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The role of ecological compensation areas on predator populations: an analysis on biodiversity and phenology of Coccinellidae (Coleoptera) on non-crop plants within hedgerows in Northern Italy

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Abstract

The role of natural vegetation, including trees, shrubs and weeds in supporting predatory insects with particular reference to Coccinellids, was investigated in a two-year field studies. The samplings were carried out by mechanical knock-down (MKD) and visual inspections (VIS) in hedgerow of Northern Italy (Bologna province) between March and October. Among trees and shrubs, *Euonymus europaeus* L. (spindle-tree) and *Prunus spinosa* L. (blackthorn) showed the highest number of predatory species, followed by *Crataegus monogyna* Jacques (hawthorn), *Populus* sp. (poplar), *Cornus sanguinea* L. (dogwood) L. and *Corylus avellana* L. (hazel). *Salix alba* L. (willow) and *Pyrus pyraster* Burgsdorf (wild pear) were characterised by the lowest level of predator diversity. Coccinellidae represented the most abundant family of insect predators on trees and weeds. Eggs and/or larvae of Coccinellidae were found in all the tree and shrub species sampled with the exception of *Sambucus nigra* L. (elder). Data demonstrate that some trees and shrubs species can provide shelter for adult ladybirds, mainly in late summer, when many crops in Northern Italy are harvested.

A list of the Coccinellid species, including relative abundance on the most important plant species, is provided. The number of species sampled by MKD on hedgerows was higher than those sampled by VIS. Among the weeds, *Cirsium* sp., *Rumex* sp. and *Urtica dioica* L. (stinging nettle) supported the reproduction of Coccinellids. Only adults of Coccinellids were found on *Daucus carota* L., *Amaranthus retroflexus* L., *Dipsacus sylvestris* Hudson, *Arctium* sp., *Crepis* sp., *Picris* sp.. Correspondence analysis was used for the ordination of both plant and Coccinellid species and it was performed on the matrix of the data collected by VIS. The role of hedgerows and weeds in landscape management is discussed. Local biodiversity of beneficials in Bologna province can be conserved and improved by increasing "island" habitats like hedgerows and field margins.

Key words: Landscape management, hedgerows, weeds, insect predators, Coccinellidae, biodiversity.

Introduction

Conservation biological control involves environmental manipulation to enhance the fecundity and longevity of natural enemies, modify their behaviour and provide shelter from adverse environmental conditions (Wratten *et al*., 2003). These strategies include the maintenance of ecological compensation areas (ECA) and are crucial in enhancing functional biodiversity for pest suppression (Rossing *et al*., 2003). Moreover, with the emergence of the science of conservation biology, the problem and the study of diversity became one of the central interests of research in biological study, involving also public opinion (Samways, 1994).

Many authors pointed out the potential importance of vegetal diversity in agroecosystems to enhancing the populations of beneficial arthropods in crops and thus contribute to control arthropod pests (Pimentel, 1960; van Emden and Williams, 1974; Risch, 1987; Ferro, 1987). Some basic reviews collected published case studies about the effects of landscape management on beneficial population (Altieri and Letourneau, 1982; Sheenan, 1986; Russell, 1989; Van Emden, 1990; Delucchi, 1997; Altieri, 1999; Andow, 1991; Paoletti, 1999; Landis *et al*., 2000; Altieri, 2003). Recently, a study group on "Landscape Management for Functional Biodiversity" within IOBC/WPRS was founded with the aim to provide a platform for discussing research results, research agenda's and methodological aspects related to functional biodiversity at different spatial and temporal scales (Rossing *et al*., 2003).

In many countries the promotion of the enhancement of floristic diversity has become an aim of agricultural policy (Rossing *et al*., 2003). In Italy, hedgerow planting and natural vegetation management have been widely used in the last twenty years, especially in orchards, by agreement of local governments. The Emilia-Romagna Region, applying at local scale the European community agroenvironmental measures within the law n. 2078/92, funded to the farmers the implantation of hedgerows to implement the ecological net of rural landscape (Maini, 1995; Burgio *et al*., 2000; Morisi, 2001; Regione Emilia-Romagna, 2001). In Italy some data are available on the management of vegetal and animal biodiversity to improve control of arthropod pests (reviewed by Altieri *et al*., 2003). On the other side there is the need to expand the studies to other trophic systems and crops. In Italy there are very little examples on management of biodiversity at lanscape scale (Morisi, 2001; Sciarretta *et al*., 2003), while in other countries this approach is studied in a higher extent (Holland and Fahrig, 2000; Marino and Landis, 1996; Rossing *et al*., 2003).

