VOL. 97 JULY 1995 NO. 3
(ISSN 0013-8797)

PROCEEDINGS

of the

ENTOMOLOGICAL SOCIETY of WASHINGTON

THE ENTOMOLOGICAL SOCIETY OF WASHINGTON · 1884 ·

PUBLISHED QUARTERLY

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All correspondence concerning Society business should be mailed to the appropriate officer at the following address: Entomological Society of Washington, ℅ Department of Entomology, MRC-168, Smithsonian Institution, Washington, D.C. 20560.

MEETINGS.—Regular meetings of the Society are held in the Natural History Building, Smithsonian Institution, on the first Thursday of each month from October to June, inclusive, at 8 P.M. Minutes of meetings are published regularly in the *Proceedings.*

MEMBERSHIP.—Members shall be persons who have demonstrated interest in the science of entomology. Annual dues for members are $25.00 (U.S. currency).

PROCEEDINGS.—The *Proceedings of the Entomological Society of Washington* (ISSN 0013-8797) are published quarterly beginning in January by The Entomological Society of Washington. POSTMASTER: Send address changes to the Entomological Society of Washington, ℅ Department of Entomology, MRC-168, Smithsonian Institution, Washington, D.C. 20560. Members in good standing receive the Proceedings of the Entomological Society of Washington. Nonmember U.S. subscriptions are $60.00 per year and foreign subscriptions are $70.00 per year, payable (U.S. currency) in advance. Foreign delivery cannot be guaranteed. All remittances should be made payable to *The Entomological Society of Washington.*

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PLEASE SEE P. 218 OF THE JANUARY, 1991 ISSUE FOR INFORMATION REGARDING PREPARATION OF MANUSCRIPTS.

STATEMENT OF OWNERSHIP

Title of Publication: Proceedings of the Entomological Society of Washington.

Frequency of Issue: Quarterly (January, April, July, October).

Location of Office of Publication, Business Office of Publisher and Owner: The Entomological Society of Washington, ℅ Department of Entomology, Smithsonian Institution, 10th and Constitution NW, Washington, D.C. 20560.

Editor: Thomas J. Henry, Systematic Entomology Laboratory, ARS, USDA, ℅ Department of Entomology, Smithsonian Institution, 10th and Constitution NW, Washington, D.C. 20560.

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Special Publications: A. G. Wheeler, Jr., Bureau of Plant Industry, Pennsylvania Department of Agriculture, Harrisburg, PA 17110-9408

Managing Editor and Known Bondholders or other Security Holders: none.

This issue was mailed 19 September 1995

Second Class Postage Paid at Washington, D.C. and additional mailing office.

PRINTED BY ALLEN PRESS, INC., LAWRENCE, KANSAS 66044, USA

♾ This paper meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).

PROC. ENTOMOL. SOC. WASH.
97(3), 1995, pp. 701–716

COCCINELLA NOVEMNOTATA IN NORTHEASTERN NORTH AMERICA: HISTORICAL OCCURRENCE AND CURRENT STATUS (COLEOPTERA: COCCINELLIDAE)

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Abstract.—A review of the literature documents that the native lady beetle *Coccinella novemnotata* Herbst (C9) was once common in the northeastern United States and Canada. Despite extensive recent fieldwork and surveys for coccinellids, only five collection records of C9 in the Northeast have been located since the mid-1980s. Its apparent decline in numbers and possible local extirpation could be the result of factors such as changes in land-use and cropping patterns, decline in aphid populations, parasitism, or disease. The factor most often suggested is possible adverse effects from the Old World *C. septempunctata* L. (C7), whose establishment in North America was detected in 1973. New World populations of C7 may have resulted from previous releases for the biological control of aphids or an unintentional importation with commerce. Without a cause-and-effect relationship having been established, proposed detrimental impacts of C7 on native coccinellids are based solely on anecdotal evidence and speculation. Even though C7 was extensively recolonized in North America by biological control specialists, the C7 project does not typify classical biological control. If C7 has had a negative effect on C9, it is more appropriately considered displacement of an indigenous species by a polyphagous nonindigenous species than an example of unintended effects of classical biological control.

Key Words: Insecta, lady beetles, biological control, faunal change

For several years we have realized that the native lady beetle *Coccinella novemnotata* Herbst (hereafter C9) has become increasingly difficult to find in the Northeast and may even be locally extirpated. One hypothesis proposed to account for its apparent decline in numbers is adverse effects from the establishment in North America of a more aggressive congener, the Old World *C. septempunctata* L. (hereafter C7).

