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Conservation biocontrol of pear psyllids

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*Anthocorid predatory bugs are known to be key natural enemies of pear psyllids but they often migrate into orchards too late and in too small numbers to effect timely and adequate natural regulation of pear psyllid populations. Tree and an herbaceous plant species for planting in hedgerows/windbreaks around pear orchards that are good sources of anthocorids early in the season have been identified. Preliminary work in 2008 indicated that goat and grey willow (*Salix caprea *and* S. cinerea*), hawthorn (*Crataegus monogyna*), nettle (*Urtica dioica*), ash (*Fraxinus excelsior*) and hazel (*Corylus avellana*) are promising sources of anthocorid predators. In 2009, established replicated plots of these were sampled on 8 occasions through the season to characterise predator communities, especially anthocorids, and their seasonal population dynamics and key prey and competing predator species present on them. A full data base of >70,000 specimens was collected and the most important insect groups were identified to species.* Anthocoris nemoralis *is the dominant anthocorid predator of pear psyllids. It is adapted to feed on psyllid eggs and nymphs.* Anthocoris nemorum *also occurs on pear, particularly later in the season.* A. nemorum *is adapted to feed on aphids. Psyllid larvae, on which* A. nemoralis *feeds, were found to be more numerous on trees very early in the season with egg laying and nymphs occurring from February onwards. Aphids become more numerous later in the season (May onwards) with a population crash or moving to a secondary host in July. Tree species that have psyllid nymphs early in the season (February to April) are most likely to support* A. nemoralis *early in the season and be good sources of these predators for pear psyllids. During the early season, the highest numbers of anthocorids were found on* C. monogyna, S. caprea, S. cinerea *and* U. dioica*. Tree species that support aphids provide large numbers of* A. nemorum *later in the season. The highest numbers of aphids were found on birch (*Betula pubescens*),* C. avellana *and* U. dioica, *though the aphids on* B. pubescens *did not appear to be preyed on by anthocorids.* U. dioica *is host to the nettle psyllid* Trioza urticae *which is abundant throughout the year in the adult stage.* U. dioica *is thus a good source of* A. nemoralis *early in the season. The nettle aphid* Microlophium carnosum *is also abundant when growth commences in spring, providing food for* A. nemorum *which is abundant later in the season. Thus* U. dioica *appears to be an excellent source of anthocorids, although it may also be a source of the common green capsid,* Lygocoris pabulinus, *a damaging though easily controlled pest of pear. It is concluded that hedgerows/windbreaks rich in* S. caprea, S. cinerea *and* C. avellana *with an abundant understory of* U. dioica *are likely to be excellent for conservation biocontrol of pear psyllids.* C. monogyna *was also found to be potentially excellent, but could be a source of fireblight if not carefully managed. Italian alder (*Alnus cordata*) windbreaks commonly provided round pear orchards provide little or no benefit for conservation biocontrol of pear psyllids. Mark and capture studies to investigate the migration of anthocorids from these conservation biocontrol subjects are in progress.*
Keywords: anthocorid predatory bugs, *Anthocoris nemoralis, A. nemorum*, hedgerows, Salix caprea, Crataegus monogyna, Corylus avellana, Urtica dioica, Cacopsylla ambigua, Cacopsylla peregrina, Trioza urticae

Erhaltung der Artenvielfalt als Maßnahme zur biologischen Bekämpfung von Birnblattsaugern. *Blumenwanzen sind die wichtigsten natürlichen Feinde von Birnblattsaugern, aber sie treten in Obstanlagen oft zu spät und in zu geringer Zahl auf, um eine zeitgerechte und ausreichende natürliche Regulierung der Birnblattsaugerpopulation zu bewirken. Baumarten und eine krautige Pflanzenart für die Pflanzung in Hecken bzw. Windschutzgürteln um Birnenplantagen, die als Habitate für Blumenwanzen sehr früh in der Saison gut geeignet sind, wurden identifiziert. Vorarbeiten im Jahr 2008 wiesen schon darauf hin, dass Salweide (*Salix caprea*) und Grauweide (*S. cinerea*), Weiß-*