For these reasons there is a growing interest to know and investigate ECA functional biodiversity in italian rural landscapes; a detailed knowledge of the tri-trophic relations “plants-herbivores-beneficials” is of basic importance for the ECA management in order to control arthropod pests and to select, for example, the plant species that are most likely to augment beneficial fauna. The rational management of ECA is important also in order to prevent the damage of arthoropod pests on crops (Altieri and Letourneau, 1982; Andow, 1991; Delucchi, 1997; Tavella *et al*., 1996; Ferrari e Boriani, 2000; Altieri *et al*., 2003).

The aims of the present research were: 1) to study the role of natural vegetation, including shrubs, trees and weeds on the cycle and phenology of beneficial predators; 2) to study the biodiversity of predators on different plant species; 3) to gain preliminary indications how to manage the ECA in order to enhancing beneficial organism populations.

The sampling techniques were selected in order to monitor predator populations, and particular attention was given to Coleoptera Coccinellidae for their importance in controlling aphid populations on many crops of Northern Italy (Ferrari *et al*., 1996; Molinari *et al*., 1998; Burgio *et al*., 1999).

Materials and Methods

Typical hedgerows were selected in five (1995) and four farms (1997) located in the Bologna province (Northern Italy). We selected ECA that were representative of rural landscape of our region, including in the sampling hedgerows with similar vegetation characteristics and structure to reduce the biological variability due to the age and plant composition of hedgerows. In all the farms Integrated Pest Management was applied. A list of the sites sampled, including the main characteristics of the farms is presented in table 1. The plants to sample in each site were selected in order to choose the more representative in the rural landscape, taking into account the preliminary data collected by Nicoli *et al*. (1995), Boriani *et al*. (1998), Burgio *et al*. (2000), Celli *et al*. (2001).

In each ECA within the sites, the most abundant trees, shrubs weeds were sampled. Tree and shrub canopies were sampled by mechanical knockdown (MKD) every 14 days and by visual inspection (VIS) every 7 days. In MKD the branches were beat by a stick: the insects falling into a 90 cm diameter funnel were collected and examined in the laboratory. Each plant species was beat

Table 1. Description of the sites investigated.

Farm	Year	Locality	Crops	Most abundant plants inside ecological compensation areas
Guazzaloca	1995	Crevalcore (BO)	Arable crops	*Prunus spinosa*, *Populus* spp., *Fraxinus* spp., *Morus nigra*, *Ulmus* spp., *Acer campestre*
Azzoguidi	1995	Sala Bolognese (BO)	Orchard	*Prunus spinosa*, *Ulmus minor*, *Quercus* spp., *Sambucus nigra*, *Robinia pseudoacacia*, *Euonymus europaeus, Cornus sanguinea*, *Fraxinus* spp., *Crataegus monogyna*, *Urtica dioica*
Maieutica-Bora	1995	S. Giovanni in Persiceto (BO)	Orchard	*Crataegus monogyna*, *Prunus spinosa*, *Ulmus* spp., *Acer campestris*, *Sambucus nigra*, *Rosa canina*, *Cornus sanguinea*, *Populus* spp., *Urtica dioica*, *Cirsium* spp., *Rumex* spp.
Gubellini	1995	Bologna	Orchard	*Salix alba*, *Sambucus nigra*, *Robinia pseudoacacia*, *Urtica dioica*, *Cirsium* spp., *Rumex* spp.
Cà il Rio (site 1)	1995	Castel S. Pietro (BO)	Arable crops	*Morus nigra*, *Ulmus* spp., *Prunus spinosa*, *Robinia pseudoacacia*, *Populus* spp., *Urtica dioica*, *Cirsium* spp., *Rumex* spp.
Cà il Rio (site 2)	1997	Castel S. Pietro (BO)	Arable crops	*Euonymus europaeus, Corylus avellana*, *Crataegus monogyna*, *Cornus sanguinea*, *Urtica dioica*, *Cirsium* spp., *Rumex* spp.
Cà il Rio (site 3)	1997	Castel S. Pietro (BO)	Arable crops	*Populus* spp., *Euonymus europaeus, Crataegus monogyna*, *Cornus sanguinea*, *Pyrus pyraster*, *Corylus avellana, Urtica dioica*, *Cirsium* spp., *Rumex* spp., *Dipsacus sylvestris*
Forni	1997	S. Giovanni. in Persiceto (BO)	Arable crops	*Euonymus europaeus*, *Crataegus monogyna*, *Prunus spinosa*, *Cornus sanguinea, Urtica dioica*, *Cirsium* spp., *Rumex* spp., *Dipsacus sylvestris, Picris* spp., *Crepis* spp.
Morisi	1997	S. Giovanni in Persiceto (BO)	Arable crops, orchard	*Crataegus monogyna*, *Prunus spinosa*, *Cornus sanguinea, Corylus avellana, Cirsium* spp., *Rumex* spp., *Dipsacus sylvestris, Picris* spp., *Crepis* spp.
Breveglieri	1997	Calderara di Reno (BO)	Arable crops	*Populus* spp., *Corylus avellana*, *Cirsium* spp., *Rumex* spp., *Picris* spp., *Crepis* spp.

