North American Distribution of *Coccinella septempunctata* (Coleoptera: Coccinellidae) and Its Mass Appearance in Coastal Delaware

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Environ. Entomol. 16: 368–373 (1987)

ABSTRACT The Palearctic sevenspotted ladybeetle, *Coccinella septempunctata* L., well established in North America, has now spread through parts of five Canadian provinces and 34 contiguous eastern states of the United States. In southern coastal Delaware in June 1984, a mass appearance of *C. septempunctata* occurred where wind systems brought masses of these beetles into the area from unknown sources and dropped them into the seawater. Large numbers then washed up on beaches, and some surviving beetles annoyed vacationers and even bit some people. We speculate on the original establishment of this insect in North America. Presenting evidence previously overlooked, we add to speculation that early intentional releases led to establishment of this predator in North America. However, accidental importation on transoceanic ships cannot be ruled out.

KEY WORDS *Coccinella septempunctata*, dispersion, beneficial insects, mass mortality, biological control, aphid predator

Coccinella septempunctata L., known commonly as the sevenspotted lady beetle or by the acronym C7, is a Palearctic species that is now firmly established in North America. Since its discovery in New Jersey in 1973 (Angalet & Jacques 1975), efforts have been expended to use it as a biological control agent against aphids. The effort was directed primarily toward moving the beetle into new areas, thereby accelerating the natural rate of dispersion and enhancing any beneficial effect of this species.

In this report, we present the latest assessment of the current distribution of *C. septempunctata* in North America based on many recent unpublished records, we document the details surrounding a mass appearance of these beetles in coastal Delaware in June 1984, and we also reflect on the possible origin of this beetle's establishment in North America.

Materials and Methods

North American Distribution. Records have been obtained from numerous sources, including collections by various USDA personnel from this laboratory and the APHIS-PPQ, Biological Control Laboratory, Niles, Mich. Other contributors of records include personnel from Pennsylvania Bureau of Agriculture, Maine Department of Agriculture, Virginia Department of Agriculture, North Carolina Department of Agriculture, and Agriculture Canada, Ottawa. For our purposes, collection of one or more specimens from a county constituted evidence for establishment and inclusion on our distribution map.

Mass Appearance on the Delaware Beaches. We became aware of this phenomenon after an article appeared in a local newspaper on 12 June 1984. Immediately thereafter, Russell Bingham (USDA, Newark, Del.) and R.J.D. visited the area near Dewey Beach, Del., and returned with a matted sample of seaweed (ca. 1 m in length, consisting of ca. 0.2 m^2 surface area) cast up on the beach in tidal flotsam. The bulk of this material was vegetation that was impregnated with many dead coccinellid beetles. In the laboratory, the beetles were separated by species, preserved in 75% ethanol, and subsequently separated by sex. Although identification of sex of individuals based on external morphological characters is possible (Baungaard 1980), it is tedious and time-consuming when done under a dissecting microscope. To accelerate this task, we developed a clearing/bleaching process that permitted rapid sex identification, often without the need for microscopic examination.

Clearing was accomplished by subjecting the ethanol-preserved beetles to 10% KOH solution at ca. 95°C for 30 min and then draining and immediately submerging specimens in 5.25% sodium hypochlorite solution for 10 min. This process cleared the integument of any pigmentation and exposed the internal male genitalia. In this manner, four samples of 100 beetles each were identified to sex.

On 20 June, R.J.D. and P.W.S. revisited the Dewey Beach area and photographed the aggregations of dead beetles on the beach. During both inspections, we interviewed various people who

