SHORT COMMUNICATION

Population patterns of *Paradoxaphis plagianthi*, a rare New Zealand aphid

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Abstract: In the first quantitative study of an endemic New Zealand aphid, the only known field populations of the rare *Paradoxaphis plagianthi* were monitored for two years from 1999 to 2001. The species appears to be anholocyclic, persisting viviparously throughout the year on its deciduous host tree, the lowland ribbonwood (*Plagianthus regius*). Local aphid abundance increased rapidly in spring as new leaves appeared, but collapsed abruptly in November, probably due to dispersal and a decline in resource quality. Numbers then remained low until leaf senescence in late autumn, when they increased again to a smaller peak. Aphids persisted on plump terminal buds for the short time in winter when host trees were completely leafless. Though several colonisation events were observed in late spring, these were generally unsuccessful in establishing new populations, and local colony extinction was common. The apparent rarity of *P. plagianthi* suggests it could be threatened by introduced predators and competitors, or climate change.

Keywords: *Paradoxaphis plagianthi*; *Plagianthus regius*; population dynamics; rarity.

Introduction

Aphids are widespread throughout temperate areas of the world, but New Zealand is notable for its paucity of species. While comparable areas of the Northern Hemisphere boast one aphid species for every three plant species (Dixon *et al.*, 1987), fewer than twenty native aphid species are known from New Zealand, and only seven of these have been described formally [three by Cottier (1953), and one each by Tillyard (1926), Sunde (1987), Carver (2000), and Eastop (2001)]. This paucity is especially intriguing since several of the New Zealand aphids have distinctive taxonomic features suggesting a Gondwanan origin (Sunde, 1987; Carver, 2000), challenging the conventional theory that the Aphidini arose in the Northern Hemisphere (Eastop, 2001).

Despite extensive searches, most of the native aphid species have been collected only once or on a few occasions. Most species appear to be rare, and some may be under pressure from introduced predators, parasitoids, and competitors, including more than 100 alien aphid species (Teulon *et al.*, 2002). Very little is yet known about the native aphids, so the threat of these new pressures cannot be estimated.

Paradoxaphis plagianthi Eastop (Aphididae: Hemiptera) is a small to medium-sized (1.3–2.0 mm) aphid endemic to New Zealand. Apterae (wingless parthenogenetic females) are red-brown and oval shaped, with a dark green median dorsal stripe on the abdomen; alatae (winged parthenogenetic females) are black with a brown abdomen (Eastop, 2001). Eggs and sexual forms have not been found.

The species was first collected in August 1966 by A.D. Lowe from a large lowland ribbonwood (*Plagianthus regius*) in the Christchurch Botanical Gardens. Thereafter, it was recorded intermittently (Teulon and Stufkens, 1998) until the senescence and removal of the tree in winter 2001. In June 1999 a single small colony was found in Riccarton Bush (43°31´S, 172°35´E), a 6.4 ha remnant of Canterbury flood-plain forest located 2 km west of the Botanical Gardens. Though the species has been sought on an informal basis at several locations throughout the country, and more intensively along the Port Hills near Christchurch, it has not been recorded outside Christchurch city (M.A.W. Stufkens, Crop and Food Research Limited, Lincoln, New Zealand, *unpubl.*). In January 1999, however, a new population was established successfully by Marlon Stufkens on a mature ribbonwood in the grounds of Canterbury Agriculture and Science Centre, Lincoln (43°38´S, 172°29´E) (M.A.W. Stufkens, *pers. comm.*).

Here I present the results from two years of monitoring *P. plagianthi* populations in the field, at Riccarton Bush and at Lincoln, as part of a larger project on the population dynamics of rarity. This contribution is the first quantitative population study of any native New Zealand aphid, and represents an early step towards understanding their ecology. It also forms an important case study in continuing research into the causes of rarity in this species, and in rare populations generally.

