasses and brown sugar for night-flying moths, I sometimes get a ladybug or two sipping on the edge of the bait patch, painted on tree bark. The polkadot ladybug seems especially easy to attract to bait, and I once had a polkadot ladybug come to a half eaten bowl of carrot and oatmeal baby food while we were on a family camping trip at Lac La Biche.

In many instances (in lawns, sedges, cornfields, and wolf willows, for example), you will encounter large populations of ladybugs but no aphids. Every time this happens, my first thought is that I have missed the aphids, but in most instances there are leaf-hoppers and plant-hoppers present, and these are the obvious prey. It's embarrassing, in retrospect, to admit that I have always been too busy to sit down with close-focusing optics and actually watch to see if the ladybugs actually eat the leaf or planthoppers.

Because some plants predictably harbour more and better quality aphids than others, it is easy to know where to look for large concentrations of ladybugs. Among my own favourite searching spots, I include the following trees: birches (especially weeping birch), lone jack pine, spruce or lodgepole trees, set apart from clumps and forests, manitoba maple trees ("boxelders"), mountain ash trees (where ladybugs may be aestivating in the berry clusters), and balsam poplar seedlings (aspen are poor). The best bushes are wolf willow, sage, caragana (where aphids feed on the pods), cherry and alder (for some lesser ladybugs on bark) and Saskatoon (with leaf mildew for wee-tiny ladybugs). I also habitually search scraggly grasses on dune ridges and pediment slopes, thistles, alfalfa fields, sedges, and honeysuckle vines with wooly aphids. Snowberry patches can also be worth searching.

Adult ladybugs live from a month or so to up to three years. Of our species, the longest-lived is the Halloween, which has been documented at three years of age. Some other sorts of beetles also live this long, but among adult beetles, this sort of longevity is certainly the exception not the rule. Seven-spot ladybugs can live for a second year as an adult, and it is tempting to suggest that longevity is in part responsible for the success of these two recently introduced species in North America. Add to this the fact that most of our ladybugs go through two breeding generations per year, and the potential for their populations to rapidly increase becomes readily apparent.

Adult ladybugs are good fliers, and they fly almost exclusively by day. Some of us, who run light traps for moths and other night-flying insects, have records of the occasional ladybug in our traps, but night flights are not a regular part of their daily life. The reason ladybugs fly so much is that they rarely settle in to a particular patch of aphids for very long. Aphid colonies boom and bust like oilfields in rural Alberta, and the ladybugs are the equivalent of rig workers following the jobs. Many female insects, while producing eggs, lose much of their flight musculature and are temporarily unable to fly, but this is not the case among ladybugs—they need to remain mobile in order to survive.

Female ladybugs lay eggs more readily in the presence of dense populations of aphids, but they will also lay eggs in places where there are no aphids at all. Egg laying can occur more or less throughout the season, but in almost all of our species, it is the adult beetle that spends the winter not the egg, larva, or pupa.

Hibernating congregations of ladybugs can be quite dramatic, and the most obvious of these are found in leaf litter (for example, seven-spot ladybugs) or in houses (two-spot or Halloween ladybugs). On hilltops, especially in the foothills, you might also find hibernating clusters of various *Hippodamia* ladybugs. This phenomenon is especially well known along the West Coast, where convergent ladybugs are collected for resale to gardeners, a laudable idea that unfortunately doesn't work.

Let me explain. The reason most entomologists recommend against ladybug releases is that the ladybugs still feel the need to make a long-distance flight when they leave what they think is their hibernaculum. They simply do not stick around to control *your* aphids, when they are faced with a wild and wonderful spring world *filled* with all the aphids they could dream of. For example, at a recent nature festival in the United States, I was asked to preside over the release of ladybugs in a town garden. I'm sure the organizers were discouraged to hear me explain to the children that the ladybugs were more than likely going to spend the next few days eating aphids on weeds in roadside ditches and along railway lines. Sure enough, 90% of the beetles took wing the moment their screen cage was opened, but I was especially saddened by all of the trampled ladybugs left on the ground when we were finished, and in general it is clear to me that ladybug harvesting does more harm than good.

A seven-spot ladybug just after emerging from its pupa, still pale in colour and soft.

So why do we persist in believing that ladybugs are "the gardener's friends"? Perhaps it has to do with the history of ladybugs as alternatives to pesticides. Way back in 1889, a type of ladybug called the vedalia beetle (*Rodolia cardinalis*) was used with great success in California, to control a pest called cottony cushion scale on citrus trees. An inexpensive, environmentally clean technique thereby saved millions of dollars, and raised the hopes of entomologists everywhere for "biocontrol." This sort of success has never been repeated with ladybugs, a fact that has never quite made it into the public consciousness. Entomologists, by the way, refer to this as the "ladybird fantasy period," admitting up front that it is likely never to return.

John Obrycki and Timothy Kring recently reviewed the use of ladybugs in biological control. They found that, in order to encourage ladybugs, you need to reduce pesticides and provide refuge for the beetles. The rate of establishment of newly introduced ladybugs is low (less than the average for all biocontrol organisms in North America) and, in general, ineffective species are used because they are easy to collect at their overwintering aggregations. Surprisingly, the efficiency of ladybugs as predators is quite poorly understood (in part because they are highly mobile and eat a variety of things), and they are

Big, green, juicy aphids—the bread and butter of the larger ladybugs.

rarely surveyed properly in biocontrol studies. Ladybugs sometimes eat other biocontrol creatures or disrupt their positive effects. For example, convergent ladybugs collected in California have been shown to have no effect on aphids where they are released and instead may spread ladybug parasites and plant diseases (in this instance, a fungus of dogwood bushes). Furthermore, as I will discuss in the next chapter, introduced ladybugs can have detrimental effects on their native relatives.

In general, aphid-eating ladybugs cannot keep up with increasing populations of aphids each year, since aphids are so much better at reproducing. From the ladybug's evolutionary perspective, this is probably a good thing, since it ensures that each ladybug has a good chance of finding aphids to eat. However, some people just won't leave nature to its own devices. There is talk of attempting to breed wingless strains of two-spot and Halloween ladybugs (that will be forced to stay in one place and control the aphids in that locality), and possibly pesticide-resistant ladybugs as well (so you can throw both pesticides and ladybugs on your crop simultaneously). These developments are still theoretical, but while we wait to see if this idea materializes, it is interesting to note that the application of "food sprays" (sugar and protein, and something called "artificial honeydew") has been shown to increase ladybug populations in crops, without adding toxins to the scene.

Returning to the subject of ladybug aggregations, if you find a ladybug in your house you can feed it bits of banana, and liver-flavoured catfood. In one study, Irene Geoghegan and her colleagues actually used magnetic resonance microimaging to show that ladybugs on an artificial diet built up a mass of nutrient in their bodies, as if preparing for hibernation. So perhaps giving the beetle some cat food and putting it back in a cool corner might be a nice thing to do. Most ladybugs will not, however, live and breed without feeding on aphids, so long-term captive breeding of ladybugs is a difficult thing, requiring long-term breeding of aphids on the side.

Alberta is not particularly well known for ladybug aggregations, but back in the early 1980s, A.M. Harper and C.E. Lilly reported huge clusters of five-spot ladybugs at various places along the eastern slopes and in the Porcupine Hills, generally between 1250 and 2439 metres in elevation. The clusters (or "colonies") were found on west-facing slopes under debris and rocks, which no doubt helped insulate the beetles, especially under snow. These same ladybugs were thought to feed down on the prairies in summer, on pea and grain aphids in cropland, and then return to the high country in the fall. With that thought as motivation, these two crop pest entomologists measured the cold tolerance of the beetles; they found that the beetles developed cold hardiness in the fall and that their resistance to cold was greatest in mid-winter. In dormant ladybugs, the gut is free of food, and the fat body grows to serve as a winter reserve. Then, during a typical spring, the beetles sun themselves during warm days, return to the aggregations each night, and mate at the aggregations before dispersing downhill. Cold hardiness (the result of glycogen in the blood that protects the ladybugs down to about −30 °C) is lost in the spring, and Harper and Lilly thought that a late spring cold snap could result in terrible mortality at these colonies. Their measured overwintering mortality in the colonies varied from 20% to 70%. They also found Colonel Casey's ladybug in small numbers in a few sites (Porcupine Hills and Turtle Mountain). The Harper and Lily study is clearly the best and possibly the only relevant work on ladybug hibernation at Albertan winter temperatures, and it would be interesting if further research was done on this phenomenon.

Why do some ladybugs aggregate for the winter? It seems to be a means of increasing the effectiveness of their warning colouration and defence chemicals. Predators that might eat a single, isolated ladybug might not have the stomach for a whole gut full. On the other hand, Karolis Bagdonas has told me that in Wyoming he has found grizzly bear droppings that contained nothing but the undigested remains of thousands of *Hippodamia* ladybugs. The bears typically, and famously, feed on winter aggregations of cutworm moths and occasionally they fill up on ladybugs as well.

Where ladybugs congregate in houses and buildings for the winter, the smell can be obvious to people ("penetratingly noticeable to man" according to Ivo Hodek and Alois Honěk), and this smell may be the means by which ladybugs find their winter colonies from year to year. In other words, it may be an "aggregation pheromone," although our understanding of such chemicals in ladybugs is still in its infancy

Some ladybugs will also enter a period of summer dormancy called aestivation, in order to sit out the period when aphid numbers are low. R.D. McMullen found that nine-spot ladybugs in California went into both aestivation (the spring generation of adults) and hibernation (the summer generation adults) in response to changes in day length during the first week of their adult life. Here, I have noticed aestivation among seven-spot ladybugs, in small clusters on the tops of thistles and wolf willow bushes, and among two-spot and polkadot ladybugs on the bark of trees.