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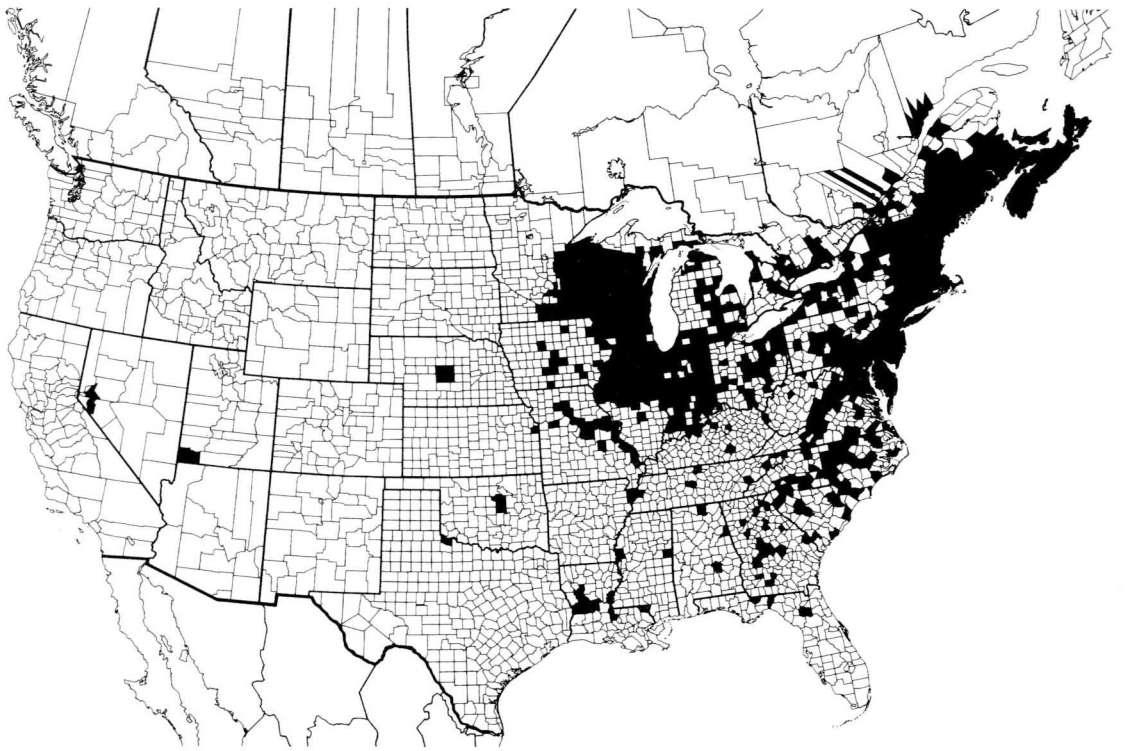

Fig. 1 North American distribution of *C. septempunctata* based on recoveries as of August 1986.

had experienced the invasion of beetles. Later we interviewed Molly Murray, who had written the initial newspaper article for the Wilmington *News-Journal.*

Subsequent to the mass appearance of the beetles, we consulted weather data and meteorologists in an effort to reconstruct the weather patterns of the lower Delaware area in hopes that this might provide clues as to the possible origin of the masses of beetles.

Origin of the North American Establishment. We examined the events in the published accounts of the appearance of *C. septempunctata* in North America. We also examined some unpublished accounts of the early releases of this species. Although no one can be certain how this species became established, we review two explanations that have heretofore not been fully considered, because it appears that Angalet et al. (1979) were unaware of some critical information that has subsequently come to our attention.

Results and Discussion

North American Distribution. The known distribution of *C. septempunctata* in Canada and the United States depicted in Fig. 1 is based on all records available to us as of August 1986. A comparison with the distribution presented by Hoebeke & Wheeler (1980) and Gordon (1985) (Gordon's map appears incomplete because it is based only on specimens he examined) suggests how rapidly this beetle has expanded its range. At present, it is established in 34 eastern and central states of the United States and in five Canadian provinces (Fig. 1). Analysis of the redistribution attempts of Angalet during the 1970's in many central and western states (Fig. 2) suggests that releases in isolated locations outside of known areas of distribution at the time resulted in establishment in Oklahoma (Cartwright et al. 1979), Georgia (Tedders & Angalet 1981), Delaware (Angalet & Jacques 1975), and Ohio (Beneficial Insects Research Laboratory, unpublished data). Releases in Florida, Texas, Nevada, and Utah led to recoveries of beetles the year following release, but the populations apparently have not persisted. In these states, we do not know its current status and reconfirmations are needed.