*dorn (*Crataegus monogyna*), Brennnessel (*Urtica dioica*), Esche (*Fraxinus excelsior*) und Hasel (*Corylus avellana*) vielversprechende Quellen für räuberische Blumenwanzen sind. Über die Saison 2009 erfolgten an diesen zu acht Terminen in Modellanlagen Probennahmen, um die Populationen räuberischer Nützlinge, speziell von Blumenwanzen, und deren Populationsdynamiken über die Saison, ihre wichtigsten Beuteschädlinge und mit ihnen konkurrierende räuberische Arten zu charakterisieren. Eine umfassende Datenbank von mehr als 70.000 Exemplaren wurde erstellt, und die wichtigsten Insektengruppen wurden auf Artenniveau bestimmt. Hinsichtlich der Bekämpfung von Birnblattsaugern ist* Anthocoris nemoralis *die wichtigste räuberische Blumenwanze, sie lebt von Psyllideneiern und -nymphen.* Anthocoris nemorum *tritt ebenfalls bei Birne auf, vor allem später in der Saison*. A. nemorum *lebt von Blattläusen. Larven des Birnblattsaugers, von denen sich* A. nemoralis *ernährt, sind auf den Bäumen sehr früh in der Saison immer zahlreicher, ab Februar erfolgt die Eiablage und Nymphen treten auf. Blattläuse sind später in der Saison (ab Mai) zahlreicher mit einem markanten Zusammenbruch der Population oder deren Abwanderung zu einem Sekundärwirt im Juli. Baumarten, die früh in der Saison (Februar bis April) Birnblattsaugernymphen aufweisen, unterstützen sehr wahrscheinlich* A. nemoralis *früh in der Saison und sind gute Quellen für diese Feinde des Birnblattsaugers. Während der frühen Saison wurden die höchsten Zahlen von Blumenwanzen auf* C. monogyna, S. caprea, S. cinerea *und* U. dioica *gefunden. Baumarten, die Blattläuse fördern, bieten eine große Anzahl von* A. nemorum *später in der Saison. Die höchste Anzahl von Blattläusen wurde auf Birke (*Betula pubescens*),* C. avellana *und* U. dioica *gefunden, obwohl die Blattläuse auf* B. pubescens *offenbar nicht von Blumenwanzen angegriffen wurden.* U. dioica *ist Wirt für den Brennnesselblattfloh (*Trioza urticae*), der über das ganze Jahr im Erwachsenenstadium in großer Anzahl vorkommt.* U. dioica *ist somit eine gute Quelle für* A. nemoralis *früh in der Saison. Die Brennnesselblattlaus (*Microlophium carnosum*) zeigt auch eine große Abundanz, wenn das Wachstum im Frühjahr beginnt, und bietet Nahrung für* A. nemorum*, die später in der Saison reichlich vorkommen. So scheint* U. dioica *eine ausgezeichnete Quelle für Blumenwanzen zu sein, allerdings auch für die Grüne Futterwanze (*Lygocoris pabulinus*), ebenfalls ein Birnenschädling, der aber leicht bekämpft werden kann. Es wird gefolgert, dass Hecken bzw. Windschutzgürtel, die reich an* S. caprea, S. cinerea *und* C. avellana *sind mit einem dichten Unterwuchs von* U. dioica*, wahrscheinlich hervorragend für die biologische Bekämpfung des Birnblattsaugers geeignet sind.* C. monogyna *wurde auch als potenziell sehr geeignet befunden, könnte aber bei sorglosem Umgang eine Quelle für Feuerbrand sein. Windschutzgürtel aus Italienischer Erle (*Alnus cordata*), die man oft um Birnenplantagen findet, bieten hingegen wenig oder keinen Nutzen für die biologische Bekämpfung des Birnblattsaugers. Rückfangstudien zur Untersuchung der Migration von Blumenwanzen hinsichtlich ihrer Bedeutung für den biologischen Pflanzenschutz sind im Gange.*

Schlagwörter: Blumenwanzen, *Anthocoris nemoralis, A. nemorum*, Hecken, Salix caprea, Crataegus monogyna, Corylus avellana, Urtica dioica, Cacopsylla ambigua, Cacopsylla peregrina, Trioza urticae

Pear psyllids (*Cacopsylla pyri* and/or *C. pyricola*) are devastating pests of pears which are currently out of control and causing serious widespread damage in many commercial pear orchards in the UK and in many other EU countries. Nymphs suck sap from leaves and fruits, excreting honeydew which turns black with sooty mould. This contaminates the foliage and fruits, ruining the crop. Attacks weaken the trees which suffer from severe depletion in fruit buds the year following attack or may even be killed. The pest transmits pear decline, a debilitating phytoplasma disease of young trees.

Pear psyllids are favoured by hot, dry conditions and damage caused by them is particularly devastating when there are prolonged periods of dry weather. Climate change is likely to seriously exacerbate the problem. This threatens the future of pear growing in the UK and limits any expansion of the area of production of this crop in the UK, which otherwise is favoured by the warmer conditions. Although no formal monitoring of pesticide resistance has been done in the UK, pear psyllids appear to have developed multi-resistance to a wide range of insecticides (OPs, carbamates, synthetic pyrethroids and various Insect Growth Regulators) and there are currently few pesticide treatments available that are adequately effective. UK pear growers typically spend > £ 200 per ha per season in prophylactic treatments against pear psyllids and this amount can rise substantially if weather conditions favour the pest.