Ladybugs have large eyes and a well-developed sense of sight. Ed Mondor and Jessie Warren found that adult Halloween ladybugs could associate yellow colour with prey, and they concluded that these beetles could find suitable plants visually in the field. The sense of smell is also apparently important for ladybugs. R.M. Hamilton and his colleagues in Utah looked at the sense of smell of convergent ladybugs, which are attracted to peach-potato aphids. They found that sensors on the antennae, near the tip, were responsible for the sense of smell. The ladybugs were attracted both to aphids on radish leaves, and to clean radish leaves, suggesting that a mixture of both scents may be attractive. These authors noted that before 1980 no one thought ladybugs could smell or see their food at any distance and were considered "blundering idiots" by most entomologists. Since then, both senses have been studied and confirmed, but not in a convincing way to everyone. The sense of smell seems to be present in convergent, seven-spot, Halloween, and eyed ladybugs (*Anatis ocellata*). The latter are attracted to the scent of pines, where they find pine aphids, their preferred prey. So a general pattern is emerging, and it seems likely that ladybugs rely quite a bit on their sense of smell.

Naturally, ladybugs also have many enemies, above and beyond their cannibalistic relatives. They are eaten by a variety of spiders and predaceous insects as well as by birds. However, according to Ivo Hodek and Alois Honěk "there is no tangible evidence of the impact of enemies on the population changes of coccinellids." Non-lethal attacks also occur, and it is common to find ladybugs with stain-like damage to their wing covers, a condition that has been interpreted as feeding damage by minute pirate bugs (family Anthocoridae) on ladybug pupae. These tiny sucking bugs merely wound the ladybug, while larger predatory hemipterans will kill them outright. It has also been suggested that although most songbirds come to recognize ladybugs as distasteful, flying insect eaters such as swallows and swifts may not recognize their warning colours in time to avoid swallowing them. I doubt this personally, since I can recognize a flying ladybug as distinct from other sorts of beetles myself, even at a considerable distance.

Playing dead and reflex bleeding are the primary defences that ladybugs have against their enemies. Since ladybugs feed on aphids, and aphids are often guarded by ants (who tend them for their honeydew in a tender sort of "mutualism" that is often likened to the relationship between dairy farmers and milk cows), ants are often a problem for ladybugs as well. This is probably why ladybugs have such short legs and antennae, and such smooth, rounded bodies. When threatened by an ant, they pull in their appendages and hunker down onto the substrate as tightly as they can. Finding nowhere to get hold of the beetle, the ant eventually gives up the struggle.

Ladybugs probably have more to fear from parasites and disease than from predators. They suffer from parastism by various tiny chalcidoid wasps, podapolipid parasitic mites, nematode round worms, sporozoans, fungi (especially *Beauveria bassiana*), and *Rickettsia* bacteria. Ladybugs are also parasitized by tachinid flies, phorid flies, and the braconid wasp *Dinocampus coccinellae*, but most of these seem to be more important ecologically in the Old World (although *D. coccinellae* can sometimes attack up to 20–30% of adult ladybugs in eastern North America). Of the ills mentioned above, only *Beauveria* seems really important in North America, since it can be, in humid areas, the main cause of death of overwintering ladybugs.

The *Rickettsia* bacteria are also significant sources of mortality, but in an odd way, since they kill only the males and are the subject of some very fascinating research, largely under the direction of Mike Majerus at Cambridge. For example, male-killing may actually be a valuable thing for the ladybugs, since they reduce the likelihood of a female mating with her brother, and the dead male eggs serve as food for the newly-hatched female larvae, reducing the likelihood of egg cannibalism. The phenomenon of male-killing bacteria seems restricted to aphid-eating ladybugs that lay their eggs in clusters—in other words, the subfamily Coccinellinae. The distribution of male-killing bacteria among North American ladybugs is still largely unknown.

Speaking of Mike Majerus, he is also the co-author, with John Sloggett, of an extraordinary paper in which they placed the origins of food and habitat preferences of ladybugs into a broad evolutionary context. In my opinion, this is one of those works of science that go far beyond providing just one more tidbit of information. Sloggett and Majerus suggest that new, specialized lineages may arise when generalized ladybugs feed temporarily but predictably in alternate habitats, on alternate prey. Some ladybug species have quite catholic tastes in habitat, while others are extreme specialist, and many lie somewhere in the middle. Those ladybugs with a predilection for life in extreme, alternative habitats may well remain in the alternate habitat early in the season, and breed there, and leave offspring that are likewise inclined to live in such places. Theoretically, natural selection could operate quite rapid in these instances, and this is the mechanism for "the origin of species" in ladybugs, as suggested by Sloggett and Majerus.

Both switching prey and moving between habitats, however, are likely to be costly to the beetles, since studies in these cases generally show a drop in ladybug fecundity. However, limited prey both early and late in the year may be an important motivating factor pushing ladybugs to search for novel prey types and, as a consequence, novel habitats. These alternate prey can include toxic aphids, low-quality aphids, aphids in galls with a defending soldier caste (believe it or not), and aphids tended by ants (some ladybugs are "myrmecophilous," living with ants, and this may explain the origin of this habit, seen in our own anthill ladybug).

In the entomological literature, scientists studying plant-feeding insects have suggested that these creatures quickly and predictably evolve to inhabit "enemy-free space," but this does not seem to be the case with predatory ladybugs. In the Sloggett–Majerus model, the important enemies are almost all parasites and parasitoids, since ladybugs are chemically protected from generalist predators. If we consider other ladybugs to be important predators, it naturally follows that a ladybug that lives in places without other ladybugs will indeed find itself in a sort of enemy-free space.

In general, zoologists have often suggested that geographic isolation is the thing that most predictably leads to the origin of new species, but this doesn't seem to be as important in ladybugs as it is in other groups (tiger beetles are a great example), since ladybugs are such good fliers. Here in western Canada, for example, Joe Belicek concluded that the Rocky Mountains are not a barrier to the dispersal of ladybugs into Alberta from the west. Species that occur on only one side of the continental divide do so because they find appropriate habitat there, not because they can't reach the other side.

Aphid-eating ladybugs are better at dispersing than scale-insect eaters, and they typically change habitats throughout the season, sometimes predictably moving from one tree or vegetation type to another. This is when they sometimes wind up in lakeshore "wash-ups," a subject that we will revisit in the next chapter. Oddly, and interestingly, Sloggett and Majerus point out that in the few studies that have investigated it, there is little ecological niche overlap among ladybugs. Instead of feeding and competing in the same place, they divide up the habitat according to such things as height above the ground, degree of sunlight exposure, and the like.

The Sloggett–Majerus model is appealing and a great bit of synthesis in an otherwise largely piecemeal field of study. I think it would be especially interesting to look at it in the context of introduced species, and Edward Evans' notion of "habitat compression," in which native species "retreat" to their "ancestral habitats" in the face of superior competitors from Europe or Asia. I suspect that, rather than retreating to ancestral habitats, species such as the transverse ladybug are probably quickly evolving to use new refuges from the seven-spot. We may well be seeing evolution in action here, but I'll come back to this theme in Chapter 4.

Edgar H. Strickland, Alberta entomology pioneer, examining a yucca plant on the open prairie, no doubt alert for rare ladybugs at the time.

3

Ladybug Study in Alberta

The scientific study of ladybugs in Alberta began with beetle collectors. Frederick S. Carr was one of the most important of these, and his story appears in my book on tiger beetles. In my own database of ladybugs records, the oldest entry is for a nine-spot ladybug, collected by F.S. Carr in Medicine Hat on May 3, 1903. In fact, the early ladybug collectors in Alberta are all men who feature in the tiger beetle and damselfly stories as well. J.B. Wallis, from Manitoba, was a school inspector and amateur entomologist, like F.S. Carr. Colonel Edgar H. Strickland, on the other hand, was the founding chair of the Department of Entomology at the University of Alberta. None of these men did much to analyze our ladybug fauna, but their specimens are all we have to reconstruct the ladybug situation in Alberta a century ago. I have found the Carr and Strickland specimens to be especially interesting in this regard.

By the 1950s, the number of beetle collectors had increased by quite a bit, and Alberta ladybug specimens were making their way to such luminaries as Theodosius Dobzhansky. Dobzhansky was not only a ladybug taxonomist, he was also an important geneticist, and one of the key figures in what we now know as the neo-Darwinian revolution, in the mid-1900s. During this time, Charles Darwin's ideas on natural selection were reexamined in the light of genetics, paleontology, ecology, and other aspects of biological science. The synthesis that resulted has been at the core of biological thought ever since, and it is particularly gratifying to know that a ladybug scientist was one of the prime contributors (although in fairness much of his research was done on fruit flies as well). Dobzhansky was born in the Ukraine (then part of Russia), and came to the United States in 1927, where he did most of his work at Columbia University and the California Institute of Technology. He was a deeply humane person, as are most evolutionary biologists (despite what some anti-evolutionists might think), and his 1967 book " The Biology of Ultimate Concern" is proof of that. He was one of many biologists who argued that we should set aside the conflict between science and religion and get on with both. Dobzhansky is probably best known for the quote "Nothing in biology makes sense except in the light of evolution;" and for the fact that Stephen J. Gould of Harvard referred to him as "the greatest evolutionary geneticist of our times."