This insect is now present in the eastern half of the United States and in five eastern Canadian provinces. It has also established on islands, such as Bon Portage Island, Nova Scotia, near Cape Sable, and, more remarkable, Sable Island, Nova Scotia, isolated in the Atlantic 300 km east southeast of Halifax, which is 175 km from the nearest point of land. These findings further illustrate the mobility of this species, and we can only wonder how it managed to reach and colonize distant locations.

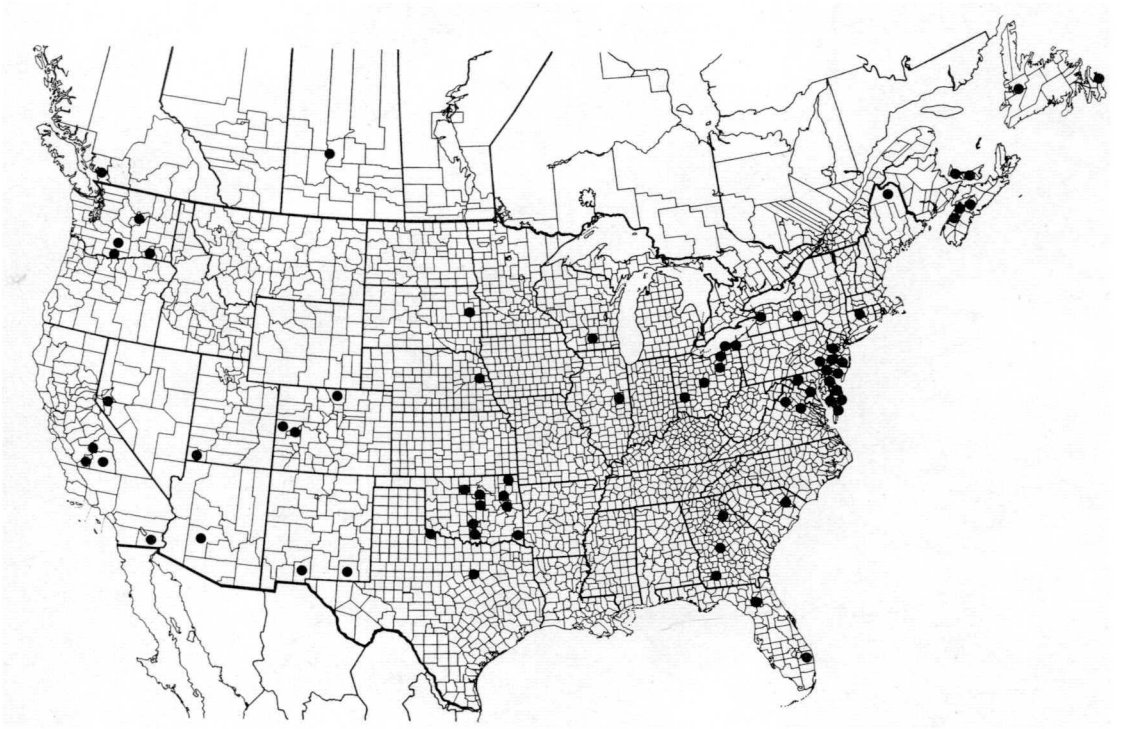

Fig. 2. Intentional release locations for *C. septempunctata* in the United States and Canada, 1958–84.