Anthocorid predatory bugs (especially *Anthocoris nemoralis*) are one of the key predators of pear psyllids. If the pesticide programme allows them to survive, they can naturally regulate populations of the pest (Santas, 1987; Erler, 2004; Solomon et al., 1989 and

2000). However, few anthocorids overwinter in pear orchards because of the lack of sufficient food or shelter. Anthocorids migrate into pear orchards from early April. This migration is responsible for the major part of the population of anthocorids found during summer. Biocontrol relies on a timely influx of adequate numbers of anthocorids in spring so that there is a high density of predators in the pear orchard early in the cropping season. Often the early season influx is inadequate and/or too late and pear psyllid populations increase to damaging levels in advance of those of anthocorid predators.

Adjacent habitats, including hedgerows and windbreaks, can promote abundance of insect predators in adjacent orchards, but little is known about the significance of certain woody hedgerow species for conservation biological control. Hedgerows and windbreaks are the source of anthocorids in spring. In order to maintain a sufficient number of these early predators the sites must provide suitable food and shelter for them. The choice of hedgerow plants and the maintenance of an adequate hedgerow structure are of great importance for how effectively natural control of pear psyllids works in adjacent pear orchards.

To sustain anthocorids and other beneficials, hedgerows must meet their dietary needs. Alternative, early season prey (e.g. psyllids, aphids and gall midge larvae) must be provided. There are reports in the literature that during the time that willow (*Salix* sp.) is flowering *A. nemorum* and *A. nemoralis* can occur on it (presumably feeding on psyllid eggs and nymphs in the female flowers (pussies)) in very large numbers (Sands, 1957; Hill, 1957; Anderson, 1962). The flowering period is usually very early, usually late March or early April, and anthocorids leave the *Salix* sp. after only a week or so. Pear psyllids and apple grass aphid are just beginning to hatch at this time, and therefore anthocorids from *Salix* sp. may colonise pear orchards in response to high numbers of these prey species. Various selections of *Salix alba* are used as windbreaks and anthocorids concentrate during flowering on these also, though not in such high numbers as on isolated *S. caprea* trees. Rieux et al. (1999) showed that ash trees host specific psyllids and gall midges that provide food and shelter for anthocorids. Solomon et al. (1999) showed that various herbaceous flowering plants attract anthocorids and can be used to enhance predator populations in orchards. Sigsgaard and Kollmann (2007) showed that hedgerows containing flowering *C. monogyna* or elderberry (*Sambucus nigra*) and herbaceous layers with *U. dioica* held high numbers of anthocorids in spring. Though pollen and sucrose diets were inferior to arthropod diets, anthocorid nymphs could survive for over a month on them when prey is temporarily scarce. Sigsgaard (2010) also studied functional biodiversity in apple orchards and adjacent hedgerows. The spring predator community in five apple orchards (*Malus domestica*) and adjacent hedgerows as a measure of the potential value of hedgerow species for biological control were compared. Arthropod communities in alder hedgerows (*Alnus incana, A. glutinosa*), in mixed elderberry hedgerows, and in the herbaceous layer under these two hedgerow types were more similar to apple orchards than insect communities in hedgerows dominated by *C. monogyna* and hazel (*C. avellana*). The total number of predators was highest on *C. avellana* and *C. monogyna* followed by apple (*Malus domestica*). Alnus sp., *C. monogyna* and herbaceous fringe vegetation with *U. dioica* held the highest number of *Anthocoris nemorum*, one of the most effective early predatory bugs in apple orchards. At the time of the field survey, *M. domestica*, *S. nigra* and *C. monogyna* were flowering, and flowering plants may be valuable for survival of pollen and nectar feeding beneficials in orchards when prey is temporarily scarce. It is likely that mixed hedgerows provide a range of alternative prey and pollen and nectar sources in succession in early spring.

Border strips of flowering herbs are often advocated as valuable sources of orchard natural enemies, though how useful they are as a practical and reliable means of fostering the migration of anthocorids into pear orchards in spring is uncertain. *U. dioica* is known to harbour high populations of anthocorid predatory bugs in spring, which are supported by the nettle aphid *Microlophium carnosum* (Perrin, 1975; Nguyen and Merzoug, 1994). The extent to which nettles can act as a timely, effective and reliable early source of anthocorids for pear orchards needs to be determined. Flowering herbs can support anthocorids in summer (Fitzgerald and Solomon, 2004) and these have been demonstrated to reduce pear psyllid populations on potted pear trees (Solomon et al., 1999).

In this work, alternative plant species for hedgerows/windbreaks as sources of anthocorids for conservation biocontrol of pear psyllids were investigated. The aim was to maximise anthocorid populations in spring and foster their migration into pear orchards when pear psyllid populations start to increase.