The first work specifically on the ladybugs of Alberta was published a year after Dobzhansky's death, in 1976. Joseph Belicek's study was based on his Masters degree in entomology, completed under the supervision of George Ball (whose name also appears often in my tiger beetle book). Joe studied the ladybugs of western Canada and Alaska, and speculated on the origins of the fauna as well as surveying the known records at the time. He recorded 64 species from Alberta.

In Belicek's opinion, most of our ladybug species spent the last ice age south of the glaciers in the United States, but some may have survived in the unglaciated Beringian region in Alaska or the ice-free area around Mountain Park in the Rocky Mountains. After all, even in an ice age, there are summers and winters, and the summers may have been warm enough for ladybugs to survive. Joe also concluded that the Rocky Mountains were not a barrier to the dispersal of ladybugs into Alberta from the west. As well, Joe described two new species from Alberta, the Hercules and Jasper ladybugs. Joe's paper was an inspiration to a number of beetle collectors and provided the foundation on which the subsequent study of the ladybugs of Alberta has been built.

The next person to look at our ladybugs in detail was Robert D. Gordon of the Smithsonian Institution in Washington, D.C. Bob published many papers on the ladybugs of North America, but his most important works were a huge revision of the subfamily Scymninae and a marvellous monograph on the North American ladybugs in general that took up an entire issue of the Journal of the New York Entomological Society. When it appeared, I was a graduate student, and I remember fellow grad student Bob Anderson coming down the hall to tell me to immediately join the New York Entomological Society, since that was the only way to get Bob Gordon's coccinellid monograph. So I did, and I'm glad—the book (it really is a book, not merely a paper in a journal) is now almost impossible to obtain now, even with on-line searches of used book dealer's lists.

Whenever Bob Gordon's name comes up among entomologists, someone invariably says something like "his coccinellid monograph is magnificent, but did you know that his true passion is for scarab beetles?" It's true, apparently, and Bob has made great contributions to the study of scarab beetles (as well as beetles on sand dunes) outside his work on ladybugs. However, the Smithsonian wanted someone to work on ladybugs, primarily because they are important to agriculture. Bob spent a great deal of his time keeping track of the various ladybugs that had been introduced to North America for aphid and scale insect control. One of his most useful papers (on identifying introduced species) was co-written with Natalia Vandenberg, the woman who took Bob's place when he retired. "Nat" is a true lover of ladybugs and a very fine scientist as well. Unlike most beetle systematists, she does not go out and collect specimens, since she has more than enough work studying the specimens already in the Smithsonian collections, and she really doesn't like the idea of killing ladybugs. She doesn't object to collecting; she just doesn't do it herself. I like Nat. She keeps singing crickets in traditional oriental cages and is involved in folk music—a well-rounded human being.

Next on the list of ladybug events in our province was the somewhat ill-fated national ladybug survey, initiated by the Canadian Nature Federation from 1995 to 2000. The objective of the survey was to monitor the effects of introduced species, but the inadequate identification guide the survey was based on made most of the data collected (some 32,579 records) difficult if not impossible to interpret. I'll tell you more about this story when we come back to the subject of native and non-native species.

In Calgary, Ed Mondor did some interesting studies of ladybugs and their response to the alarm chemicals given off by aphids, but his time there was limited, on a post-doctoral appointment, and he has gone on to work in the Hawai'ian Islands now.

Over the past decade, I have been fortunate to work with a number of talented undergraduate students with an interest in ladybugs. Much of what I know I learned from their studies, and it is no exaggeration to say that they collectively laid the groundwork for this book. In 1996, Shelley Ryan was a student at the Northern Alberta Institute of Technology, and she decided to do her final project in the biological sciences program on the seven-spot ladybug. She came to me for help, at the suggestion of her instructor Robin Leech, and we set up some simple experiments to see how well the seven-spot handled Alberta winters. Surprisingly, over 97% of the beetles survived the winter (compared to about 50% in Europe), and in experimental cages the temperature did not drop below −9 °C, even when the air temperature dipped below −30 °C. We suggested that seven-spots benefit from this in North America, and that here they are not as susceptible to overwintering mortality from *Beauveria* fungus infection. As well, Shelley looked at the fecundity of captive transverse and seven-spot ladybugs and found them to be roughly equivalent. Since then, Shelley has informally repeated some of her work and found that the initial studies benefited from unusually deep snow—survival in subsequent winters was not as high. Still, Shelley keeps up an active interest in ladybugs and has contributed many records to our database.

My first undergraduate ladybug student was Wendy Harrison (now Wendy Wheatley). I teach in the Department of Renewable Resources at the University of Alberta, as a Sessional Lecturer. In other words, I am at the bottom of the academic totem pole in some ways; however, I am also spared the burden of administrative work, and I am free to pursue projects such as this book, rather than focusing on obtaining grant money and publishing research papers. I can't supervise graduate students, but I do supervise undergrads doing independent research. Wendy told me of her interest in insects, so I suggested a project to her, in which she collected historical records for Alberta ladybugs and analyzed these to see if she could detect evidence that the introduced seven-spot ladybug had caused the decline of native species. This project was motivated by a review of Shelley Ryan's and my paper, by Cedric Gillott from Saskatchewan (again, there is more about him in the damselfly book). Cedric had quite rightly asked us if perhaps the seven-spot had become abundant without affecting other species and if the so-called declining species might only be relatively (but not absolutely) less common.

Wendy collected all of the specimen and observational data she could find and then calculated the relative proportion of the fauna (not including the seven-spot) each year after the seven-spot arrived in Alberta for a ten-year period. Of course, we only expected a rough indication of abundance trends, since the specimens had been collected haphazardly, by other people, with no particular point in mind. Acknowledging this, Wendy performed linear regression analyses on each of the species' data with a large enough sample size. Linear regression is a technique for determining whether there is a trend in your data (and if you've ever gathered data, you will know how fuzzy these trends can be!), how strong the trend is, and how steeply things are either increasing or decreasing over time. Wendy's study showed that at least some species (the transverse and the convergent) appeared to have decreased in abundance among the native species as a whole, while two (the two-spot and the polkadot) actually seemed to increase, at least in relative terms (Table 1). These latter two species may not have changed at all in their absolute abundance, but they would have appeared to become more common if the rest of the native fauna had declined relative to them. Interestingly, four native species (the thirteen-spot, parenthesis, painted, and the wee-tiny ladybug) did not change in relative abundance, and when the overall fauna was analyzed, the seven-spot did not show any trend either, suggesting that it became the most abundant species very quickly. I'll come back to these results later; however, at the time Wendy's study was both perplexing and tantalizing, and she did a fine job of presenting it to the annual meeting of the Entomological Society of Alberta at their annual meeting in the fall of 2000. Since the relevant statistical measures for these regression analyses were not published in the abstract of that talk, here they are for posterity. Note that a high r^2 indicates a clear trend without much scatter around the trend line, while a P lower than 0.05 indicates a "real" trend, not likely due to chance alone.

Another student, Patsy Drummond, worked as a park interpreter at Lesser Slave Lake Provincial Park, and in 2001, she made weekly searches of the beach at Lily Creek. She managed to count 1778 ladybugs (representing 14 species) early in the season, but forest fires seemed to reduce ladybug activity to almost nil past June 18. Patsy therefore focused on other things, including a complete reworking of our provincial ladybug database, the preparation of new range maps for all of our larger ladybug species (which were the basis for the maps

TABLE 1 Linear regression statistics for change in relative abundance (percentage of total larger ladybug fauna excluding *Coccinella septempunctata*) from 1989 to 1999 of all ladybug species for which sufficient data was available.

Species	*Slope*	$F_{1,7}$	*P*	r^2	*Error*
Decreasing abundance					
Transverse	−0.03	5.36	0.05	0.43	0.11
Convergent	−0.05	16.02	0.01	0.70	0.13
Increasing abundance					
Two-spot	0.05	11.52	0.01	0.62	0.15
Polkadot	0.01	17.56	<0.01	0.71	0.02
No change					
Thirteen-spot	0.01	0.37	0.56	0.05	0.12
Parenthesis	0.00	0.03	0.87	0.00	0.10
Seven-spot*	−0.02	0.76	0.41	0.10	0.23
Painted	0.00	0.06	0.81	0.01	0.16
Wee-tiny	0.01	0.50	0.50	0.07	0.08

****The analysis for* C. septempunctata *itself included all larger ladybugs data for the period.***

in this book) and a general assessment of the conservation needs of Alberta's ladybug fauna. I was especially pleased that Wayne Nordstrom at the Alberta Natural Heritage Information Centre gave Patsy space in which to work and made her feel welcome and useful at this government office.

Then, in 2002, Mira Snyder completed a survey of the ladybugs at Waterton Lakes National Park. Mira worked there during the summer, and we obtained a permit for the research. The objective was to see if the Halloween ladybug had arrived yet, since it would be expected first in the southwest corner of the province. Mira did not find the Halloween, but she did collect great data from the beaches of Waterton Lake and from sweeping vegetation at various locations in the park. Mira found 14 species (out of 27 historically recorded for the park) even though she only encountered 153 ladybugs over the season. Like Patsy, Mira was plagued by bad weather, and in Mira's case it was early summer snowstorms that likely reduced the numbers of ladybugs.