Mass Appearance on the Delaware Beaches. *C. septempunctata* is an active flier, often to the detriment of biological control colonization efforts (Azam & Ali ca. 1969,[2] Ali & Azam 1977). Mass aggregations of *C. septempunctata* are known; however, Hodek (1973) cautioned against attributing all such aggregations (especially for overwintering purposes) to *C. septempunctata*, because many observers in Eurasia have mistakenly identified *Semiadalia undecimnotata* (Schneider) as *C. septempunctata*. Nevertheless, *C. septempunctata* aggregates in clusters of 5–50 beetles, overwintering in grass clumps, under stones, in litter, in holes in soil surfaces, or near bases of plants, but generally near breeding habitat (Hodek 1973). Most important, these aggregations may occur during August and September, when beetles may cluster on vegetation such as pines (Hodek 1973, Angalet et al. 1979), in close proximity to the site where they will eventually overwinter. In spring, aggregations may again occur before dispersal to breeding sites. Under most conditions, dispersal to and from overwintering sites is not over large distances. This is in contrast to other species, for example *Semiadalia undecimnotata* in Eurasia and *Hippodamia convergens* Guérin-Méneville in North America. They often migrate to high, prominent sites and aggregate in great numbers (Hodek 1973). Migration and aggregation in *C. septempunctata* has been reported in agricultural (Tsai et al. 1980), mountainous (Sem'yanov 1979, Rubin 1981, Yan et al. 1981), desert (Cloudsley-Thompson 1984), and coastal (Yan et al. 1983) habitats. In the account by Yan et al. (1983), the conditions described are most similar to those we observed in Delaware. Beetles appeared en masse in Northeastern coastal areas of China in June and were believed to have been carried by winds from southern China (Yan et al. 1983). Similar yet much more dramatic mass mortality of a congeneric species was reported in North Africa (Oliver 1943).

Our first awareness of a mass appearance came through a newspaper article citing the lower Delaware locations of Lewes Beach, Dewey (Rehoboth Bay), Indian River, and Assawoman Bay as having been invaded by large numbers of lady beetles (Murray 1984). This prompted R.J.D. to visit the Dewey Beach area on 12 June 1984. At that time, vast quantities of beetles were dead on the beaches and relatively few live beetles were present on any nearby vegetation. No aphids or immature *C. septempunctata* could be found to suggest that the populations had been produced locally. Initial evidence suggested that the adult beetles had been carried from other areas and had settled out of the atmosphere along this coastal section. It was evident that many such beetles had

[2] Azam, K. M. & M. H. Ali. (undated, ca. 1969). A study of factors affecting the dissemination of the predatory beetle, *Coccinella septempunctata* L. Andhra Pradesh Agric. Univ. Final Tech. Rep.

fallen into the waters of Rehoboth Bay (inner beach side) and the Atlantic Ocean (outer beach). The greatest quantities of beetles were present on the inner beach, where winds and tides skimmed these mostly dead beetles off the water surface and cast them up on beaches. Examination of the flotsam sample revealed 2,027 coccinellid beetles; 89.6% were *C. septempunctata,* 5.3% *H. convergens,* 4.3% *Coleomegilla maculata lengi* Timberlake, and the remaining 0.8% represented several other species. Of the *C. septempunctata,* 64.7% were females.

A revisit by R.J.D. and P.W.S. to Dewey Beach on 20 June 1984 again revealed large quantities of dead beetles on the inner beach and very few live beetles on any nearby vegetation. We concluded that the influx of beetles had not continued during the interim period (12–19 June) at the rate that apparently preceded the 12 June visit. On the outer beach, examination of the most recent high tide mark revealed the following coccinellid beetles (combined samples from Dewey Beach and Indian River): 19 *Epilachna varivestis* Mulsant, 11 *C. septempunctata,* nine *H. convergens,* seven *Chilocorus stigma* (Say), six *Cycloneda munda* Say, four *C. maculata lengi,* and five other specimens representing four other coccinellid species. Also, eight *Leptinotarsa decemlineata* (Say) were collected in the same examination of beach drift.