Materials and Methods

In 2008, three old established mixed hedgerows surrounding pear orchards in Kent, UK, were identified for sampling. These were at Ightham (site 1), West Malling (site 2) and Brenchley (site 3). A wide and varying range of different woody species were present in the hedges and two replicate sampling points for each species present in a particular hedge were identified for sampling. Two areas of each pear orchard were also included. In addition to the woody species, *U. dioica* was sampled at sites 2 and 3. Each woody plant species plot was sampled at 3 to 4 week intervals from mid-April to the end of the growing season using the beating method over a standard sampling net with funnel. Ten (~1 per meter) beats per plot were made, keeping the sampling effort/method as uniform as possible. However, the size and form of the canopies of the different species were very variable. *U. dioica* was sampled by sweep netting; 10 sweeps, spread out along the plot. Each sample was collected in an individual polythene bag and the insects were sorted and identified. The data was collated into a Microsoft Excel data base. A preliminary rating (1 = poor ... 5 = excellent) of each plant species as a potential conservation biocontrol subject for pear psyllids was ascribed based on the following factors:

1. Numbers of *A. nemoralis* found, especially early in the season
2. Numbers of *A. nemorum* found
3. The occurrence of psyllids as food sources, especially dominant species early in the season
4. The occurrence of aphids as food sources for anthocorids
5. The occurrence of competing heteroptera or other predators
6. Likelihood of the plant being a source of pests or diseases of pears

In 2009, based on the 2008 results, it was decided to study hairy birch (*Betula pubescens*), *C. avellana*, *C. monogyna*, ash (*Fraxinus excelsior),* goat willow (*Salix caprea)* and *U. dioica* in more detail. Larger plots of these species were identified in old established hedges adjacent to large commercial pear orchards at four new sites in Kent: Stone Street (site 1) (all sp.), Cooling (site 2) (*B. pubescens, U. dioica*); West Malling (site 3) (*C. monogyna*): Linton (site 4) (*S. caprea*). Up to five replicate plots of each plant species were identified and labelled at the four sites for sampling. Each woody plant species plot was sampled at 2 to 3 week intervals from early April to mid-June, with monthly samples through the end of the growing season. Sampling was done using the same methods as in 2008. Samples were transported to East Malling Research and held in a fridge. They were sorted into taxa, identified to species where possible, stored in 70 % alcohol and a data base was constructed using a Microsoft Excel spread sheet.

Results

2008

The samples were taken on 15 April, 2 May, 22 May, 16 June, 22 July and 3 September. A total of 30,092 arthropods were collected.

Psyllids, Anthocoridae and Miridae found on five example old established hedgerow species in 2008 are given in Table 1. *A. nemorum* was the most common species of Anthocoridae on most of the plants. *A. nemoralis* was also abundant on some plant species. *A. nemoralis* was the dominant anthocorid predator of pear psyllids. It is adapted to feed on psyllids (eggs and nymphs). *A. nemorum* also occurred on pear, particularly later in the season, but comprised about 30 % of the total population. *A. nemorum* is adapted to feed on aphids, which were more numerous later in the season. The best early season host plants for anthocorids were *C. monogyna*, *S. caprea*, grey willow (*Salix cinerea)* and *U. dioica.* The best host plants later in the season were field maple *(Acer campestre),* grey alder *(Alnus glutinosa), B. pubescens,* buddleia *(Buddleia davidii), C. avellana, S. caprea, S. cinerea* and *U. dioica*.

C. pyri was found to be the dominant (> 90 %) pear psyllid species present at two sites, *C. pyricola* was the dominant species at the other. Both species occurred at all three sites. When the species were last characterised in the 1980s, *C. pyricola* was universally the dominant species in the UK. *Cacopsylla melanoneura* (from hawthorn) was also present on pear in moderate numbers and *Cacopsylla brunneipennis* in small numbers.

The highest numbers of psyllids were found on *A. campestre*, *C. monogyna*, *F. excelsior*, *Pyrus communis*, *S. caprea*, *U. dioica and Viburnum opulus.* However, at the critical time early in the season, numbers were greatest on *C. monogyna*, *S. caprea* and *U. dioica. C. monogyna* is the main host of *C. melanoneura* and *C. peregrina* including nymphs. *S. caprea* and *S. cinerea* are the hosts of numerous psyllids species, but *C. ambigua* and *C.*

brunneipennis were found in higher numbers. *U. dioica* was host to the nettle psyllid (*T. urticae*) which was abundant throughout the year in the adult stage. The nymphs are very flat and strongly attached to the plant and are not collected efficiently by sweep sampling. *T. urticae* is a good food source for *A. nemoralis* and thus *U. dioica* is a good source of *A. nemoralis*. It also has abundant aphids when growth commences in spring and *A. nemorum* is abundant later in the season. Thus nettles appear to be an excellent source for anthocorids. The highest numbers of aphids were found on *A. campestre*, Norway maple (*Acer pseudoplatanus*), *B. pubescens*, *C. avellana*, blackthorn (*Prunus spinosa*), wild rose (*Rosa* sp.), white willow (*Salix alba*), *S. cinerea* and *U. dioica.* Plant species that support aphids will provide large numbers of *A. nemorum* later in the season. Aphids become more numerous later in the season (May onwards) with a population crash when moving to a secondary host in July. Numerous other Heteroptera were identified, including many predatory and some pest species. In some cases they compete with *A. nemoralis* for psyllid food sources. Note that *U. dioica* and *C. monogyna* supported considerable numbers of the common green capsid, *Lygocoris pabulinus,* a poten-