In this paper we will demonstrate that *C. novemnotata* was once a widespread and sometimes abundant coccinellid in northeastern North America (Delaware, Maryland, and New Jersey north to Ontario and Quebec) and that it has been collected only once during surveys and extensive fieldwork in the Northeast in the 1990s. Our intent is (1) to document what others have suspected: that C9 is no longer a common species in the Northeast; (2) to stimulate entomologists, ecologists, and conservation biologists to search for C9 populations in the Northeast and to deposit voucher specimens in major entomological collections; (3) to encourage workers in western North America, where C7 has become established more recently, to begin, or continue, to monitor populations of C9; and (4) to increase interest in documenting the effects of adventive species—whether intentionally or unintentionally introduced—on indigenous species.

C7 in North America

The first U.S. releases of this well-known Old World coccinellid (e.g. Hodek 1973) were made by the U.S. Department of Agriculture (USDA) in California in 1957, based on material from India. Adults were recovered after a month but no further individuals were collected, and no eggs or larvae were observed. From 1958 to 1973, beetles from India, France, Italy, Norway, and Sweden were released (nearly 150,000) for aphid control in eastern and western states by the USDA (Angalet et al. 1979, Schaefer et al. 1987). In eastern Canada small numbers were released in New Brunswick during 1959–1960 (Clark et al. 1971, Schooley et al. 1984). A particular effort was made to establish C7 in Maine for suppression of potato-infesting aphids; about 80,000 individuals were released in test plots at Presque Isle (Shands et al. 1972). Although the F1 generation was recovered at several localities, these releases apparently did not lead to permanent colonization in the United States or Canada (Angalet and Jacques 1975, Angalet et al. 1979, Schaefer et al. 1987).

C7's detection in New Jersey (Angalet and Jacques 1975) and Quebec (Larochelle and Larivière 1979) in 1973 renewed interest in this predator and led to redistribution efforts during 1974–1978 (Angalet et al. 1979). More than 500,000 beetles were released in 20 states and the District of Columbia (Schaefer et al. 1987), and in Canada they were redistributed in Nova Scotia (Kelleher 1984). The beetle's natural dispersal from the area of detection in New Jersey was considered slow: by 1975 records were available only for 10 counties in Connecticut, New Jersey, and New York; its presence in Delaware was considered the result of recolonization (Angalet et al. 1979). But C7's rapid spread began to be documented (Hoebeke and Wheeler 1980). Natural spread, aided by successful recolonization in Georgia, Ohio, and Oklahoma, resulted in recoveries from 15 states by the end of 1979 (Schaefer et al. 1987 and references therein).

By 1986, C7 was established in 34 eastern and central states and in 5 Canadian provinces (Schaefer et al. 1987). In Iowa and Missouri this recently established predator was still less abundant than any of the native coccinellids found in croplands, abandoned fields, and roadsides (Obrycki et al. 1987).

Additional releases were planned for the western two-thirds of the United States (Comis and Heppner 1986). Detection of the Russian wheat aphid, *Diuraphis noxia* (Mordvilko), in Texas in 1986 (Stoetzel 1987) further emphasized the need to redistribute C7 in the West (Olkowski et al. 1990, Gordon and Vandenberg 1991). This project was led by the USDA-Animal & Plant Health Inspection Service's National Biological Control Laboratory in Niles, Michigan, and redistribution of C7 in four western states was initiated in 1989 (Flanders et al. 1993). It is now the most commonly collected species of *Coccinella* east of the Rocky Mountains (Gordon and Vandenberg 1991), one of the dominant coccinellids of agricultural crops in Michigan (Maredia et al. 1992), and is known from all 48 contiguous states (Prokrym et al. 1992; see also Rice 1992). In western Canada it occurs in the Prairie Provinces and in central British Columbia (Humble 1991, McNamara 1991). Gene diversity of North American populations is similar to that among Eurasian C7, such a broad genetic basis being characteristic of other successful adventive insects in the New World (Krafsur et al. 1992).

The origin of North American populations of C7 remains in doubt. It was first suspected that the beetles found at the Hackensack Meadowlands in New Jersey were associated with disposal of trash at sites near Kennedy International Airport (Angalet and Jacques 1975). C7's collection in

Quebec, however, suggested separate introductions with transoceanic commerce—along the St. Lawrence Seaway in Quebec and the Upper Bay of the Hudson River and at New Jersey ports of entry (Schaefer et al. 1987). Although an unintentional introduction with ship traffic remains a strong possibility (Schaefer and Dysart 1988, Day et al. 1994), an alternative hypothesis should be considered: that classical biological control releases of C7 made during 1958 to 1973 led to its establishment in the East (Schaefer et al. 1987). Studies of genetic diversity in North American populations have not discriminated between these two hypotheses (Krafsur et al. 1992).