100 times, sampling five branches per tree or shrub. Plants and branches were randomly selected for each sampling date. Trees and shrubs were monitored by VIS through random selection of 100 branches per plant species in each hedgerow. Branches were classified into four classes of aphid density (0, 1-10, 11-100, >100), the more abundant pests on hedgerows in Northern Italy (Ferrari *et al*. 1999), and all stages of predators were counted.

Weed species were randomly sampled by VIS, counting the insect predators and estimating the aphid infestation on a variable number of plants (20-100). Number of stems was decided according to the density of the plant species and to the abundance of insects, evaluated by preliminary samplings.

Data analysis

In 1995 insect predators were identified to family, in 1997 were identified to species or genus. The phenology of predators was analysed by data collected with VIS. Relative abundance of the families of predators on each plant species was calculated for 1995 and 1997 data. Biodiversity of predators for each plant species was calculated by Shannon's index (H') by data collected by MKD in 1997. As dominance measure, Berger-Parker's index *d* was calculated (Magurran, 1988). As with other dominance measures, the reciprocal form of *d* was adopted so that an increase in the value of the index is correlated with an increase in diversity and a reduction in dominance.

The jack-knifing technique was calculated to the samples taken for each plant species in the different sites (Magurran, 1988), in order to improve the estimate of H' and *d*.

Correspondence analysis was used to ordinate the plant species on the basis of the abundance of Coccinellid species recorded by visual inspection, on a matrix ***p*** x ***n***, where ***p*** are Coccinellid species and ***n*** are plant species. In our case this method was calculated on a ***10*** x ***36*** matrix. This ordination method can be used on data that can be presented as a two-way table of measures of abundance, with the rows corresponding to one type of classification (*Coccinellid species*) and the columns to a second type of classification (*plant species*) (Manly, 1994). The aim of this multivariate method was to associate plant species to relative abundance of Coccinellids, in other words to give an ordination of both plant and Coccinellid species at the same time.

Results and discussion

Tables 2 and 3 summarise the relative abundance (%) of the families of predators on trees and shrubs sampled by MKD in hedgerows in 1995 and 1997. Coccinellidae

Table 2. Relative abundance (%) of predators on trees and shrubs sampled by mechanical knock down (MKD) in hedgerows (1995) from beginning of April to end of September. Data pooled for all sampled sites.

	Salix alba	*Crataegus monogyna*	*Prunus spinosa*	*Populus* spp.	*Ulmus minor*	*Sambucus nigra*
Coccinellidae	35.1	13.4	26.7	59.5	22.4	43.5
Hemerobiidae	1.5	3.6	0.8	0.8	2.8	1.4
Chrysopidae	15.5	12.5	18.8	13.6	18.4	20.3
Syrphidae	1.1	0.9	3.3	0.0	0.9	2.9
Anthocoridae	10.8	0.4	8.5	6.6	2.8	5.8
Nabidae	1.5	24.2	8.4	2.3	3.4	4.3
Miridae	34.5	5.4	10.8	1.7	24.5	18.8
Carabidae	0.0	7.2	4.3	4.1	5.9	1.4
Cantharidae	0.0	0.0	8.8	4.2	5.8	1.4
Forficulidae	0.0	23.7	7.5	6.8	12.8	0.0
Staphylinidae	0.0	8.5	2.0	0.4	0.3	0.0

Table 3. Relative abundance (%) of predators on trees and shrubs sampled by mechanical knock down (MKD) in hedgerows (1997) from beginning of April to end of September. Data pooled for all sampled sites.