During both visits to the beach areas, some of these people who experienced the beetle "plague" reiterated that they had been annoyed by the sheer numbers of beetles walking over beach towels and on sunbathers. Park attendants stated that some people who came for a day on the beach and entered areas for which daily use fees were collected had been so troubled by the lady beetles that they asked for refunds and left the beaches early in the day. Gate attendants stated that at the height of the beetle influx there were hundreds crawling over the state park buildings. Another stated that many beetles were present on the boats and docks of the marina at Indian River. During this influx of beetles, there were several reports of people being "bitten" by the beetles. Joseph Tropp, of this laboratory, reported being bitten by a *C. septempunctata* while on a beach outing in the area on 9 June 1984. This behavior suggests that the beetles were hungry. Similar accounts of biting occur for *C. septempunctata* or other species in England (Owen 1976, Gough 1977) and for *Adalia bipunctata* (L.) in the Pacific Northwest (Svihla 1952).

From all available evidence, we conclude that the greatest influx of beetles occurred during the period of 5–9 June 1984. Examination of the weather patterns during this period revealed unseasonably warm temperatures, reaching 34–36°C each day from 8 to 14 June 1984 in Dover, Del., due to a Bermuda High lying near the North Carolina coast. It was also especially dry, with 0.5 mm of rain recorded for the first half of June. On 28 May a warm front, and on both 30 May and 4 June cold fronts, moved across the Delmarva Peninsula with some accompanying high winds, predominantly from the west.

In retrospect, we cannot precisely identify what attribute of the passing weather conditions may have caused the beetles to accumulate and then fall into the seawater. Such phenomena are known elsewhere, in seawater (Oliver 1943, Rothschild 1971, Owen 1976, Yan et al. 1983) or fresh water (Lee 1980), and we are only beginning to understand the micrometeorological conditions that may affect insect movements and mortality (Drake 1982, Pedgley 1982, Pedgley et al. 1982). We suggest only that they came from areas southwest or west of the beaches mentioned and probably came from the Delmarva Peninsula under conditions similar to those described by Dixon (1985).

Origin of the North American Establishment. Because no proof is available for *C. septempunctata* establishment in North America, we offer some further speculation on possible means of introduction based on some data that were unavailable to Angalet & Jacques (1975), who speculated that it might have arrived in trash at disposal sites from Kennedy International Airport. A review of the historical facts suggests that, although R. L. Jacques collected the first specimens of *C. septempunctata* in the Hackensack meadowlands, Bergen County, N. J., on 28 June 1973, during the same season, on 17 September 1973, R. Morrissette collected one specimen at Repentigny, L'Assomption Comtes, Québec, Canada (Larochelle 1979). In New Jersey, the population was found to be quite abundant in 1974 and immediate efforts to recolonize the beetles began (Angalet et al. 1979). In Québec, the population was not as plentiful at first, but records show the following collections: 1973, 1 specimen; 1974, 11; 1976, several specimens in 2 localities; 1978, in 12 localities; and 1979, in 43 localities in 18 Québec counties, summarized for the entire period as 53 localities in 22 counties (Larochelle 1979). In the United States, by 1975 *C. septempunctata* had been collected in a total of 10 counties; New Jersey (6 counties), New York (3), and Connecticut (1), all apparently due to natural dispersal, and in New Castle County, Del., due to successful recolonization efforts (Angalet & Jacques 1975). By 1979, the beetles had been recovered in 37 counties in five eastern states (Hoebeke & Wheeler 1980) as well as Oklahoma (2 counties) (Cartwright et al. 1979) and Georgia (2 counties) (Tedders & Angalet 1981). By the end of 1979, this beetle had been recovered from 74 counties in 15 states (unpublished data).

In considering the locations of the first known discoveries of *C. septempunctata* in North America, one common thread appears. Both sites are in close proximity to major waterways on which transoceanic freighter movement is common: in Québec, the St. Lawrence Seaway and in New Jersey, the Upper Bay of the Hudson River and the New Jersey shipping ports. This suggests that sep-

arate accidental introductions may have occurred from transoceanic ships near the sites of the two 1973 recoveries.