Mira also analyzed wash-up data from around the province and was surprised to find that there was no increase in overall ecological diversity from south to north, even though the northernmost wash-up samples, from Lake Athabasca, had relatively few seven-spots in them (only 19%). It is worth mentioning here that ecologists do not simply count species when they assess diversity. They have also developed indices of diversity that take into account the relative abundance of all species in the fauna. For most people, including many trained biologists, it is difficult to believe that a fauna containing one or more super-abundant newcomers can be more diverse than the fauna that came before it. However, these people, and their intuitive notion of how things work, are simply wrong. Most of the time, introduced species increase biodiversity (no matter how you measure it), and that is the simple ecological truth of the matter, even if it goes against the invasion biologists' cry that such newcomers are by definition a threat to biodiversity.

Wash-ups have proven to be some of our best sources of information on ladybug numbers. A wash-up happens when beetles in flight fall into a lake and wash up on the shore. In general, this happens most readily on warm afternoons, with a storm brewing at the end of the day. The beetles (ladybugs, as well as a variety of other beetles, as well as some other insects) are usually alive when they reach the shore, and if the temperature is still warm and the sun is shining, they quickly take flight again. But more often, they accumulate in a sort of windrow, and can be counted easily.

We have wanted to assume that the composition of ladybugs in a wash-up is a good measure of the composition of the fauna in the surrounding area, but although there is little reason to think otherwise, there is also little evidence that this is true. In the US Midwest, Richard Lee found that some ladybugs remain at the wash-up for two to three weeks and suggested that migration to and from overwintering sites might account for wash-ups. I suspect this is not the case here, because wash-ups occur all through the season, not just in spring and fall. As well, there are other questions. Are all species in an area equally likely to wind up in the lake? Are all species in the lake equally likely to wind up on shore? How long do individuals live once they hit the water? How far off shore do the ladybugs come from? Do winds force them down into the water, or do they just fall in? Is there any reason to think that they fall in the water on purpose? Are all wash-ups afternoon phenomena? Is ladybug survival/fecundity affected by being in a wash-up? Are ladybugs adapted to breathe while they float? Are all wash-ups the result of dispersal for food, or for overwintering sites as well? The list goes on. Also, wash-ups are not a universal occurrence. In many places, they are almost unheard of. Thus, we are probably in a good position here to study this phenomenon.

My own interest in ladybugs began as a child and as a beetle collector. Then, when we were preparing the pilot episode of my television series "Acorn, the Nature Nut," I chose ladybugs as the subject, because there are ladybugs almost everywhere in the television-watching world. That was when I realized that the transverse ladybug of my childhood had been replaced by the seven-spot ladybug from Europe. I began keeping track of the ladybugs I encountered and collecting the literature on ladybug science as well. As my students worked on their research projects, I compiled notes for this book.

Mike Majerus gives a spruce tree a firm but gentle beating, hoping to dislodge some rare beetles.

I should also give credit to Mike Majerus here. When Wendy Harrison began her studies with me, I instructed her to read Mike's New Naturalist volume, "Ladybirds" cover-to-cover, and we discussed each chapter together on a weekly basis. At the end of this process, I wrote to Mike, who is the Reader in Evolution at the Department of Genetics at Cambridge University in the United Kingdom. I told him that we had enjoyed the book, despite its tight focus on the British fauna and, therefore, its limited applicability to the situation in Alberta. Mike wrote back and told me that he was working on a new book with a broader geographic focus and was coming to North America in the summer of 2000 to familiarize himself with the North American fauna. I suggested that he "stop by while he was here," and so he did. Mike and his family landed in California, drove to Alberta, stayed with my family for 11 days, and then drove to Miami, Florida. During our visit, I learned more from Mike about ladybugs and how to study them in the field than I could have absorbed in years of reading. He has become a good friend, and I was happy to be able to invite him back, with his wife Tina in 2005, to serve as the Plenary Lecturer for the joint meeting of the Entomological Societies of Alberta and Canada. Mike has focused his career on both ladybugs (which he calls ladybirds, in keeping with British usage) and moths and is probably best known for defending the classic work on the peppered moth and industrial melanism, a textbook example of evolution in action that has recently come under critical scrutiny and therefore needs a champion and some fresh data.

4

Introduced Ladybugs and Conservation

Without a doubt, the biggest news in Alberta's ladybug history has been the recent arrival of non-native species and their effects on the native fauna of our province. The *Edmonton Journal* reported the story, on Sunday, July 9, 1998 (page A5):

> **Problems "Spotted" in Ladybugs' Rivalry**
> *Ross Henderson, Journal Staff Writer*
>
> She may be a ladybug, but she ain't no lady.
>
> In fact, in the tiny world of ladybugs, a battle for insect supremacy is being waged between two of Canada's predominant species.
>
> No kidding. Right below your feet.
>
> The spoils of the war? The 473 other species.
>
> The prospect of one species taking over in Canada has convinced the Canadian Nature Federation in Ottawa to launch a study that's expected to continue for several years.
>
> The non-profit federation is using an Internet page and sending out thousands of kits to school kids, libraries, and other groups to help spot ladybug species.
>
> Marc Johnson, a spokesperson for the federation in Ottawa, says two species are battling it out over pests and aphids, their favourite food. Both the competing ladybugs were foreign to Canada, and as a result, lack our peacekeeping skills....

Further on in the article, Henderson writes "As the nineteen-spotted, southern and seven-spot ladybugs take over turf, the diversity of species—which assures a biological safety net—is lessened and reduces the delicate balance of the ecosystem." The article ends with the chilling observation that

The seven-spot ladybug: an unfair, alien, super-competitive invader, or a hard-working new immigrant that deserves its new place as the most common member of the Alberta ladybug fauna?

"the nine-spotted ladybug was, until recently, the most prevalent species in Ontario. It can't be found now."

Like most naturalists, I was convinced that this was a major ecological disaster. I would not have gone so far as to suggest that our "biological safety net" was in danger (I deeply dislike environmentalist hyperbole, and as much as I love ladybugs, I'm sure we could survive without them; many other creatures also eat aphids, scale insects, and spider mites), but I was upset nonetheless. During the mid-1990s, as I searched in vain for the transverse ladybug, the most common species of my childhood, I came to the conclusion that this was the most profound ecological change I had ever witnessed in a lifetime of insect studies in Alberta. So I began spreading the bad news, on my television show, in public talks, and in university lectures. I also started submitting my own observations to the Canadian Nature Federation Ladybug Survey.

The ladybug survey was circulated to schools, naturalists, and garden centres. It was immensely popular, with over 45,000 survey form requests received in a single year. As the Federation put it, "the purpose of the lady beetle survey is to determine the geographical range of native and non-native lady beetle species in Canada. Once we have determined these ranges, we can find out if alien lady beetle species inhabit the same areas as our native species." However, it was already apparent to naturalists across the country that this was clearly the case. The survey's real purpose, in my opinion, was to affirm the obvious (not that this is unusual in science) using citizen-science data and to spread awareness of the dangers of introduced species. The Seeing Spots Newsletter wrote: "A major concern among survey participants is the presence of alien lady beetle species in Canada," and although the Federation never really claimed it could do anything to get rid of the so-called "aliens," this was clearly the implied goal for many of the people I spoke to. It was not uncommon to watch naturalists crush seven-spot ladybugs as soon as they recognize them as unwelcome invaders. I was an active participant in the survey, and I was as concerned as anyone about the "invasion" at the time, but I didn't kill seven-spots.

"Invasion biology" is a relatively recent development, and the scientists who work in this field are primarily concerned with the negative impacts that introduced species have on agriculture, forestry, or other industries. Invasion biologists see their discipline as originating with the publication of Charles Elton's "Ecology of Invasions by Animals and Plants" in 1958. According to my friend Matt Chew, a Ph.D. student at Arizona State University, there were numerous other biologists who laid the groundwork before Elton, but it was Elton who had the highest profile and who established the use of military and political metaphors to describe the arrival and spread of new species in terms such as "alien invasion," "take-overs" and "battles." Go back and read the newspaper clipping at the head of this chapter and notice how the language is emotive and military, not objective and scientific. Elton, along with his good friend the conservation pioneer Aldo Leopold, also invoked aesthetics as a primary justification for anti-alien sentiment, especially in the field of conservation. In other words, he thought that in any given place "native" organisms and ecosystems were intrinsically more beautiful than non-natives and that this should be apparent to everyone. The concept of nativeness, by the way, is a tough one to meaningfully define biologically (after all, living things move around, and always have), and this is only recently becoming apparent, again largely thanks to Matt Chew and a small group of equally courageous scholars.

Invasion biologists have declared that invasive species are a major threat to the biological integrity of the planet, and these people have recently received a great deal of attention and money. It is important, however, to recognize that they are primarily applied biologists, working on problems of economic importance (often with the blessings of both government and the pesticide industry). Biologists who are more interested in the workings of nature than in the affairs of people have been less alarmist in their interpretations, and many have accused the invasion biologists of showing strong cultural biases. These include a tendency toward racism (in the form of "nativism"—a prejudice against non-native species), xenophobia (the fear of things that are new or unfamiliar), nationalism, and stabilism (the belief that things should forever stay the way the Creator, or the "balance of nature" intended them). However, back in the late 1990s, the debate about the motives and biases of invasion biology had not yet surfaced, and it certainly hadn't filtered down to the ladybug crowd.