Table 1: Psyllids, Anthocoridae and the most abundant Miridae found on five different example old established hedgerow species in 2008; dominant psyllid species and competing Heteroptera species are given in bold; average seasonal total numbers of individuals and numbers of aphids collected per sample (10 beats) are given .

Plant species	Sites	Psyllids (dominant species are in bold)	Aphids	Anthocoridae (*Anthocoris*, *Orius* sp.)	Miridae (competitive predatory sp., in probable order of dominance, are in bold)†
Corylus avellana	1, 3	None	94.8	*A. nemorum* 22.0 *A. nemoralis* 0.3	***Phylus coryli*** 19.8 ***Orthotylus prasinus*** 11.5 ***Malacocoris chlorizans*** 7.0 ***Phytocoris longipennis*** 6.0 ***Psallus varians***. 4.8 ***Campyloneura virgula*** 3.5 *Lygocoris pabulinus* 1.8 ***Orthotylus marginalis*** 1.5 *Pinalitus cervinus* 1.5
Crataegus monogyna	1, 2	***C. melanoneura* 48.5** ***C. peregrina* 6.3**	38.0	*A. nemoralis* 7.5 *A. nemorum* 3.5 *A. confusus* 0.3 *Orius vicinus* 0.3	***Campyloneura virgula*** 7.8 ***Atractotomus mali*** 4.8 ***Heterotoma planicornis*** 2.8 ***Deraeocoris flavilinea* 2.0**
Salix caprea	1, 2, 3	***Cacopsylla ambigua* 5.2** ***C. brunneipennis* 5.0** *C. pulchra* 0 *C. moscovita* 0 *C. saliceti* 0 *Bactericera curvatinervis* 0 *B. salicivora* 0	40.0	*A. nemoralis* 9.2 *A. nemorum* 8.2 *A. confusus* 0.2 *Orius* vicinus 3.0 *O. laticollis* 0.5 *O. laevigatus* 0.2 *Orius* sp. nymph 0.8	***Orthotylus marginalis*** 22.3 ***Deraeocoris lutescens*** 1.8 ***Psallus haematodes*** 1.8 ***Malacocoris chlorizans*** 1.7
Urtica dioica	1, 2, 3	***Trioza urticae*** 113.2	104.4	*A. nemorum* 23.2 *A. nemoralis* 1.6 *Orius niger* 1.2 *O. laevigatus* 0.2 *O. vicinus* 0.2 *Orius* sp. nymph 2.2	*Liocoris tripustulatus* 44.8 ***Plagiognathus arbustorum*** 38.0 *Lygocoris pabulinus* 13.6 ***Orthotylus marginalis*** 13.0 *Closterotomus norwegicus* 7.2 ***Heterotoma planicornis*** 4.0 ***Dicyphus epilobii*** 2.0

† species that occurred in numbers on average over the season at less than 1.5 per sample

tial pest of pears which can be controlled readily with insecticides. *C. monogyna* is known to be a host for fireblight, a serious disease of pears.

Based on the results obtained and other known factors, *S. caprea*, *S. cinerea* and *U. dioica* were given the highest rating (5) as potential conservation biocontrol subjects for pear psyllids (Table 2). *C. monogyna* would have been in this category had it not also been a well known host of fireblight.

2009

Sampling was done at each site on eight occasions through the season, on 6 April, 22 April, 11 May, 29 May, 15 June, 1 July, 23 July and 1 September, respectively. A total of 71,138 arthropods were collected, the major part of which, except the aphids, have been identified to species. The findings with respect of each of the key taxa are summarised below:

The best early season host plants for anthocorids were *C. monogyna*, *S. caprea*, and *U. dioica* (Table 3). *C. avellana*, *S. caprea* and *U. dioica* were the best host plants later in the late season. Although *B. pubescens* was host to large numbers of aphids, these were large and aggressive, and possibly unpalatable and they did not appear to be suitable food sources for the anthocorids. *F. excelsior* was also disappointing. Though host to early season psyllids, numbers of anthocorids were relatively small. The sparse branching structure, vigorous growth and late leafing of this species make it less than ideal as a conservation biocontrol subject.

The seasonal dynamics of the key predators *A. nemoralis* and *A. nemorum* and their principal psyllid and aphid prey species on *S. caprea*, *U. dioica* and *C. avellana* are shown in Figures 1 to 3, respectively. Because of the wide variations in numbers data are plotted as Williams mean proportions.