C9 in North America

Widespread in North America, this native lady beetle ranges from Maine, Ontario, and Quebec to Florida and west to British Columbia and southern California (Dobzhansky 1931, Gordon 1985) and occurs in all northeastern states (Dobzhansky 1931, Procter 1946, Belicek 1976). In Canada it is found north to 46° in Quebec, 45°30′ in Ontario, and 62° in the Northwest Territories (Brown 1962).

Recorded prey includes numerous aphid species (Thompson and Simmonds 1965), and in laboratory evaluations C9 fed more on aphids than on spider mites or lepidopteran eggs (Putman 1957). Larvae and adults similarly preferred aphids to larvae of the alfalfa weevil, *Hypera postica* (Gyllenhal), or leafhopper nymphs (Yadava and Shaw 1968). Although C9 has been considered an important natural enemy of the European corn borer, *Ostrinia nubilalis* (Hübner) (Sparks et al. 1966), more recent work indicates that predation on corn borer eggs is unimportant (Andow 1990). Feeding has also been observed at extrafloral nectaries (Putman 1964, Pemberton and Vandenberg 1993; see also van den Bosch and Telford 1964: Fig. 92).

C9 is especially common in gardens and other cultivated lands (Leng 1903, Blatchley 1910, Stehr 1930, Chapin 1974, Belicek 1976), occurring in field crops such as alfalfa (Fluke 1925, Goodarzy and Davis 1958, McMullen 1967a, Neuenschwander et al. 1975; see also Hodek 1973), clover (Folsom 1909, Smith 1958), corn (Everly 1938, Bartholomai 1954, Smith 1971, Wright and Laing 1980), cotton (Bell and Whitcomb 1964, Whitcomb and Bell 1964, van den Bosch and Hagen 1966), potatoes (Leonard 1963, Day 1965, Mack and Smilowitz 1980), small grains (Kirk 1970, Shade et al. 1970, Bernal et al. 1993), and soybeans (Blickenstaff and Huggans 1962, Dumas et al. 1964, Tugwell et al. 1973). In Connecticut (Britton 1914) and Minnesota (Stehr 1930), C9 has been ranked as one of the coccinellids of greatest economic importance. C9 can also be collected on weeds in disturbed areas (e.g. McMullen 1967a, Richerson and DeLoach 1973, Dailey et al. 1978, Lago and Mann 1987, Maredia et al. 1992), as well as on apple (Smith 1958, LeRoux 1960, Oatman et al. 1964, Hagley 1975, Travis et al. 1978, Carroll and Hoyt 1984), peach (Putman 1964, Kirk 1970), conifers, and hardwood trees (Felt 1906, Smith 1958, Gagné and Martin 1968, Drooz 1985).

Detailed life history studies of C9 have not been conducted, although Burgess (1903) and Palmer (1914) provided information on fecundity and duration of life stages in the laboratory. Data on preoviposition period, fecundity, and longevity were obtained by McMullen (1967b) and duration of egg and larval stages by Gagné and Martin (1968). Studies on the sex ratio, weight, and size of adults have also been conducted (Smith 1966). Its relative abundance, seasonal history, adult behavior, and factors inducing diapause were studied in California (McMullen 1967a, b). This predator is apparently univoltine in Ontario (Gagné and Martin 1968) and bivoltine in Colorado (Palmer 1914). An important mortality factor may be parasitism by the Holarctic braconid *Dinocampus coccinellae* (Schrank)

Hudon 1959, Richerson and DeLoach 1973).