	Salix alba	*Corylus avellana*	*Crataegus monogyna*	*Prunus spinosa*	*Cornus sanguinea*	*Euonymus europaeus*	*Populus* spp.	*Pyrus* sp.
Coccinellidae	66.41	71.67	65.20	67.14	72.48	67.29	52.37	48.94
Hemerobiidae	0.76	0.40	0.00	0.35	0.63	0.00	0.00	0.00
Chrysopidae	0.76	1.20	2.10	4.59	2.73	1.25	2.21	1.42
Syrphidae	0.00	0.32	0.38	2.12	0.00	1.04	0.32	0.00
Anthocoridae	1.52	1.44	9.75	1.40	4.41	1.67	1.58	7.09
Nabidae	1.52	4.41	3.82	0.35	7.35	3.54	0.63	0.00
Miridae	3.05	1.85	2.10	2.12	1.26	1.25	1.90	1.42
Carabidae	3.05	0.16	0.00	0.71	0.42	0.83	0.32	0.00
Cantharidae	19.80	3.85	2.10	1.06	1.05	7.71	36.91	33.33
Forficulidae	6.87	13.32	14.53	19.43	8.61	14.58	3.15	7.80
Staphylinidae	0.00	1.36	0.00	0.71	1.05	0.62	0.63	0.00

was the dominant group and in 1997 this family showed, for example, a relative abundance of 67 and 71%, on *Prunus spinosa* L. (blackthorn) and *Cornus sanguinea* L. (dogwood), respectively. In 1995, relative abundance of Miridae and Chrysopidae was 34 and 20%, respectively, on *Salix alba* L. (willow) and *Sambucus nigra* L. (elder). Cantharidae and Forficulidae were more abundant in 1997, with a relative abundance of 37% and 20% on *Populus* spp. (poplar) and blackthorn, respectively.

A comparison of the biodiversity of predators collected by MKD among the different trees and shrubs species in 1997 is shown in table 4. Shannon's index and the dominance measures were calculated by means of the jack-knife technique in order to improve the estimation of replicated samples, with the exception of pear (sampled on one site). Predator diversity for trees and shrubs is summarised by index measures in table 4. *Euonymus europaeus* L. (spindle-tree) and *P. spinosa* were richest in predator diversity, followed by *Crataegus monogyna* Jacq. (hawthorn), *Populus* sp., *C. sanguinea* and *Corylus avellana* L. (hazel). *S. alba* and *Pyrus pyraster* Burgsdorf (wild pear) showed the lowest level of biological diversity.

Coccinellidae was the most abundant family; a list of the species sampled by MKD and VIS is shown in tables 5 and 6, respectively. The number of species sampled by MKD was higher than those sampled by VIS. For some plant species (i.e. *E. europaeus* and *C. sanguinea*) the difference was very pronounced. VIS demonstrated to be particularly useful to study the phenology and the cycle of beneficials but in our research this sampling technique showed a lower precision in comparison to MKD for the evaluation of species diversity.

Table 4. Shannon's index (H') and Berger-Parker's index (*d*) of predators sampled on hedgerow (1997) by mechanical knock down (MKD). Data pooled for each farm. H' and *d* were calculated by Jack-knifing technique on samples of different farms (Magurran, 1988) except for pear.

	All predators			Coccinellidae		
	No species	H' (±se)	*d* (±se)	No species	H' (±se)	*d* (±se)
Prunus spinosa	25	2.94 (±0.20)	5.99 (±0.88)	12	2.02 (±0.06)	4.03 (±0.44)
Crataegus monogyna	20	2.64 (±0.20)	5.20 (±1.00)	10	1.54 (±0.24)	3.22 (±0.46)
Populus spp.	17	2.62 (±0.38)	3.58 (±1.30)	9	1.88 (±0.38)	3.63 (± 0.06)
Euonymus europaeus	22	3.02 (±0.33)	8.46 (±2.20)	11	1.96 (±0.19)	4.55 (±0.17)
Cornus sanguinea	23	2.67 (±0.16)	4.53 (±0.75)	12	1.90 (±0.08)	3.09 (± 0.48)
Salix alba	12	2.14 (±0.57)	1.56 (±1.21)	6	1.46 (±0.28)	1.24 (±0.43)
Corylus avellana	22	2.82 (±0.44)	3.44 (±1.21)	10	1.52 (±0.27)	2.31 (±0.58)
Pyrus sp.	15	2.06	3.03	9	1.70	2.56

Table 5. Comparison of Coccinellidae species sampled with mechanical knock down (MKD) and visual inspection (VIS), on trees and shrubs of hedgerows sampled in 1997.