As the ladybug survey came to an end, it was obvious that it had not been entirely successful. The website had some distribution maps posted for a while, but the data were bizarre and the maps did not remain on the site for long. It was clear to those of us who really knew ladybugs that misidentifications were common, and that the colour pamphlet that came with the survey was oversimplified to the point where misidentifications were almost a certainty. As soon as I realized that the pale, prairie morph of the two-spot ladybug could be mistaken for the Halloween, I gave up on at least this aspect of the project, and it is now clear that the organizers gave up as well, albeit still saving face, and making the best of a messy data set.

I did, however, print off the "results" section of their website on August 11, 2001, at http://cnf.ca/beetle/spotted_results.html. They received a total of 32,579 reports, 60% of which were either seven-spots or Halloween. They found the seven-spot across Canada and apparently "moving northward" (something the survey could not have detected, in my opinion). They also found the Halloween to be "well established across the country," which it is not, and the fourteen-spot ladybug (*Propylea quatuordecimpunctata*) to be "successful in establishing itself across the country," despite its total absence from Alberta and perhaps other parts of the west. The American eyespot ladybug was "historically found across Canada, but a scant 220 sightings indicate a sparse presence in the east, with few sightings in the west." This didn't surprise me since here in the west the species has always been uncommon (and 220 sightings have to count for something). The report finished with the notion that alien species seem to be causing the decline of natives but that the survey can't prove it for sure. No summary publication appeared, and no great truths were revealed. The main effect, then, was to spread fears about "alien invaders" among the naturalist community in Canada. As I write this, there is a new version of the "results" on the web, acknowledging the weaknesses in the data but perpetuating the anti-invader theme.

So what really happened, and what is happening now? Let's first review what we know from data in Alberta. Wendy Harrison and I gathered all the records we could from naturalists and collections and determined that transverse and convergent ladybugs declined after the arrival of the seven-spot. Four other species showed no such trend, and for the rest of the fauna, we don't have adequate data to say one way or the other. I have already mentioned this in the last chapter, but it bears repeating here.

Now let's go back and start at the beginning. R.L. Jacques found the first North American seven-spots in 1973 in New Jersey. Seven years later, Richard Hoebeke and A.G. Wheeler Jr. mapped the distribution of the seven-spot, and in 1986 Paul Schaefer, Richard Dysart, and Harold Specht looked again at its distribution. By that point, it was still mainly an eastern species, nowhere near Alberta. The latter paper added that at a mass wash-up in Delaware, some people were bitten by the new ladybug, thereby suggesting that it was both ecologically and behaviourally "aggressive." Europeans knew that the seven-spot might occasionally bite, but everyone realized this was trivial.

It was clear that the seven-spot was headed our way, and in Nova Scotia, David McCorquodale estimated that the four species of "adventive" ladybugs (I like that neutral term, as well as the term "newcomer") in that province had spread at rates between 30 and 400 km/year. Bob Gordon and Nat Vandenberg pointed out, however, that the seven-spot got to the west at least partly with the help of people, since it was being released to control the Russian wheat aphid (*Diuraphis noxia*) in the west, a newly established pest of wheat that arrived in the late 1980s. The ladybug doesn't control the aphid, by the way, but that disappointment seems to have been forgotten in the ensuing kafuffle over its so-called rise to dominance.

In West Virginia, M.W. Brown and S.S. Miller were monitoring their own changing ladybugs. They started with 25 species in 1983, in their study area (the total ladybug fauna of West Virginia is much greater than that). Then, from 1989 to 1994, the seven-spot arrived and "dominated the fauna." In other words, it became the most common species. In 1995, the Halloween ladybug arrived in West Virginia, and "displaced" the seven-spot as the most common species. The seven-spot comprised 100% of the fauna in 1992 ("all but one" record), then dropped to around 90% in 1993, before the arrival of the Halloween in 1994, when it dropped again to about 80%. By 1996, the seven-spot made up about 10% of the fauna, and the rest were Halloweens. Clearly, there were few native species left to count. Brown and Miller did find a bit of good news in all of this—the Halloween ladybug did a better job of controlling the green citrus aphid (*Aphis spiraecola*) than did the seven-spot, or the native species that preceded it.

It is easy to bemoan the loss of the native fauna, and the short sightedness of entomologists who cared only about aphid control, but there are also reasons to remain skeptical of the notion that all is lost. In their encyclopedic work on ladybug ecology, Hodek and Honěk state, "coccinelid communities contain a few dominant species. Usually two to four species represent more than 90% of the individuals." They also point out that "there is no record of a global extinction of a coccinellid species since the beginning of scientific interest in the family." Is it possible, then, that what we are witnessing is the replacement of one "dominant" species by another and not much ecological change among the less abundant species in the fauna? If so, we need studies that survey ladybugs in all of their different habitats, carefully searching for each and every species, and not just sweeping a net through monotonous agricultural crops and fruit orchards.

In Maine, Andrei Alyokhin and Gary Sewell looked at 31 years of ladybug data, collected from 1971 to 2001, but entirely in potato patches. At the beginning of the study, the most common species were the native transverse and thirteen-spot ladybugs, although there was tremendous year-to-year variation in the relative abundance of both. In 1980, the seven-spot arrived and became the most abundant species in the study. In 1995 and 1996, respectively, the Halloween and the fourteen-spot arrived, and they became common as well. The effect of their arrival was not only to decrease the numbers of transverse and thirteen-spot ladybugs but also to increase the overall diversity, measured by diversity indices (ecological measures that incorporate not only the number of species but also the relative abundance of each). Only when the Halloween ladybug arrived did aphids detectably decline in abundance, and of course that is what the potato farmers were interested in. Transverse and thirteen-spot ladybugs persisted in the potatoes, but the authors suggested that the arrival of the new species caused the old species to retreat to ancestral habitats in a process called "habitat compression," citing Edward Evans, and a paper he published in 2000.

Just last year another Mainer, a graduate student of Andrei Alyokhin named Christine Finlayson, investigated the habitat compression hypothesis in habitats other than potato fields. With the help of Andrei Alyokhin and Kristine Landry (an undergraduate field assistant), she discovered that the non-native species were clearly dominant in all habitats, including the "ancestral" habitats such as forests and riparian areas, and the native species showed no tendency to do best in so-called natural places. Thus, the habitat compression hypothesis was not supported by this study. In a letter to me on February 7, 2006, Christine wrote, "lady beetle diversity was shown to increase as the number of non-native species increased. However, native lady beetles were found in very low numbers in all of the habitats surveyed. *H. tredecimpunctata* [the thirteen-spot] and *C. transversoguttata* [the transverse], the two native species that were once dominant here, made up only 1.09% and 0.07% of the total aphidophagous lady beetles collected, respectively." I think this work is a major step in the right direction and that the next logical step should be to take the naturalists' approach and search for the native species one at a time, exploring a wide variety of microhabitats rather than broadly surveying hypothetical ancestral habitats.

In Manitoba, the seven-spot arrived in 1988, and two biologists, Glen Wylie and Frank Matheson were keen to document its arrival in crop fields. They therefore began systematically sampling the crops with sweep nets. Earlier, in 1978, Bill Turnock and Russ Mead (of the Delta Marsh field station) began recording wash-up aggregations on Lake Manitoba at Delta Bay (when the convergent ladybug made up 96% of the wash-up) Turnock and Mead were initially interested in the wash-up for it own sake and noted that wash-up happens "whenever a northerly wind follows a warm, windy day." They sampled the following morning, and recorded their highest counts in spring and fall during ladybug movements to and from over-wintering sites, in keeping with what we have seen here in Alberta. Ian Wise has also been continuing the crop sweep sampling begun by Wylie and Matheson for Agriculture Canada. Encouragingly, the results of the two surveys are very similar, suggesting that wash-ups are indeed a good way to survey local ladybugs. The seven-spot rose to 67% of the sample in 1992, then dropped to 4% in 1994 (a cold summer when the thirteen-spot made up 95% of the sample), and now varies from 20% to 35%. Their conclusions? The seven-spot ladybug has not affected the thirteen-spot but probably has affected the convergent and the transverse (as well as parenthesis and three-banded ladybugs). Or perhaps the thirteen-spot has somehow indirectly benefited from the change in fauna. Either way, what they recorded were changes in species abundance, not local extinctions.

There are other studies as well. In South Dakota, Norman Elliot and his colleagues found that, when seven-spot ladybugs arrived the abundance of transverse ladybugs in alfalfa fields declined to between 3% and 5% of its original level but that overall ladybug numbers did not increase, suggesting that the alfalfa environment could only support a certain number of ladybugs. In the northeastern United States, Donna Ellis and her colleagues suggested that the spread of non-native ladybugs had reduced the abundance of nine-spot and convergent ladybugs. In Tennessee, in non-agricultural "natural" habitats, a group of researchers from the University of Tennessee failed to find the convergent ladybug and thought that perhaps the seven-spot and Halloween had resulted in its absence.