Historical occurrence before establishment of C7.—C9 is referred to as frequent throughout Indiana (Blatchley 1910), one of the most abundant coccinellids in Oregon (Ewing 1913), common in Iowa prairies (Hendrickson 1930), and the most common species of *Coccinella* found in Minnesota and the Upper Mississippi Valley (Stehr 1930, Wingo 1952). Occurring statewide in North Carolina (Brimley 1938), South Dakota (Kirk and Balsbaugh 1975), and several northeastern states (see Table 1), C9 is included in many field guides and general references (e.g. Lutz 1948, Jaques 1951, Zim and Cottam 1956, Dillon and Dillon 1961, Swan 1964, Borror and White 1970, Swan and Papp 1972, Milne and Milne 1980, Arnett and Jacques 1981, Arnett 1985, Boyd 1991). In fact, C9 is used as the lead illustration for the coccinellid sections in Arnett (1968) and Borror and White (1970) and in 1989 was designated the official state insect of New York (see Hoffmann and Frodsham 1993). In addition, the USDA's *Cooperative Economic Insect* (later *Plant Pest*) *Report* contains numerous references to C9 on various crops. Examples of these state reports include: "Extremely active" on crimson clover, vetch, and cotton in Mobile Co., Alabama (Seibels et al. 1963); "extremely heavy feeding" on woolly apple aphid, *Eriosoma lanigerum* (Hausmann), on apple in Tallapoosa Co., Alabama (Webb et al. 1965); and the most abundant coccinellid in alfalfa (75–100/100 sweeps) in Lafayette Co., Arkansas (Boyer 1970). At one time C9 was routinely collected in the Northeast (Table 1; see also locality records in Dobzhansky 1931).

C9 in the Northeast, 1973–1985.—After C7's detection in North America, C9 continued to be collected in insect surveys in the Northeast during 1973 to 1985. From 1974 to 1978, C9 was scarce at the Hackensack Meadowlands, where C7 had become the dominant coccinellid, and it was also much less numerous than C7 at a nearby site in Connecticut in 1978 (Angalet et al. 1979; see also Table 2). When C7's establishment was first reported in Pennsylvania, similar numbers of both coccinellids were obtained in limited sweepnet samples (Hoebeke and Wheeler 1980; Table 2). Two years earlier, large numbers of C9 had been found on apple in Pennsylvania (Travis et al. 1978; Table 2).

C9 was not found in surveys of managed, abandoned, and "organic" apple orchards in New York, Pennsylvania, Virginia, and West Virginia during 1983 and 1984, although C7 was present (Brown et al. 1988). Three specimens of C9, however, were collected in Jefferson Co., West Virginia, in 1982, 1984, and 1985 (2 in blacklight traps, 1 in an unsprayed orchard); this species has not since been collected on apple in Jefferson Co. (M. W. Brown, pers. comm. 1994). C9 also was not among the 10 coccinellid species, including C7, collected during a survey of corn insects in the Connecticut Valley of Massachusetts from 1982 to 1984 (Eaton 1984).

C9 in the Northeast since 1985.—We are aware of only five collections of C9 since 1985 (Table 3). One adult was collected at each of two localities in Maryland in 1986 during a survey of coccinellids associated with nursery stock from 1986–1988; C7, however, was taken at 87 of the 186 locations and was the most abundant of the 28 species collected (Staines et al. 1990). C9 has not been seen in Maryland since 1986 (C.L. Staines, Jr., pers. comm. 1994). Populations of the aphid *Cinara pilicornis* (Hartig) were monitored on spruce (*Picea* spp.) seedlings and transplants in a southcentral Pennsylvania nursery during 1987–1988, and two C9 adults were observed on 13 May 1987. But it was C7 that was the most abundant coccinellid associated with aphid-infested spruce (Wheeler 1989 and unpubl. data). In Delaware during a census of overwintering Coccinellidae in a 0.5 ha plot containing >1000 grass clumps, 27 C9 adults were found at Delaware City in winter 1987–

Table 1. Examples of historical occurrence of *Coccinella novemnotata* (C9) in Northeast before establishment of *C. septempunctata* (C7).