	Prunus spinosa		*Populus alba*		*Crataegus monogyna*		*Corylus avellana*		*Euonymus europaeus*		*Cornus sanguinea*	
	MKD	VIS	MKD	VIS	MKD	VIS	MKD	VIS	*MKD*	VIS	MKD	VIS
Coccinella 7-punctata	●	●	●	●	●	●	●	●	●	●	●	●
Hippodamia variegata	●	●	●	●	●	●	●	●	●	●	●	●
Propylaea 14-punctata	●	●	●	●	●		●	●	●	●	●	●
Adalia 2-punctata	●	●	●	●	●	●	●	●	●	●	●	●
Synharmonia conglobata	●	●	●	●	●	●	●	●	●		●	●
Stethorus punctillum	●	●	●	●	●		●	●	●		●	●
Scymnus apetzi	●		●				●		●		●	
Scymnus rubromaculatus	●	●	●		●		●	●	●		●	●
Scymnus frontalis					●		●		●		●	
Scymnus interruptus											●	
Pullus (*Scymnus*) *auritus*	●			●	●		●		●		●	
Scymnus subvillosus	●	●	●	●	●	●			●		●	
Coccidula rufa	●				●							
Lindorus lophantae							●	●	●		●	
Thea (*Psyllobora*) *22-punctata*							●	●	●		●	●
Chilocorus 2-pustulatus	●					●						
Total of species sampled	12	8	9	8	11	6	12	9	13	4	14	8

Table 6. Relative abundances (%) of Coccinellids sampled by visual inspections (VIS) on weeds.
Weeds: DC = *Daucus carota*; RU = *Rumex* sp.; CI = *Cirsium* sp.; AR = *Arctium* sp.; AM = *Amaranthus retroflexus*; DI = *Dipsacus sylvestris*; CO = *Conyza canadensis*; CR = *Crepis* sp.; PI = *Picris* sp.; UD = *Urtica dioica*.

Coccinellid species	Weeds									
	DC	RU	CI	AR	AM	DI	CO	CR	PI	UD
Coccinella 7-punctata	0.2	20.7	52.5	0	0	0	0	0	0	8.8
Hippodamia variegata	99.8	61.3	25	81.2	100	100	100	100	100	62.4
Propylaea 14-punctata	0	10.9	10	12.5	0	0	0	0	0	8.0
Adalia 2-punctata	0	0	0	0	0	0	0	0	0	4.8
Synharmonia conglobata	0	0	0	0	0	0	0	0	0	0.4
Scymnus sp.	0	3.7	2.5	0	0	0	0	0	0	0
Scymnus apetzi	0	1.1	0	0	0	0	0	0	0	1.5
Pullus (Scymnus) auritus	0	0	0	0	0	0	0	0	0	4.2
Scymnus interruptus	0	0	0	0	0	0	0	0	0	2.16
Scymnus rubromaculatus	0	0.7	0	0	0	0	0	0	0	7.2
Scymnus subvillosus	0	0	0	0	0	0	0	0	0	0.5
Scymnus frontalis	0	0.4	0	0	0	0	0	0	0	0
Chilocorus 2-pustulatus	0	0.4	0	0	0	0	0	0	0	0
Lindorus lophantae	0	0	0	6.25	0	0	0	0	0	0
Platynaspis luteorubra	0	0.7	0	0	0	0	0	0	0	0
Thea (*Psyllobora*) *22-punctata*	0	0	10	0	0	0	0	0	0	0

Table 7 provides the stages of predators found in the sampled plants, including weeds. Eggs and/or larvae of Coccinellidae were found in all the trees and shrub species, with the exception of *S. nigra*, thus demonstrating that hedgerows can supply multiplication sites for ladybirds. An example of the role of trees and shrubs in supplying prey food for Coccinellids is shown in figures 1 and 2; *P. spinosa* demonstrated in some cases to supply multiplication sites also for hoverflies (figure 3).