A second hypothesis must also be considered. Early efforts to introduce *C. septempunctata* in North America began in 1958. Before 1973 (when discovery of established populations was made separately in Québec and in New Jersey), the following numbers of beetles had been intentionally released in the areas listed: Arizona, 992; California, 23; Delaware, 5,427; Florida, 4,161; Georgia, 924; Maryland, 500; Maine, ca. 80,000 (35,631 in 1964 alone and all in Presque Isle); New Jersey, 41,909 (71% in Burlington County); Nova Scotia, 5,000; Pennsylvania, 1,172; South Carolina, 154; Virginia, 2,600; and Washington, 10,088 (USDA, unpublished data). In Maine, large numbers of these beetles were released in trials to reduce aphid damage in potato fields. Shands et al. (1972) stated that *C. septempunctata* were released every year from 1964 to 1969. Richard Storch (personal communication), estimated that ca. 80,000 beetles were released in Presque Isle during that period. These and all known release locations in the United States and Canada through 1985 are depicted in Fig. 2.

Although there is no absolute certainty, the aforementioned intentional introduction efforts may have resulted in the establishment of this beetle in North America. Beetles could have become established in Maine and then made their way to the St. Lawrence River valley (a minimum distance of <200 km). Similarly, beetles released in New Jersey may have led to the population establishment in the Hackensack Meadows (a distance from Burlington County of ca. 80 km). Released beetles were frequently F_1 progeny and as such they normally overwinter before reproducing. This might encourage dispersion and could easily lead researchers to think that establishment had not occurred following a release. Considering the recent mass appearance of beetles on Delaware beaches and their natural appearance in such remote sites as Sable Island, it becomes increasingly more evident that these beetles are highly mobile, and perhaps the same dispersal tendencies were present in those beetles that were originally released. Mobility is further evidenced by a newly discovered recovery of *C. septempunctata* collected at Indiana Dunes Park, Porter County, Ind., on 10 September 1977 by N. M. Downie (specimen forwarded to Beneficial Insects Research Laboratory for confirmation, December 1985). Surprisingly, this specimen was taken 4 years after the original 1973 recoveries, on the shores of Lake Michigan. The nearest possible release location at that time was Champaign County, Ill., where our records show that 1,960 beetles were released in 1976 and another 1,700 beetles in 1977.

Unfortunately, both possible explanations seem plausible and neither is testable. We must be satisfied that *C. septempunctata* is now well established in North America and that we can look forward to potential benefits in the form of aphid population reduction in various crops due to this, perhaps fortuitous, establishment of a coccinellid in the Nearctic region. Now we need to assess the impact of this invading species on other native coccinellids and on the various aphid pest species that may serve as food for this predator.

Acknowledgment

We thank the many people who have contributed their records of collections of *C. septempunctata*, especially Karen G. Wilson (North Carolina Department of Agriculture, Raleigh), Alfred G. Wheeler, Jr. (Pennsylvania Department of Agriculture, Harrisburg), James S. Kelleher (Agriculture Canada, Ottawa), E. Richard Hoebeke (Cornell University), Donald F. Mairs (Maine Department of Agriculture, Augusta), and various personnel of this laboratory, Robert M. Hendrickson, Jr., Russell G. Bingham, Joseph M. Tropp, John A. Plummer, and Frank C. Elia. We are also in possession of numerous records based on specimens collected or transmitted by Steven Bonanno, Jane R. Schaefer, Jim Carroll, W. Blau, W. L. Tedders, Robert W. Meyer, M. Kelleher, R. Pienkowski, S. Roach, David R. Prokrym, P. Larkins, K. Bereza, P. Kingsley, John Tate, J. C. Parr, Sally Gladstone, Earl Stadelbacher, O. T. Forrester, and L. Marko. Richard H. Storch and Geddes W. Simpson (University of Maine) and W. A. Shands (Salem, S.C.) provided historical information on the early release work in Presque Isle, Maine. The draft manuscript was reviewed by R. D. Gordon, G. D. Butler, Jr., W. L. Tedders, and two anonymous reviewers. To all people involved, we express our thanks.

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Received for publication 19 May 1986; accepted 20 November 1986.