In contrast, Georgia researchers Leonard Wells and Robert McPherson wrote that "although we have no record of *H. convergens* population levels in Georgia tobacco before invasion by *C. septempunctata* and *H. axyridris* [the seven-spot and Halloween ladybugs], these exotic coccinellids do not as yet appear to have had any adverse effects on *H. convergens* populations in Georgia tobacco." These researchers did find that the seven-spots appeared to leave the tobacco once large numbers of Halloween ladybugs had arrived, and cited a similar study that showed the same thing on pecans, by Louis Tedders and Paul Schaefer, in 1994. Tedders and Schaefer chronicled the establishment of the Halloween ladybug in the American southeast, and commented that the pecan growers were happy with the way it controlled two species of aphids.

The cause for the success and spread of introduced ladybugs is not at all clear. Certainly, both seven-spot and Halloween ladybugs can lay huge numbers of eggs, but this fact alone does not explain why they have done well in North America—after all, they coexist with hundreds of other ladybug species in Europe and Asia. Most explanations for the success of the newcomers are based on assumptions about competition. For example, Edward Evans found that the seven-spot is more variable in body size than related native species, and considered this to be evidence that it was more of an ecological generalist, adaptable and a good competitor.

Competition is often assumed to be at the heart of "alien invader" success in general, and at least one author, David Theodoropoulos, has suggested that the same sorts of sentiments that make people angry at new immigrants "taking our jobs" motivate the thinking of some ecologists when confronted with "new immigrant" species. Theodoropoulos calls himself an "invasion skeptic" and although his book "Invasion Biology: Critique of a Pseudoscience" is unlike your average scholarly book and more of a rant against the ecological establishment, he makes some very interesting points, especially with respect to misplaced assumptions about invasion biologists' ideas regarding so-called unfair competition. In that context, it is interesting that Edward Evans found that similar-sized larvae of different ladybug species were roughly equivalent in terms of their competitive ability, and in their effect on aphid numbers (working in the lab with convergent, sinuate, thirteen-spot, and seven-spot larvae). I for one am skeptical that competition has much to do with the success of our new ladybugs, and I readily admit that the more I work with ladybug studies the more I see myself as a bit of an "invasion skeptic" as well.

Two studies by John Obrycki and his colleagues (both published in 1998) illustrate the complexity of the issue, and how little we actually know. Both studies involved seven-spot and twelve-spot (*Coleomegilla maculata*) ladybug larvae. In one study, it was suggested that when there are more aphids, the larger seven-spot ladybug larvae have the advantage because they can bully the smaller twelve-spot larvae (bullying is technically called "interference competition"), but when there are few aphids the smaller twelve-spot larvae have the advantage because they need less food. In other words, they can coexist. In the second study, it seemed that the seven-spot wins out at low aphid densities either because it out-competes the twelve-spot or simply eats them.

In my opinion, the success of introduced ladybugs probably has to do with the general nature of ladybug guilds and a variety of quite simple factors that are nonetheless difficult to detect or measure. Yes, the new ladybugs reproduce well, they live in a variety of habitats, and they do well in the sorts of habitats that people produce, including agricultural crops, orchards, and shrubs. That is why they were introduced in the first place. We also know that ladybugs eat each other, and this is especially true of larvae eating eggs and of larvae eating other larvae. We also know that it is typical and normal for a few species to "dominate" the rest in any given environment. So, is there really any mystery why the seven-spot and the Halloween are common? The real mystery, in my opinion, is why there are so many species of ladybugs in the first place and how they coexist!

One piece that is completely missing from this puzzle is the state of the ladybug fauna before we began the scientific study of the insects of North America. In Alberta, our record goes back just a hair past 100 years, and there is no doubt that most of what we know about what was "normal" before the arrival of the seven-spot is based on ladybugs already inhabiting such man-

The transverse ladybug: once the most common species in Alberta and now a minor but persistent member of the fauna.

made environments as crops, gardens, parks, and the like. The species that were formerly common, such as the transverse ladybug, were also common in man-made habitats, and it is entirely possible that such species built up their numbers in disturbed areas before flying into natural areas only to be collected by entomologists and counted as part of what was assumed to be the normal fauna. After all, we can find adult seven-spots in places where we cannot find their larvae, such as above timberline in the Rockies. Perhaps other species have been spending time in marginal habitats all along. Other species, such as the thirteen-spot, tell a different story. In natural habitats, it is pretty clear that, both here and in Europe, the thirteen-spot is a species of marshes and grassy wetlands. Yet it also does well in lawns, gardens, and some sorts of cropland—places that did not exist here 300 years ago. Does that make it an abundant native species or a former habitat specialist that has subsequently "invaded" man-made environments? It seems to me that, for the most part, we cannot answer these questions, and the relevant evidence is forever lost in times past. The importance of disturbed or "man-made" habitats, however, should not be underestimated.

Returning to the transverse ladybug, I find this our most intriguing species. It was once super-abundant in all manner of habitats in Alberta. Then, with the arrival of the seven-spot, it almost disappeared. Wendy Harrison and I backed this up with data, but any good naturalist could tell what was happening at the time. During the late 1990s, we would find a transverse here or there, but always alone, and always in the company of huge numbers of seven-spots. Then, during Mike Majerus' visit, a different pattern began to emerge. One afternoon, while we were preparing to host a party in Mike's honour, I dropped Mike off south of Edmonton at the University of Alberta's Sandy Mactaggart Nature Sanctuary (at a spot that is now part of the Anthony Henday freeway), and the rest of Mike's family at the West Edmonton Mall. When I came back to get Mike, he told me that he had spent many hours searching the "good" habitat, only to realize that the ladybugs were instead living on the dry pediment slope at the base of the reclaimed coal mine hill, among scraggly grasses (a spot that is now underneath the new ring road around west Edmonton). There, he found only 2 seven-spots, but 21 transverse, along with about 20 larvae and 7 pupae (along with a good number of parenthesis ladybugs and their larvae). We were both puzzled—what were they eating, and why were they living in this harsh, hot, dry microenvironment.

I have since found more transverse ladybugs in this sort of habitat, which is typical of Alberta badlands where the Cretaceous sandstones weather in such a way as to create nearly horizontal pediments at the bases of badland hills. This habitat, by the way, is much more common than the ladybugs. But the story doesn't end there. With Mike and his family, we also found transverse ladybugs (27 of them, along with 30 seven-spots) on the crest of partially vegetated open sand dunes northwest of Opal. Shelley Ryan and I had noticed before that this habitat sometimes produced transverse ladybugs, and since then I have found that it is probably the best place to look for them. Prairie sand dunes (such as the Great Sand Hills of Saskatchewan) are also good places to search for transverse ladybugs and nine-spot ladybugs as well. The situation at Opal is confusing, however. On one occasion we found three tamarack ladybugs, and no transverse, and on another occasion the dune ridge was home to plenty of seven-spots but neither of the other two species.

If we apply Edward Evan's idea of habitat compression to this species, it would seem obvious that the transverse is retreating to its ancestral habitats (ancestral in the sense of where it lived before the advent of human development and agriculture) in the face of the seven-spotted newcomer. I suppose this might be true; however, it seems unlikely to me, and parsimony (the assessment of such likelihoods) is an important part of science. After all, what would have kept the transverse ladybug on sand dunes and pediment slopes to begin with? My own suspicion is that Sloggett and Majerus' model makes more sense of the transverse ladybug. If we think of these arid microenvironments as alternate, temporary habitats originally, then it makes sense that the transverse is able to persist in these habitats that are still in some way unwelcoming to the seven-spot. After all, the transverse is a western species, and the west is often a land of aridity and heat. The seven-spot, by contrast, is at home in more humid, lush environments (think "England"), such as those we find in eastern North America.

A close relative of the transverse, the nine-spot ladybug, may tell a similar story. Like the seven-spot, it is a member of the genus *Coccinella*, most of which are western in North America. As Dobzhansky was first to note, the nine-spot is the only species in the genus that is native in the southeastern United States, and it is in the east that the nine-spot ladybug is declining in the wake of seven-spot and Halloween newcomers. In Alberta, by contrast, the nine-spot appears to be persisting in low numbers, especially on the prairies, and it would be wonderful to know what sorts of environments it is breeding in. Personally, I think it will show the same pattern as the transverse. In the final stages of preparation of this book, I found two nine-spots in scurf pea on the edge of a sand blowout in the stabilized sand dunes north of Purple Springs, Alberta, and a few days later, I found more nine-spots on scurf pea at the edge of an active sand dune near Burstall, Saskatchewan. The connection between the now-uncommon nine-spot and transverse ladybugs, and sand dunes, seems obvious and strong to me.

In the case of the nine-spot, it seems to me that its survival in the west and not the east does indeed support the notion that this species has retreated to ancestral habitats, but in a broadly geographical sense, not in a local sense. It is worth noting, however, that Al Wheeler and Richard Hoebeke argue that the almost complete disappearance of the nine-spot from the northeastern United States might or might not have been caused by the seven-spot. It might also have been due to changes in land use, declines in aphids, parasitism or disease. I think this is entirely plausible, at least in the sense that the seven-spot may have been able to completely replace the nine-spot in a landscape without much undeveloped land.

Ladybug coexistence is clearly possible ecologically, and transverse ladybugs coexist with Halloween ladybugs and seven-spot ladybugs over vast areas of Eurasia, in a variety of habitats. Victor Kuznetsov, the leading expert on Russian ladybugs, had about ten times as many Halloweens as transverse in his collections when he wrote his book. Kuznetsov also says that the Halloween ladybug shares the broad-leaved deciduous forests with polkadot ladybugs in Russia. As you read the species accounts that follow, notice how many of our species also occur in Europe and Asia, alongside the dreaded "invaders."