Methods

A complete population census was made, at 1- to 2-weekly intervals from August 1999 to July 2001, on the isolated, 2 m long branch where the Riccarton Bush population (colony A) was discovered. The life stage of each aphid was recorded, as early instar (1 to 3) nymphs, winged or wingless fourth instar nymphs, alatae, or apterae. In addition, the presence of parasitised or fungus mummies, or aphid predators was recorded. Regular searches were made at 2- to 4-weekly intervals for new colonies, searching throughout the forest but concentrating on a 20 m radius around colony A. When found, the branch was tagged and the new colonies were monitored as for colony A.

Likewise, the experimentally-established population at Lincoln (colony B) was monitored at regular intervals from August 1999. The size of the tree at Lincoln and the more scattered distribution of aphids meant that a comprehensive survey was not practical, so instead all leaves were searched when aphids were known from nearby branchlets, while the rest of the accessible tree (in practice, the first tier of branches, up to around 3 m high) was searched less intensively.

Results

Seasonal population patterns

Aphid abundance varied considerably throughout the year, with peaks generally ocurring in spring and late autumn (Fig. 1), although these trends were clearer in the fully-monitored colony A than in colony B. At Riccarton Bush, the spring increase and peak in aphid abundance occurred almost two months earlier in 2000 than in the previous year. In both years, however, spring population growth coincided with increasing leaf numbers, while the smaller autumn peak occurred as leaf numbers declined rapidly (Fig. 2). For the short period of winter when host trees were leafless, the few

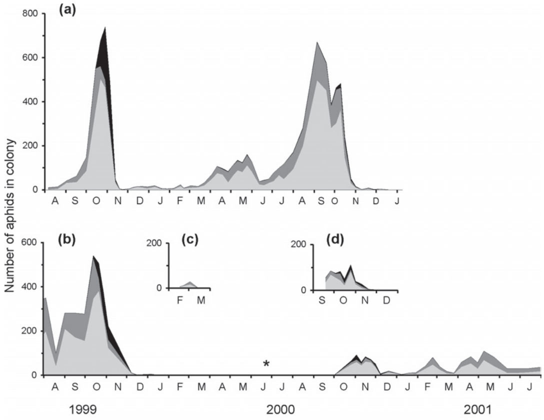

Figure 1. Abundance of *P. plagianthi* (stacked; light grey = instars 1 to 3, dark grey = apterous fourth instars and adults; black = alate fourths and adults) in four colonies over two years from August 1999: (a) Riccarton bush, original colony; (b) Lincoln colony experimentally seeded in January 1999; (c) and (d) new colonies discovered in Riccarton Bush during the course of the study. All graphs are plotted on the same scale. The star in (b) indicates where two aphids were present.

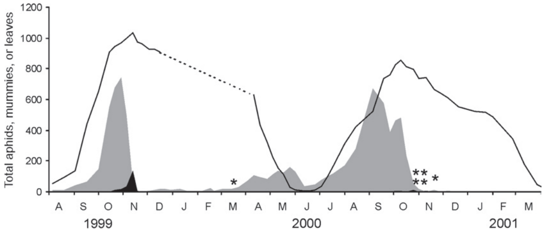

Figure 2. Seasonal trends in total *P. plagianthi* (grey area), fungus mummies (black area), parasitised aphids (stars, one star per parasitised aphid), and total leaves (line, dotted section is interpolated) present on the branch hosting colony A at Riccarton Bush.

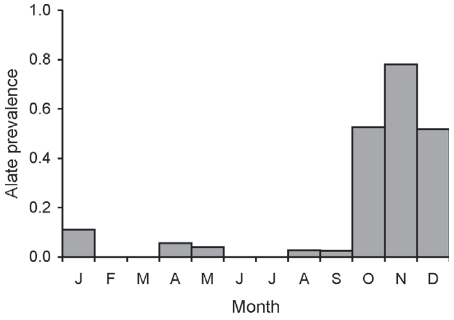

Figure 3. Seasonal prevalence of alatae in colony A, measured as the proportion of fourth instar nymphs having wing buds. Results are pooled across colonies and years.

aphids present survived on plump terminal buds, thereby persisting viviparously throughout the year.