State/Province	Remarks	Reference
Connecticut	Common throughout state; of >30 coccinellid spp. recorded, among the 12 considered most economically important	Britton 1914
	Very common at Meriden	Johnson 1915
Maine	Scarce in Mount Desert Region	Procter 1946
Massachusetts	On white birch at Malden, feeding on aphid eggs, 1898	Burgess 1903
	Common on Nantucket Island	Johnson 1930
	Present in cranberry bogs	Franklin 1950
New Jersey	Common throughout state	Smith 1910
	Larvae, adults on *Hibiscus moscheutos* L.	Weiss and Dickerson 1919
	On *Oenothera biennis* L., feeding on aphids	Dickerson and Weiss 1920
	On *Asclepias syriaca* L., *A. tuberosa* L.	Weiss and Dickerson 1921
New York	Abundant on *Pinus rigida* Mill. at Karner (Albany Pine Bush)	Felt 1906
	A common species on Staten Island	Leng and Davis 1924
	4th in abundance of 8 coccinellid spp. on alfalfa at Ithaca: 8 adults collected during 10 min. of sampling; one of most abundant coccinellids at Ithaca	Pack 1925
	More localities listed than for any of the other 66 coccinellids recorded from state	Leonard 1928
	Present in small numbers on collards at Ithaca, 1957–1958; 1966–1968	Pimentel 1961, Root 1973
	2nd most numerous coccinellid on potatoes on Long Island, 1956–1958 (19% of family); sometimes abundant late June–early July	Leonard 1963, Day 1965
	On cruciferous crops on Long Island, 1960–1963	Sutherland 1966
	Present in low densities on alfalfa at Ithaca, 1966–1969	Pimentel and Wheeler 1973
	Present in 100-sweep samples of alfalfa in Columbia, Orange, and Steuben counties, May–Aug.; largest number/100 sweeps = 12 in Columbia Co., 15 July 1970	A.G.W., unpublished data
Ontario	Ranked 3rd in abundance among 9 most numerous coccinellid spp. in survey of forages, weeds, and trees; 13% of 2300 specimens collected, 1957	Smith 1958
	Ranked 6th of 10 coccinellid spp. collected, 1948–1960, on peach; 2.9% of 888 specimens identified	Putman 1964
	Represented 19.1% of coccinellids associated with establishment stage of red pine, 1964; numbers dropped drastically in 1965	Gagné and Martin 1968
	Represented 20% of coccinellids (6 spp.) on corn, 1963	Smith 1971
Pennsylvania	Very abundant on oak, feeding on *Archips semiferana* (Walker)	Nichols 1971
Quebec	On apple at Rougemont, 1951–1955 and 1955–1957; predacious on aphids	LeRoux 1960, Parent 1967
	Known historically from 24 localities	Larochelle 1979
Vermont	Known historically from 25 collections	Parker et al. 1976

Table 2. Examples of occurrence of *Coccinella novemnotata* (C9) in Northeast, 1973–1985, after establishment of *C. septempunctata* (C7).

State/Province	Remarks	Reference
Connecticut	16 adults collected (vs. 175 for C7) during survey at Hammonasset, Aug. 1978	Angalet et al. 1979
New Jersey	Scarce at Hackensack Meadowlands, 1974–1978; C7 the most abundant of 17 coccinellid spp. occurring at site	Angalet et al. 1979
	Common in Pine Barrens	Boyd and Marucci 1979
Ontario	On apple at Vineland, 1969–1974	Hagley 1975
	On *Onopordum acanthium* L., 1976	Judd 1978
	"Never numerous" in corn, 1977–1978	Wright and Laing 1980
Pennsylvania	High population levels on apple, 1977; aided significantly in reducing aphid numbers	Travis et al. 1978
	Occasionally common on *Euonymus alatus* (Thunb.) Sieb. infested with *Aphis fabae* Scopoli, 1977	Wheeler and Stimmel 1979
	10 adults/300 sweeps of weeds in ruderal site (vs. 12 for C7), Harrisburg, 1979	Hoebeke and Wheeler 1980
	Collected 4 times (vs. 5 for C7) on soybeans, 1980–1982	Wheeler and Stimmel 1983
	Larva reared from aphid-infested shoots of *Physocarpus opulifolius* (L.) Maxim., 1979	Wheeler and Hoebeke 1985
Quebec	Collected at 5 localities (vs. 43 for C7), 1979	Larochelle and Larivière 1980
Vermont	On apple in Chittenden Co., 1973–1974	Hauschild 1975

1988; this survey yielded 3000 C7 adults (P. W. Schaefer, pers. comm. 1993). In a study in Maine, C9 was the second most abundant coccinellid (C7 was most abundant) found in potato plots and the second most numerous lady beetle in barley plots adjacent to potato in 1992. C9 was not encountered in either crop in 1993 (F. A. Drummond, pers. comm. 1994), which could reflect normal year-to-year fluctuations in density rather than an actual decline in numbers.