On *S. caprea*, as expected from the 2008 observations, *A. nemoralis* and the two psyllid species (*C. ambigua* and *C. brunneipennis*) occurred earlier in the season (April to May) with *A. nemorum* and aphids building later in the middle of the season (June to July) with a decline in numbers late in the season with the decline in aphid numbers (Fig. 1). On *U. dioica*, a herbaceous perennial plant that re-grows from the ground each year, numbers of aphid and psyllid prey built up to

Table 2: Species surveyed in the three old established hedgerows in 2008 and their preliminary ratings (1 = poor, 5 = excellent) as subjects for conservation biocontrol of pear psyllids

	Sites	Rating
Acer campestre	1	3
Acer pseudoplatanus	1	3
Alnus glutinosa	3	2
Alnus incana	2, 3	1
Betula pubescens	3	3
Buddleia davidii	2	2
Castanea sativa	2	1
Corylus avellana	1, 3	4
Crataegus monogyna	1, 2	4‡
Fraxinus excelsior	1	4
Ilex aquifolium	1	2
Lonicera periclymenum	3	2
Malus domestica	2	3
Prunus avium	1	2
Prunus spinosa	1	3
Pyrus communis	1, 2, 3	4
Quercus robur	2	1
Rosa sp.	1, 3	3
Salix alba	3	3
Salix caprea	1, 2, 3	5†
Salix cinerea	1, 3	5†
Sambucus nigra	1, 2, 3	2*
Urtica dioica	1, 2, 3	5†
Viburnum opulus	3	2

* flowers as pollen/nectar sources not considered

‡ possible source of fireblight

† possible source of *Lygocoris pabulinus*

Table 3: Average seasonal total numbers of Anthocoridae collected per sample (10 beats) on the plant species in 2009

	Betula pubescens		*Corylus avellana*	*Crataegus monogyna*		*Fraxinus excelsior*	*Pyrus communis*				*Salix caprea*		*Urtica dioica*	
Site	1	2	1	1	3	1	1	2	3	4	1	4	1	1
A. confusus	0.6	0.0	0.2	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
A. nemoralis	0.2	0.6	0.8	1.6	11.4	0.2	1.6	1.6	1.6	12.2	1.6	18.0	3.0	9.8
A. nemorum	5.6	0.0	19.2	7.2	8.2	4.0	7.8	0.2	6.0	6.6	20.6	17.6	97.6	3.2
Orius sp.	0.2	0.6	0.2	0.2	0.8	0.2	0.2	0.6	0.2	0.0	0.0	4.8	1.0	33.4