So what are we to make of the situation here in Alberta, with the seven-spot ladybug fully established, and the Halloween right on our doorstep, so to speak? Well, let's start with the observation that in nature it is normal for some species to be rare, and not all rare species are destined for immanent extinction. It is also normal for things to change and there is nothing ecologically unusual about rare species becoming common and *vice-versa*. However, remember the prediction that appears at the beginning of this chapter—the immanent extinction of some 473 native species. Even if you revise that figure (which presumably refers to the entire North American ladybug fauna) to include only the 51 aphid-feeding species (in the tribe Coccinellini) of ladybugs in Canada, the prediction is clearly out to lunch, because not a single one of our ladybugs has disappeared—at least so far as we know. In straightforward common sense terms, we have added two species to our fauna, lost none that we know of, and we have increased, not decreased, our biodiversity (even when we measure diversity carefully, using ecological diversity indices). Our ladybugs, in other words, can't be used as examples of the evils of "alien invaders" unless you simplistically equate ecological change with ecological damage (and yes, many people do).

I think that ladybugs are a wonderful example of how nature can change profoundly without "collapsing." They show us, as do most other examples from invasion biology, that the dangers of "alien invaders" are primarily tied to our emotions, and our economy. We like to think that things were "the way nature intended" when Europeans first arrived here some 300 years ago, and that any changes that befell this version of paradise were, by definition, tragic and regrettable. I have to say that I no longer feel much sympathy with these ideas. I suspect that most people with a background in historical biogeography (and especially a familiarity with the fossil record from the past few thousands of years) feel the same way that I do, since we are deeply aware of how so-called ecosystems or communities disassemble, shuffle their components, and reassemble over time, looking not at all like well-integrated "systems" and much more like independent species moving around and adapting to a constantly changing world, not a constant set of ecological companions.

Recently, a very fine collection of scholarly papers has been published in a mainstream book entitled "Species Invasions: Insights Into Ecology, Evolution, and Biogeography," editied by Dov Sax, John Stachowicz, and Steven Gaines. In this book, the contributors "take a different course" and present what the editors refer to as "results that we suspect will be somewhat controversial": competition has been overestimated in the past, extinction is "idiosyncratic" and impossible to predict, evolution can be very rapid, the damaging effects of genetic bottlenecks have been overestimated, invasions increase diversity rather than decreasing it, and fears of biological homogenization of the earth are without clear support. How about that—the majority of these conclusions are exactly what Theodoropoulos predicted. It seems to me that invasion biology is either on the brink of what philosopher Thomas Kuhn called a "paradigm shift" (wherein the more progressive members of this community are busily reinterpreting their subject matter, rewriting their own history, and trying at the same time to diplomatically avoid the ire of their colleagues the anti-alien crusaders) or an even deeper schism between the anti-alien crusaders and the more neutral observers of nature.

Another recent book, "Conceptual Ecology and Invasion Biology: Reciprocal Approaches to Nature" takes the position that conceptual ecologists can help understand invasions, and in turn, invasions can help to fine tune the principles of conceptual ecology. The book clearly acknowledges the long-standing schism between mainstream ecology and invasion biology, the need to reconnect the two, and the dangers of emotional bias when thinking about newly arrived species. It also returns frequently to the idea that "invasions" and their effects are difficult if not impossible to predict, or to prevent.

Given that the unique characteristics of individual species are the key to understanding most invasions, let me finish this discussion with three more comments about the Halloween ladybug. First, although introduced ladybugs are a bad idea, and they are lousy biocontrol agents for aphids, some American entomologists still see value in the Halloween ladybug, whereas the seven-spot makes no difference whatsoever to aphid numbers. Thus, the most hated ladybug in North America may well be the species most deserving of the title, "Gardener's Friend."

Second, the Halloween ladybug is hard to live with, at least for people. They congregate in houses, they smell, they bite people, and they can even affect the taste of wine, as they have in such places as Ohio, New York, Pennsylvania, Indiana, and Ontario. The beetles tuck into the grapes in the fall, both for shelter and for food, and it is difficult to get them out before the grapes are made into wine. Apparently, the resulting wine does not taste like alkaloids, but instead a bit like peanut butter, oddly enough. So again, it is clear that the importation of this beetle was a bad idea, and that applied entomologists should avoid this sort of mistake in future.

Third, it seems clear that the Halloween has a more profound effect on the composition of the ladybug fauna than the other newcomers. Even if we ignore the fact that anti-alien fears were misplaced with respect to the seven-spot, perhaps the Halloween is a scarier beast. It forages not only in low vegetation, but also in trees, and it seems to be responsible for at least local extinctions ("extirpations") in the eastern United States. I still think it is important to remember that we do not have published studies in which good naturalists have searched for native species in all possible habitats after the establishment of the Halloween, but I'll also admit that this is still not sufficient justification for believing that the native species are out there somewhere, hiding. As I was taught, "absence of evidence is not evidence of absence." Of course, it is difficult to picture just what "evidence of absence" should look like, but the fact is we haven't searched as thoroughly as we could have. Here in Alberta, we are in a good position to watch our ladybugs carefully if and when the Halloween "invades" But will it? The answer lies not in some general theory of biological invasions but in our understanding (or lack thereof) of the biology of this particular species.

The closest established populations of Halloween ladybugs are on the west coast. They seem to like the warm, humid climate there, but will they do well in our cold, dry winters? David James, a professor at Washington State University, thinks that eastern Washington is too arid for the Halloween (in an information pamphlet published by his university), and if that is true, then Alberta is probably even more so. In Texas, I have noticed that the Halloween is only moderately common in the dry southern tip near Mission and McAllen but much more abundant in the more humid parts of the state, around Houston for example. The species does, however, do well in Siberia, and for that reason, most ladybug experts predict it will do well here also. It may be, however, that the original stock that was used for introducing this species to North America was adapted to more southerly, humid areas, in which case the species might or might not adapt to northern conditions here. Only time will tell.

Another factor might also come into play. At the 2005 meeting of the Entomological Society of America, two of the research presentations were devoted to the study of a sexually and socially transmitted fungus (*Hesperomyces virescens*) that infects the Halloween ladybug and was discovered in the late 1990s. Christine Nalepa and her colleagues are the primary researchers in this area. Will this fungus spell the end of the Halloween's success in North America? Will it affect only the Halloween? Again, only time will tell.

We are, therefore, in an interesting position, at an interesting point in time. Coincidentally, the British are just a few years ahead of us. With very good identification resources, and an established network of ladybug reporters and a good national database, they are watching with interest as the Halloween spreads across the British Isles, after arriving in 2004. Mike Majerus is the coordinator of the Harlequin Ladybird Survey, and you can follow the progress of this project at www.harlequin-survey.org. Mike, along with Vicky Strawson and Helen Roy, have also published a paper outlining the reasons they are apprehensive about the arrival of the Halloween ladybug.

If you have read this far, you are probably in a position to help here as well, at least with respect to clarifying our understanding of what is going on. I hope that enough naturalists get to know our Alberta ladybugs and begin to keep records of what they see. I keep such records myself, and I'm glad to help anyone else add their data to the communal pool. With the co-operation of such institutions as the E.H. Strickland Entomology Museum, at the University of Alberta, and the Alberta Natural Heritage Information Centre, we can follow the British lead and document our ladybugs as the fauna changes. Of course, introduced species are not the only factors that might affect the ladybugs of Alberta. Other things, such as climate change, changing land use patterns, and interactions with changes in the plants and other animals may also play a role. Without data, we will never know, and without educated naturalists, we will never have the data. With that as a pep-talk, let's proceed to the most enjoyable subject of all, the species-by-species treatment of the ladybugs of Alberta.

The lugubrious ladybug—a rarely seen gem from the sandiest prairies in southeastern Alberta.

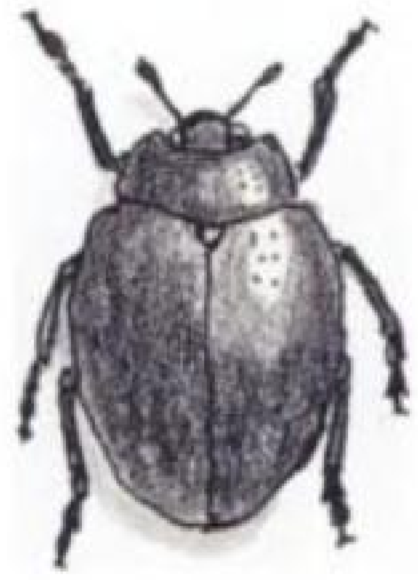
5

The Lesser Ladybugs of Alberta

In this book, I have divided the ladybug family into two broad groups. The first is the "lesser ladybugs," so named because most are generally small, rare, and ecologically unlike their larger cousins. So far, they have been of interest primarily to beetle collectors and taxonomists, although some species have been used for biocontrol in the United States.

Technically, these lesser ladies belong to the subfamilies Sticholotidinae and Scymninae. Some are just as colourful and cute as the "larger ladybugs," but none are familiar to the average person. Only one of our lesser ladybugs exceeds four millimetres in length, and most are between two and three millimetres long. Thus, the size range of the lesser ladybugs overlaps that of the larger ladybugs. This arrangement was inspired by the traditional distinction between "micro moths" and "macro moths," a division that is also based on taxonomy, not size (although most "micros" are small and most "macros" are large). If lepidopterists can live with such an arrangement, perhaps ladybugsters can too.