No detections of C9 were made in the Northeast during 1993 coccinellid surveys conducted as part of the USDA's Cooperative Agricultural Pest Survey program. In Connecticut, an alfalfa field in each of 4 counties was sampled 6 times (400 sweeps/visit) from 10 June to 19 August and once in September; supplemental 200-sweep samples were taken at 16 sites in 4 counties during June to September (D. Ellis, pers. comm. 1993). New York surveys consisted of 1500 sweeps taken 4–5 times in alfalfa or clover fields in each of 4 counties (1 was sampled only 3 times) from 15 July to 9 September; additional samples from forages and goldenrod were taken in 5 counties during August and September (J. J. Knodel, pers. comm. 1993). In Pennsylvania, 3 alfalfa fields in 3 counties were each monitored 6 times (400 sweeps/visit) from 18 June to 1 September; 52 additional fields or disturbed weedy sites were surveyed in 18 counties from June to August. Similar coccinellid surveys in various disturbed habitats in Pennsylvania (136 sites in 23 eastern counties) were also negative for C9 in 1994 (A.G.W., unpubl. data).

Moreover, C9 was not observed during an extensive survey for the adventive *Hippodamia variegata* (Goeze) in the Northeast in 1992. Nearly 600 adults of 8 coccinellid species, including 66 C7, were collected in 8 states (Wheeler 1993). We have not seen C9 in general collecting since 1985 or in our surveys of disturbed and relatively undisturbed habitats ranging from urban vacant

Table 3. Known records of *Coccinella novemnotata* (C9) in Northeast since 1985; see text for additional information on collections.

State	Remarks	Reference
Delaware	27 adults at Delaware City, winter 1987–1988	P. W. Schaefer, pers. comm.
Maine	Common on barley and potatoes in study plots at Presque Isle, 1992	F. A. Drummond, pers. comm.
Maryland	Two collections during 1986–1988: 1 adult on nursery stock in Allegany Co., another in Carroll Co.	Staines et al. 1990
Pennsylvania	Two adults on spruce transplants in Cumberland Co. nursery, May 1987	Wheeler 1989, unpubl. data

lots to pitch pine-scrub oak barrens, serpentine barrens, and shale barrens. No recent records of C9 were available in the insect collections that were checked: American Museum of Natural History, New York; Canadian National Collection, Ottawa; Carnegie Museum of Natural History, Pittsburgh; Cornell University, Ithaca, N.Y.; Florida State Collection of Arthropods, Gainesville; National Museum of Natural History, Washington, D.C.; Ohio State University, Columbus; Pennsylvania State University, University Park; University of Maine, Orono; and University of New Hampshire, Durham.

Discussion

Adverse effects from the establishment of C7 is only one possible explanation for the apparent decline in C9 populations. Other factors that could be involved are changes in land-use and cropping patterns, decline in aphid densities, parasitism, disease, or even global warming. It is C7, however, that has been proposed most often as the likely cause of C9's decline.

Soon after C7's establishment in eastern North America, its possible detrimental effects on native coccinellids began to be noted. There was no evidence for C7's replacement of native coccinellids in Georgia within three years of its release and establishment for suppression of pecan aphids (Tedders and Angalet 1981), but by the early 1980s a possible "antagonistic relationship with *C. novemnotata* appeared to be developing" in Ontario (W. Y. Watson, letter to A.G.W., 11 Feb. 1983). The need to evaluate the effects of the rapidly spreading C7 on the native coccinellid fauna became apparent (Schaefer et al. 1987). When field surveys were conducted during a three-year period in Maryland (186 localities), the once "very common" C9 was collected only twice. Competitive displacement by C7 was suggested as a reason for the apparent diminished numbers of C9 in Maryland (Staines et al. 1990). Ehler (1990) also emphasized C7's potential for affecting nontarget species (see also Evans 1991, Tedders 1992, Elliott et al. 1993, and Wheeler 1993). The sevenspotted lady beetle's possible effects on endangered lycaenid butterflies have recently been evaluated in Ohio. Although their population declines coincided with increases in C7 and this coccinellid fed on lycaenid eggs in the laboratory (Horn 1991), no field data are available to substantiate any adverse effect of C7 on these endangered lepidopterans.

Populations of C9 in the Northeast seem to have declined sharply during the 1980s and 1990s, a period when the Old World C7 was undergoing rapid range expansion. Our after-the-fact evidence for the adverse effects of C7 on C9 must be considered circumstantial. Populations of C9 were not monitored systematically during the time when C7 was becoming established in the Northeast and assuming dominance among coccinellids in disturbed and relatively undisturbed communities. Coccinellid densities often fluctuate widely from year to year (e.g. Foott 1974, Elliott and Kieckhefer 1990, Kieckhefer and Elliott 1990, Elliott et al. 1993). Quantitative data from sampling at several sites over a 10- to 15-year period—beginning even before the establishment of C7 in the local fauna—would therefore be needed to assess accurately C7's role among various other factors that may be responsible for a decline in populations of C9.