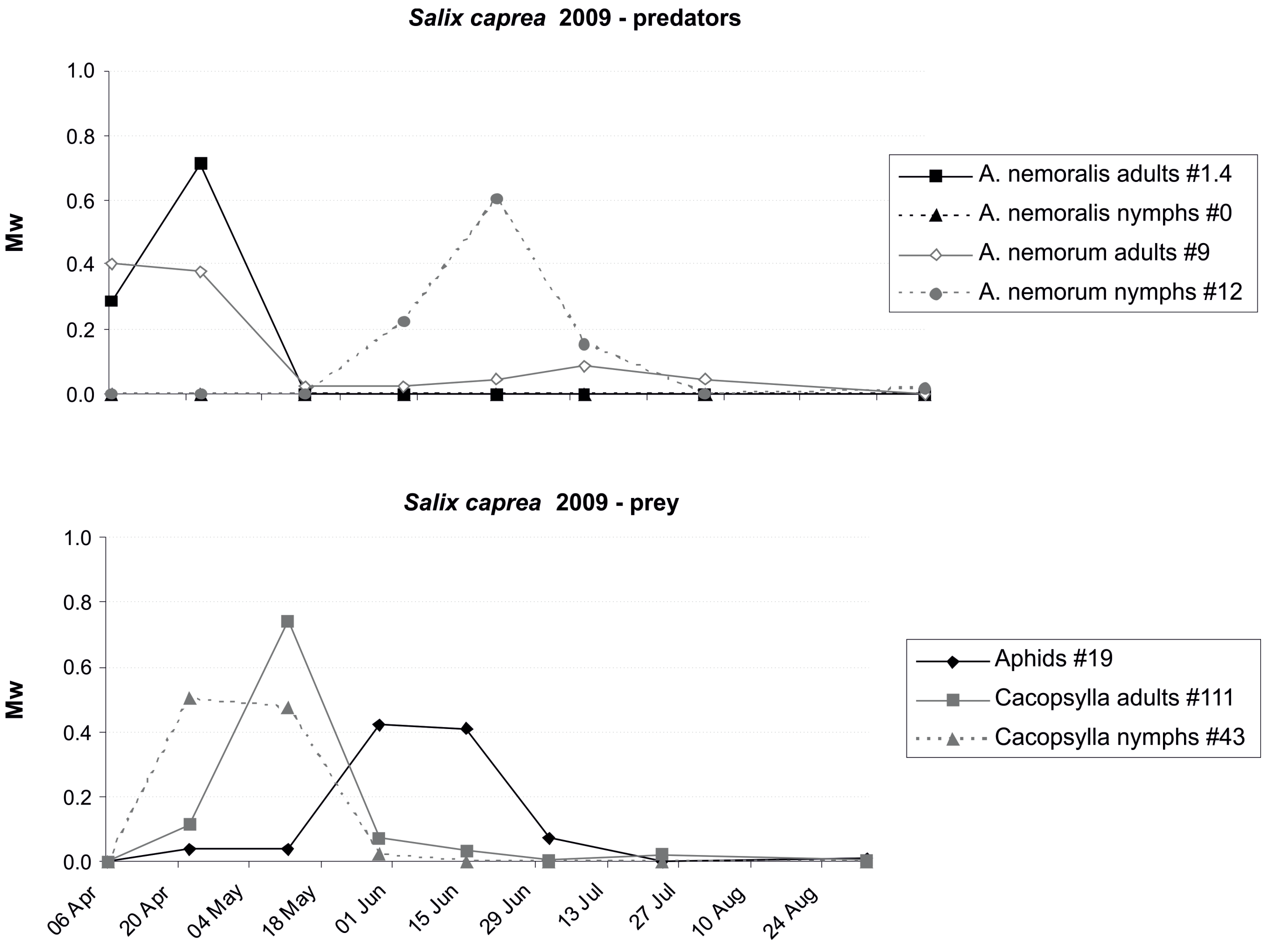

Fig. 1: Williams mean (Mw) proportions of anthocorid predators (upper graph) and psyllids (*Cacopsylla ambigua* + *C. brunneipennis*) and aphids (lower graph) through the growing season on *Salix caprea* at Stone Street in 2009. For Williams means (Mw) the mean catch per sampling data is calculated and reduced to the proportion of the total catch for the year (Boorman and Goddard, 1970). Total numbers are given following the # symbol in the figure legends.

very high numbers in May, June and July, with numbers declining to low levels subsequently (Fig. 2). The population dynamics of the anthocorids varied considerably between sites, but at Cooling (Fig. 2), large numbers of *A. nemorum* adults occurred in April followed by nymphs in May to June. *A. nemoralis* numbers were lower and increased later in the season.

No psyllids occurred on *C. avellana* but aphids were abundant in the middle of the season and these were good food sources for *A. nemorum* (Fig. 2).

Discussion

The main limitations of the preliminary screening in 2008 were that 1) the volume and quality of the canopies of the different plants sampled was very variable 2) the species were not uniformly represented at each site and there was limited replication 3) the range of woody plants sampled, though large, was far from exhaustive and there are several important species that were not represented 4) the canopies of the different plant subjects were intermingled to varying degrees so the samples taken were contaminated to some extent by arthropods that were not associated with the target species. The ratings of their suitability as subjects for conservation biocontrol of pear psyllids are thus preliminary. To some extent, we relied on the existing knowledge of the plants that are hosts of psyllids in the UK (Hodkinson and White, 1979). Comparatively few UK native woody tree species are host to psyllids