Prevalence of alatae was greatest in late spring and early summer (Fig. 3), and generally coincided with major aphid population peaks, except in the case of colony A in spring 2000 (Fig. 1). Some alatae were also produced in late autumn (Fig. 3), around the time that smaller population peaks were observed in colony A in 2000 and colony B in 2001.

The November 1999 decline in aphid numbers in colony A also coincided with an outbreak of a fungal pathogen of the genus *Erynia* (Fig. 2), possibly *E. nouryi* (T. Glare, AgResearch Limited, Lincoln, New Zealand, *pers. comm.*). Only a small incidence of the fungus was noted in spring 2000. Parasitism was rare: just six parasitised aphids were observed in colony A over the course of the study (Fig. 2), and none in colony B. The parasitoid appears to be of the *Aphidius* genus, and a laboratory colony has been established for the purpose of identifying it (M.A.W. Stufkens, *pers. comm.*). Other natural enemies, such as spiders, mites, and lacewing larvae were encountered infrequently (typically fewer than 1 per 100 leaves), and only from October through March. On one occasion native syrphid larvae were seen amongst aphids at Riccarton Bush (not colony A), but no coccinelids were observed near aphids during the study period. At least one species of introduced aphid, *Aulacorthum solani*, was found regularly on ribbonwood, often on leaves also inhabited by *P. plagianthi*.

Colonisation and local extinction

Colony A in Riccarton Bush persisted for seventeen months after its discovery, but disappeared in December 2000. During this time twelve colonisation events, defined as aphids being found on trees or branches where they were previously absent, were observed in the vicinity of colony A (Table 1). In only one case, however, (shown in Fig. 1d) did the new population persist for several generations. Colony B at Lincoln appeared to go extinct in January 2000, but aphids were observed again on the same branches in June 2000 and from October 2000 onward (Fig. 1b).

In mid February 2000, ten small aphid colonies were found scattered through a copse of ribbonwood in a previously unsurveyed area near the eastern edge of Riccarton Bush. A total of 112 live aphids, plus 26 fungus mummies and 4 parasitoid mummies, were counted on 12 trees, after searching an estimated 50 000 leaves in the lower 6 m of 67 ribbonwood trees. Most aphids occurred between 3 and 4 m from the ground, and there appeared to be a preference for young leaves or short soft shoots sprouting directly from the main trunk. By early March, however, no aphids could be found in this area. Figure 1c documents change in one of the larger discrete colonies in this area.

In November 2000, *P. plagianthi* was observed on the juvenile growing tips of New Zealand jasmine (*Parsonsia heterophylla*) in Riccarton Bush (M.A.W. Stufkens, *unpubl.*). All seven of the *P. plagianthi* colonies found on jasmine vines at this time were beneath ribbonwood trees, and all disappeared in December 2000 at around the same time as those on nearby trees.

Discussion

The seasonal pattern of *P. plagianthi*, with greatest abundance in spring, very low levels over summer, and a smaller peak in autumn, is similar to that of several Northern Hemisphere tree-dwelling aphids, such as

Table 1. Colonisation and local extinction of *P. plagianthi* populations observed near colony A in Riccarton Bush. Persistence time is estimated as the time between discovery and local extinction, proximity is the distance to the nearest colony, and host tree size is measured as trunk diameter at breast height (dbh; a zero value indicates a sapling of less than 1.5 m height).