Except in classical biological control of weeds programs, rarely are such quantified data available assessing the effects of adventive species on indigenous organisms; however, there are incomplete baseline data documenting the presence and abundance of C9. Literature references adequately support the view that C9 was once routinely collected or observed in the Northeast, often in considerable numbers. If C9 were still relatively common, it should have been detected during recent surveys for Old World coccinellids in the Northeast or in our extensive fieldwork involving agricultural crops, herbaceous weeds, shrubs, and trees since 1987. Adults of C9 are conspicuous because of their size (Britton 1914). Even though adults somewhat resemble those of C7, the two species are easily recognized. The head of C9 has a solid white rectangle instead of two white dots, and the anterior pronotal margin has a narrow white border, which is lacking in C7. C9's recognition in the East is not complicated by the pronounced color polymorphism that characterizes certain native or naturalized lady beetles in our fauna; only the fully maculate nine-spotted morph occurs in eastern North America (Belicek 1976, Gordon and Vandenberg 1991). As evidence for a recent decline in C9 populations, data from extensive fieldwork probably should be weighted more heavily than the absence of new material in collections (museum accessions sometimes are not processed for several years).

The sevenspotted lady beetle is a voracious, nearly ubiquitous aphidophage in the Old World that can also be characterized as eurytopic, polyphagous, and ecologically plastic (Hodek 1973). The aggressive adults (see Miller 1992) will attack early-instar chrysopid larvae, even when other prey are available (Şengonca and Frings 1985). For a summary of studies on its foraging behavior, see Kareiva (1986) and Andersen and Kareiva (1993). C7 is an active flier and an aggressive colonizer that has become established on Sable Island, Nova Scotia, which is isolated in the Atlantic about 175 km from the nearest land (Schaefer et al. 1987), and also at high elevations (nearly 3500 m) in the Rocky Mountains (Rice 1992).

The only evidence available that C9 might be susceptible to interspecific competition is the possibility that its gradual disappearance from establishment-stage red pine in Ontario was the result of competition from other coccinellids (Gagné and Martin 1968). Competitive displacement and interspecific predation by C7, as well as pesticide use and changes in land management, could contribute to declining populations of C9 in the Northeast. Determining the precise nature of C7's detrimental effects on C9 would prove difficult.

C7's explosive colonization of North America provides an opportunity for evaluating the effects of an aggressive polyphagous predator on nontarget organisms. Ehler (1990) found "it difficult to believe that this introduction will not have an impact on non-target species in the United States," and Evans (1991) suggested that C7 "may have profound impact on the ladybeetle fauna native to North America through complex interactions of Old and New World ladybeetles." Indeed, uncommon coccinellids temporarily disappeared from cropfields in South Dakota following the invasion and establishment of C7 (Elliott et al. 1993), although C7 was not shown to be a direct cause of their decline; factors other than C7's establishment could be involved.

C9 is still common in parts of western

North America. In fact, its relatively high densities (and those of *Hippodamia convergens* Guérin-Méneville) may have hindered or delayed C7's establishment in California (Flanders et al. 1993). At most, C9 may be only locally extirpated in the East. Workers in the Northeast and even the Southeast (C9 appears at least to have declined in Alabama and Mississippi during the past five years; P. M. Estes and R. L. Brown, pers. comm. 1994, 1995) are encouraged to look for this native species. Workers in areas where C7 is a more recent invader may want to begin, or continue (Elliott et al. 1993), to monitor its potential effects on C9 and other native coccinellids, as well as document a decline in populations of injurious aphids (see Kauffman and Schwalbe 1991). There is also a need to determine if other recently established Eurasian lady beetles—*Harmonia axyridis* (Pallas), *Hippodamia variegata,* and *Propylea quatuordecimpunctata* L.—are affecting native coccinellids in the East (see Day et al. 1994).

Most people will not be concerned if an introduced predator having superior attributes reduces pest populations more than do indigenous natural enemies. So many plant and animal species have been affected by the needs of human society (e.g. Soulé 1990) that a decline in numbers of one or a few native predators will be viewed as inconsequential. Local extirpation or extinction of C9 would elicit more concern.

It is likely that C9 will find habitats in which it can coexist with C7; such populations, as yet undetected, may exist in the Northeast. Its populations may again build to sizable levels. The current low densities of C9 in the Northeast may actually be similar to those that existed before the advent of agroecosystems, which facilitated increases in aphid numbers, allowing C9 perhaps to reach population levels greater than before human intervention.