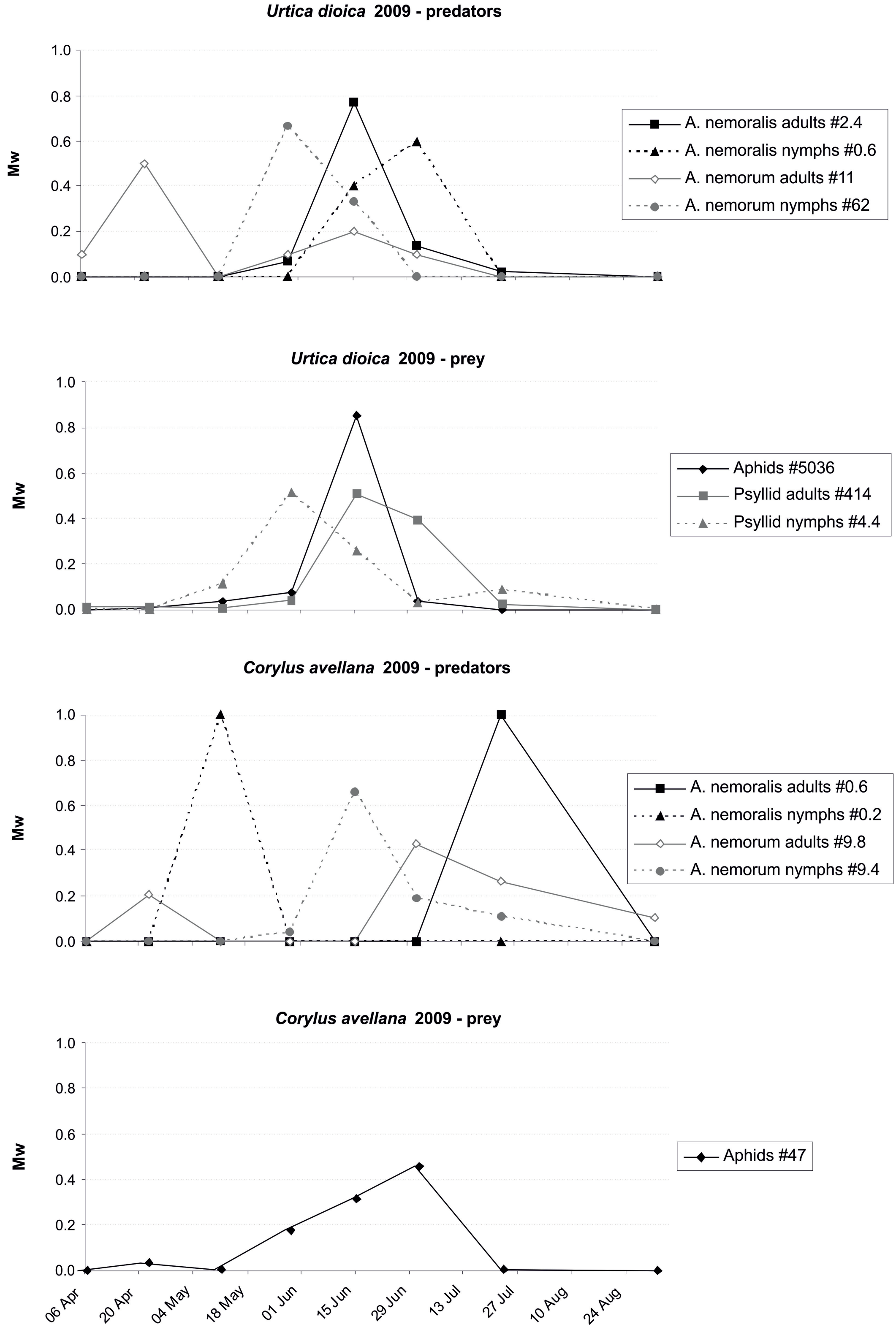

Fig. 2: Williams mean (Mw) proportions of anthocorid predators and psyllid and aphid prey through the growing season on *U. dioica* and *C. avellana* at Cooling in 2009

that are likely to provide alternate food sources for *A. nemoralis.* We did not investigate herbaceous plants (except *U. dioica*) or shrubs, though several are known hosts of psyllids, so there is much scope for further screening.

The 2009 work provided a wealth of data on the seasonal population dynamics of anthocorid predators, their psyllid and aphid prey and the heteroptera that are likely to compete with them. Examples of the data obtained are shown in Figures 1 to 3. There were considerable variations in the numbers and seasonal occurrence of the predators and prey between sites. The results were based on greater replication, larger plots, better spatial separation of plant species and a greater number of sampling dates. The conclusions reached are thus more reliable and robust. However, some potentially good subjects may have been ruled out on the basis of inadequate data in 2008. Further investigation of the role of flowers as sources of nectar and pollen and the importance of these to anthocorids is needed as well as further consideration of the candidate host plant as sources of pests and diseases. We believe that in early spring on *S. caprea* and *S. cinerea*, the large numbers of anthocorids that are found in flowers (catkins) are actually feeding on psyllid eggs and nymphs which are abundant in the flowers then, especially the female flowers (pussies), rather than on pollen or nectar. No leaves are present at this time.

A number of other generalist predators are likely play an important part in natural regulation of pear psyllid populations, especially spiders, the common European earwig (*Forficula auricularia*) and ladybirds (Santas, 1987; Erler, 2004). Hedgerows/windbreaks adjacent to pear orchards are likely to be important sources of these as well, especially species with a longer distance migratory ability. In reality, guilds of a wide range of predators are probably needed for stable, long term natural regulation of pear psyllid populations. Our database contains extensive data on these other predator groups, which requires further analysis.

In 2010, we started to study the migration of anthocorids from our selected hedgerow/windbreak subjects to adjacent pear orchards using protein-based Monoclonal Antibody (MAB) mark and capture methods developed by Hagler and Naranjo (2004) and Hagler (2006). In a first experiment, migration of anthocorids from cut-down versus uncut *U. dioica* into an adjacent pear orchard has been quantified. Further long term work is needed to study these migrations and how they can be enhanced, as well as practical ways to grow and manage hedgerows of mixed subjects so that they are rich sources of anthocorids and other predators of pear psyllids.

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