I have to admit that, before working on this book, I had very little interest in the lesser ladybugs myself. In fact, I strongly considered leaving them out altogether, because there are so many of them and they are so rarely encountered. In the end, however, I decided that it would be better to treat them alongside their larger cousins for the sake of completion, and now I'm glad I did. They are mysterious, poorly known beetles and perhaps increasing their profile might result in interesting discoveries and new information coming to light. I am also inspired by the British approach to ladybug appreciation in which all ladybugs, no matter how small, rare, or colourless, are treated equally. Searching for lesser ladybugs is a great example of field entomology at its most refined—they don't simply pop out at you the way larger ladybugs do (or butterflies, damselflies, or tiger beetles for that matter). You have to search carefully and skilfully, and it can be remarkably rewarding when you find a species you haven't seen before.



MICROWEISIA MISELLA (LeConte) *("MIKE-row-VYSE-ee-ah miss-ELL-ah")*

"Look at this ladybug!" says author John,
"You gotta be kidding," most readers respond.

THE NAME

"Micro ladybug" seems obvious for this beetle (although one friend of mine calls it "micro-wee-wee-weisia"). Micro means small in Greek, and J. Weise was a beetle scientist in the early 20th century. *Misella* comes from Latin, meaning small, poor, and wretched.

IDENTIFICATION

1.0–1.5 mm, entirely black (or brown when newly emerged), shiny, and only very slightly hairy. Not many other beetles, of any sort, are this small, and if they are, they are generally some other shape or colour. Note that American hairy ladybugs are noticeably more hairy, with lighter-coloured legs, and a less pointy face and butt. If you get a close-up view, another way to tell a micro ladybug is by the conical and pointed (not wedge-shaped and expanded at the tip) last segment of the maxillary palp (the mouth part "feeler" that is shorter than the antennae).

NOTES

Getting to know such a minute beast is, to me, a treat. Once you can recognize the micro ladybug (and even a 1.5 mm all-black ladybug still elicits "aww, how cute" from some people), you begin to feel in your heart that it is truly possible to identify even the smallest of creatures. Gerry Hilchie told me that he had found more than 25 micro ladybugs on the bark of alder trees in the river valley in Edmonton, and I have now found them there as well. I have also found the species on chokecherry, balsam poplar, and mountain ash bark. I weighed one too, by the way, at a whopping 0.0007 grams (i.e., a little over half a milligram)! The micro ladybug is widespread across southern Canada and most of the United States excluding the southwestern deserts.

STETHORUS PUNCTILLIUM Weise (*"STETH-orr-USS punk-TILL-ee-um"*)

Each time you find Stethorus prowling on bark,
It's your duty to look at its postcoxal arc!

THE NAME

Punctillium is Greek and refers to the tiny punctures on the pronotum and wing covers of this beetle. I have distinguished the newcomer hairy ladybug from the American hairy ladybug with no intention of denigrating the newcomer because of its origins.

IDENTIFICATION

About 1.5 mm. Black, covered with slightly curved pale hairs, and with dark legs and a shallow postcoxal arc.

NOTES

This is an introduced species that came accidentally to North America from Europe in the 1950s. Perhaps it is established here, perhaps not. In Taber in 2001, Ted Pike found a single female beetle that might be this species. The postcoxal arc of the specimen is relatively shallow, but the punctures on the head and pronotum appear to be equal in size, not "subequal" as expected. It is a female, so dissection of the genitalia was not able to resolve its identity. To put our hairy ladybug records in perspective, this genus was reported from Manitoba for the first time in 2001, by Ian Wise and Bill Turnock. So, we are not far behind in our understanding.

CRYPTOLAEMUS MONTROUZIERI Mulsant
("KRIP-toe-LEE-muss mon-TROO-zee-ERR-eye")

On entering greenhouses through airlock foyers,
Be always on guard for mealybug destroyers.

THE NAME

Crypto means hidden, *laemus* means neck (both are Greek). The species name honours Xavier Montrouzier, a French born entomologist who described many beetles, other insects, and plants in New Caledonia in the 1800s. And yes, the English name makes me laugh. Why not just "mealybug eater"? I suppose "destroyer" probably sells more ladybugs to more greenhouses.

IDENTIFICATION

About 4.5 mm. Like a big, bright *Scymnus* ladybug—dark and hairy, with a rusty orange head, pronotum, and tips of the wing covers.

NOTES

This is a biocontrol ladybug in Alberta that is sold for use in greenhouses, where it feeds on various sorts of scale insects, including "mealybugs." It does not occur in the wild here. This species was originally brought to North America from Australia for this purpose and is now established in the warmer parts of California and Florida. It is highly unlikely that this species could survive outdoors in Alberta, but you might encounter escaped individuals from time to time. I have included it here mostly for anyone who might see one in a greenhouse and wonder what it is.

DIDION LONGULUM Casey *("DIDD-ee-on lonn-GEW-lum")*

Look there on the bark for the angular lady,
I find them in sunlight, rather than shady.

THE NAME

Longulum comes from the Latin, and means elongate but small. "Angular ladybug" draws attention to its distinctive outline.

IDENTIFICATION

About 1.5 mm. Black. Much like the immaculate form of the twice-stained ladybug but with finer punctures on the wing covers, and a more rounded shape (although still noticeably more elongate than the American and newcomer hairy ladybugs). I always notice the angular shape of the pronotum, which does not form a smooth continuation of the curve of the wing covers.

NOTES

A widespread western species in Canada and the United States that is probably found throughout Alberta. May feed on spider mites, at least in part. I have found it twice on the bark of young balsam poplar trees (making it part of an ecological threesome including the twice-stabbed and micro ladybugs as well). In some ways, it is easier to distinguish from other small black ladybugs in the field than it is under the microscope, because its overall body shape is more apparent at a distance. It truly is more elongate.

"Despite what many people think, little ladybugs don't grow up to be big ladybugs."

—JOHN ACORN

Everybody loves a ladybug, and no one is more passionate about these spotted creatures than John Acorn, who has produced this, the first regional ladybug field guide in North America. With comprehensive maps, colour photographs, and illustrations of 75 different species, Acorn educates readers on the beauty and diversity of ladybugs in Alberta. He also explains the impact that introduced species have had on these remarkably diverse insects. Professional entomologists, bug-loving kids, and nature-walk enthusiasts will find ladybug identification enjoyable and rewarding with Acorn's combination of expertise and humour.

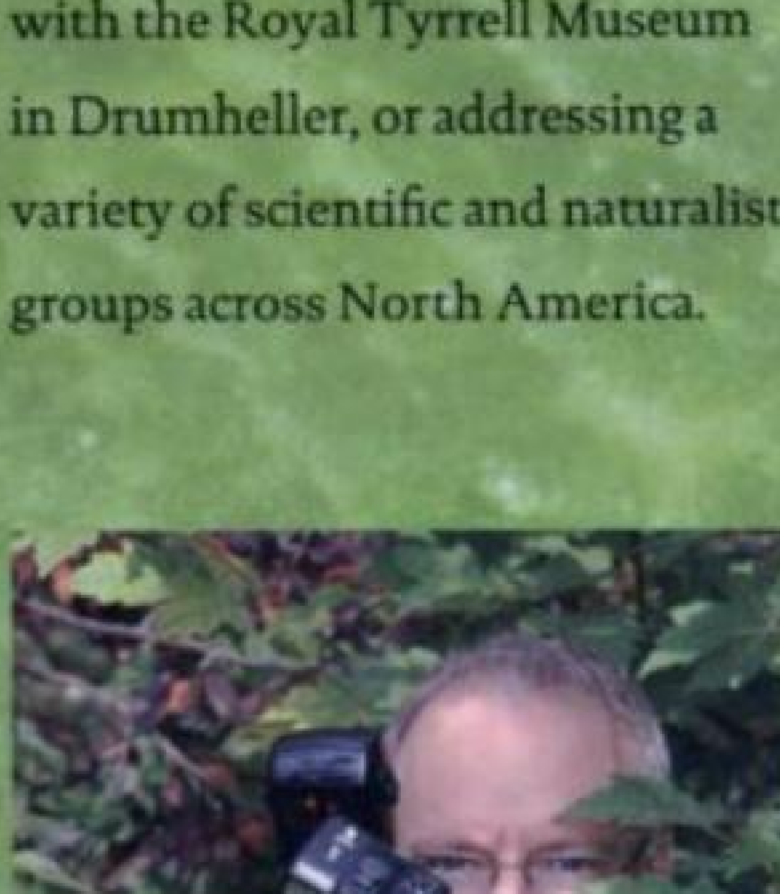
"John Acorn knows his beetles."

—JOHN J. OBRYCKI
Professor and Chair, Department of Entomology
University of Kentucky

"...a delightfully readable style..."

—NATALIE J. VANDENBERG
Entomologist, U.S. Department of Agriculture

JOHN ACORN, a lifelong Albertan, lives in Edmonton with his wife Dena and their two boys, Jesse and Benjamin. When John isn't chasing ladybugs, he can be found lecturing at the University of Alberta, working with the Royal Tyrrell Museum in Drumheller, or addressing a variety of scientific and naturalist groups across North America.



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