The benefits of C7's presence in the Nearctic fauna may outweigh any costs to the environment. Use of pesticides against an important crop pest may actually pose more of an environmental threat than does the release of some biological control agent (e.g. Nechols et al. 1992). The establishment of C7 can be viewed as representing a continuum of ecological changes. We have discussed C7 as a principal factor contributing to a decline in populations of C9, although the evidence is speculative and anecdotal. But C7 may even be having positive effects on other nontarget organisms.

The importation of any biological control agent is an experiment. Most introduced species fail to become established, relatively few provide substantial suppression of target pests, and fewer still cause serious environmental problems (e.g. Hall and Ehler 1979, Hall et al. 1980, Samways 1988, Ehler 1990). Whether any environmental disruption associated with C7's establishment is considered acceptable should await the results of long-term ecological monitoring, preferably at sites where C7 and C9 do and do not co-occur, and critical evaluation of the accumulated quantitative data. Even then, an evaluation of the program to recolonize C7 in North America will be influenced by one's environmental, political, and social views.

Summary and Conclusions

Classical biological control has traditionally been favorably received by conservationists and environmentalists (Samways 1988) but is under increasing pressure from such groups (Howarth 1983, 1991, Nechols and Kauffman 1992, Simberloff 1992, Lockwood 1993, Miller and Aplet 1993, U.S. Congress 1993). We realize the introduction of biological control agents has been viewed as part of the larger problem of environmental disruption resulting from invasion of nonindigenous species (Howarth 1983, 1991, Samways 1988, Ehler 1990, 1991, Miller and Aplet 1993). Moreover, we support the need to analyze and evaluate biological control projects, but the data used and conclusions reached should have a sound scientific basis and avoid inference and speculation.

We cannot document a cause-and-effect relationship between the establishment of C7 and the decline of C9. What can be stated with reasonable certainty is that C7 has increased and, at the same time and in some of the same places, C9 has decreased. Proposed adverse effects of C7 on native coccinellids, such as *Hippodamia convergens* (Tedders 1992) and *C. transversoguttata richardsoni* Brown, are now based entirely on speculation.

That all forms of pest control—biological as well as chemical—pose some environmental risk is well known (Taylor 1955, Elton 1958, Turnbull and Chant 1961, Ehler and van den Bosch 1974, Beirne 1975, Pimentel et al. 1984, Carruthers and Onsager 1993, Drea 1993, Miller and Aplet 1993). Consequently, biological control practitioners generally, especially those involved with weeds, have attempted to minimize potential environmental problems (e.g. Zwölfer and Harris 1971, Harris 1973, Goeden 1983, Klingman and Coulson 1983).

It is tempting to look at the case of C7 and C9 within the context of classical biological control. Even though C7 was recolonized extensively by biological control specialists, this project does not typify classical biological control. Initially there was no target pest (e.g. Comis and Heppner 1986); only later was the Russian wheat aphid identified as the target aphid for redistribution. It is also uncertain whether the successful invasive genotype of C7 should be attributed to intentional releases in North America or to an accidental introduction with commerce. If C7 has indeed adversely affected C9, that interaction is more appropriately viewed as displacement of an indigenous species by a polyphagous, aggressive nonindigenous species. It should not be cited as an example of negative effects of classical biological control. Instead it reemphasizes the continuing need to assess host (and prey) specificity of all agents considered for release in classical biological control programs.

Acknowledgments

We are grateful to M. W. Brown, F. A. Drummond, D. Ellis, P. M. Estes, J. J. Knodel, R. L. Brown, P. W. Schaefer, C. L. Staines, Jr., and W. Y. Watson for allowing us to refer to their unpublished data or correspondence; E. C. Becker, S. W. Bullington, D. S. Chandler, J. R. Coulson, W. H. Day, L. E. Ehler, R. D. Gordon, K. I. Hauschild, L. A. Hull, W. C. Kauffman, J. V. McHugh, R. Mack, J. J. Obrycki, S. C. Passoa, T. M. Peters, P. E. Skelley, W. L. Tedders, and M. C. Thomas for checking collections or files for records of *C. novemnotata* or providing copies of papers; R. L. Stewart and C. A. Stoops for helping survey for coccinellids in Pennsylvania during 1993–1994; and E. S. Delfosse, L. E. Ehler, J. H. Frank, J. C. Miller, J. J. Obrycki, and R. L. Pienkowski for useful comments on the manuscript.

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