First observed	Persistence time (days)	Peak abundance	Proximity (m)	Host tree dbh (cm)	Notes
November 1999	0	1	1.8	0.0	Found as a fungus mummy
November 1999	20	1	1.8	1.3	
September 2000	92	112	3.4	2.9	See Fig. 1d
October 2000	0	1	1.8	0.0	Found as a fungus mummy
November 2000	0	1	6.4	2.0	Found dead
November 2000	9	1	8.3	3.1	
November 2000	9	2	7.1	0.7	
November 2000	40	11	2.0	11.9	On a different branch of the tree hosting colony A
November 2000	18	2	1.8	1.3	
November 2000	9	1	8.3	3.1	
November 2000	9	1	1.8	1.3	
December 2000	13	1	9.8	1.1	On *Parsonsia heterophylla*

Myzocallis boerneri on Turkey-oak (Dixon *et al.*, 1996), and *Chromaphis juglandicola* on walnut (Sluss, 1967). Interestingly, periods of aphid population increase coincided with relatively rapid changes in leaf abundance (Fig. 2), whether this was spring growth or autumn senescence. The soluble nitrogen content of deciduous tree leaves tends to be highest in these seasons because nutrients are being translocated (Dixon, 1998). The increased availability of nitrogen in spring and autumn results in more favourable conditions for aphids at these times (Kennedy *et al.*, 1950; Kennedy, 1958; Dixon, 1963, 1970). Similarly, the abrupt collapse in *P. plagianthi* abundance in late spring may be due in part to the cessation of leaf growth (Fig. 2), although other factors such as increased predation are likely to contribute.

In many aphids, such as *Myzocallis boerneri*, seasonal population crashes are driven mainly by dispersal (Dixon *et al.*, 1996). Certainly, the prevalence of winged morphs in *P. plagianthi* was greatest in late spring (Fig. 3), and at least some of these alatae were dispersing, as indicated by the observation of colonisation events (Table 1) and the appearance of transient colonies on vines beneath ribbonwood trees at this time. The production of alatae in aphids may be induced by a variety of cues such as crowding, resource depletion, temperature, and photoperiod (Dixon, 1998). In *P. plagianthi*, the consistent timing of alate production in November (Figs. 1 and 3) compared with the variable timing of spring population peaks (early November in 1999, but early September for colony A in 2000) suggests that alate production is primarily induced by temporally-fixed cues such as photoperiod, rather than time-variable factors such as crowding. The collection of further data should help clarify this issue.

Nevertheless, the decline and extinction of colony A in late 2000 despite low prevalence of alatae (Fig. 1a) suggests that dispersal by flight cannot be the only factor contributing to the collapse of local populations in late spring. Barlow and Gill (1987) suggested that aphid dispersal by walking is more important than by flying in seasonal population declines of *Acyrthosiphon kondoi*, but *P. plagianthi* was rarely observed walking along the branches of host trees, and only ever within aphid-populated areas. Sluss (1967) proposed that spring and autumn peaks in walnut aphid abundance are caused by increased activity of natural enemies through the summer. Population crashes of *P. plagianthi* in Riccarton Bush were associated with fungal disease in 1999, and parasitism in 2000 (Fig. 2), but the number of aphids killed by these factors was not nearly enough to have caused the observed decline. Similarly, predator abundance was generally low, and although it is difficult to judge the effect of these and less visible enemies, it is unlikely that the dramatic decline in aphids in late spring was due to a sudden increase in predation pressure. Nevertheless, predation might be important in the suppression of low aphid populations through the summer months.

The onset of apparently unfavourable summer conditions caused by poor leaf quality and increased abundance of natural enemies coincides closely with the timing of aphid dispersal. Perhaps not surprisingly, observations in Riccarton Bush suggest that most colonisation attempts by *P. plagianthi* fail (Table 1). Even well-established colonies may go extinct, as demonstrated by colony A, although the apparent extinction and recolonisation of colony B in 2000 (Fig. 1b) was probably a case of persistence at undetectably low densities, as discussed by McArdle (1990).

Finally, Dixon (1998) pointed out that anholocyclic aphids such as *P. plagianthi*, which persist viviparously throughout the year, may be especially sensitive to the effects of long-term climate change on winter temperatures. In addition, the limited distribution and low local abundance of *P. plagianthi*, especially through the summer, means it might be vulnerable to displacement by introduced aphids, and to attack from alien predators and parasitoids. We need further investigation into the basic ecology and long-term status of this and other rare New Zealand aphids in order to evaluate the threats they may face.

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