VIS demonstrated also that trees and shrubs could supply a shelter for adult ladybirds mainly in late summer, a period in which many crops in our region are harvested. Evidence of this refuge role is shown by the presence of adult stages of Coccinellids without the presence of aphids (figures 4 and 5). The aphid species infesting trees and shrubs in Northern Italy were described by Nicoli *et al*. 1995 and Boriani *et al*. 1998.

A total of seventeen ladybird species were collected on shrubs and trees of hedgerows (table 5). Aphidophagous species were the predominant group and the commonest species on trees and shrubs was *Adalia bipunctata* (L.), followed by other species belonging to the

Table 7. Summary of the presence of most abundant predators on trees, shrubs and weeds sampled by visual inspection (VIS) in 1995 and 1997.
E = eggs; L = larvae; P = pupae or nymphs; A = adults

Plant Species	Coccinellidae			Syrphidae		Chrysopidae			Miridae		Nabidae		Anthocoridae	
	E	L-P	A	E	L-P	E	L-P	A	L-P	A	L-P	A	L-P	A
Prunus spinosa	+	+	+	+	+	+	+	+						
Populus spp.	+	+	+	+	+	+	+	+						
Crataegus monogyna	+	+	+	+	+	+	+	+					+	
Corylus avellana	+	+	+		+	+	+	+						
Salix alba	+	+	+	+	+	+	+	+					+	
Cornus sanguinea		+	+			+	+	+						
Euonymus europaeus		+	+	+	+	+	+	+						
Ulmus minor	+		+	+		+	+	+						
Sambucus nigra			+	+	+	+	+	+						
Cirsium arvense		+	+			+	+	+				+		+
Rumex spp.		+	+			+		+				+		
Urtica dioica	+	+	+			+	+	+	+	+		+	+	+
Daucus carota			+			+		+						
Dipsacus sylvestris		+	+		+									
Amaranthus retroflexus			+											
Conyza canadensis			+									+		+
Arctium spp.			+									+		
Crepis spp.		+	+	+										
Picris spp.			+											+

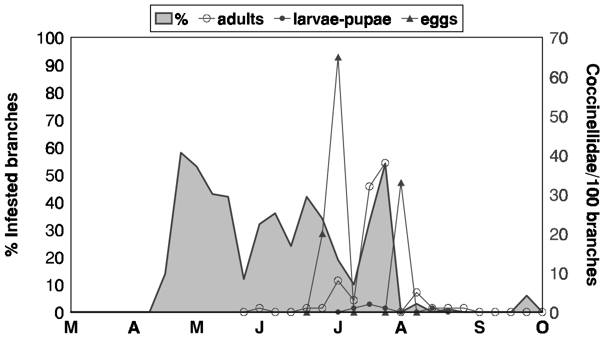

Figure 1. Trends of Coccinellid populations and branches infested by aphids on *Populus* sp.

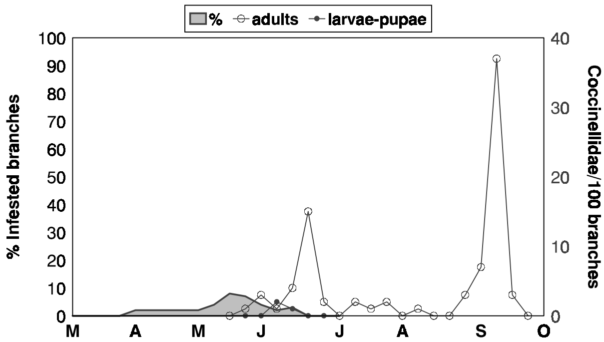

Figure 4. Trends of Coccinellid populations and branches infested by aphids on *Euonymus europaeus.*

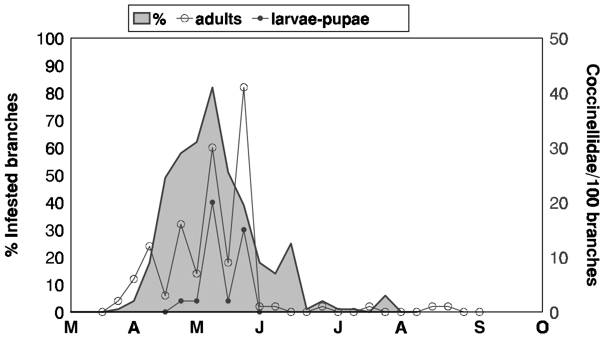

Figure 2. Trends of Coccinellid populations and branches infested by aphids on *Prunus spinosa*.

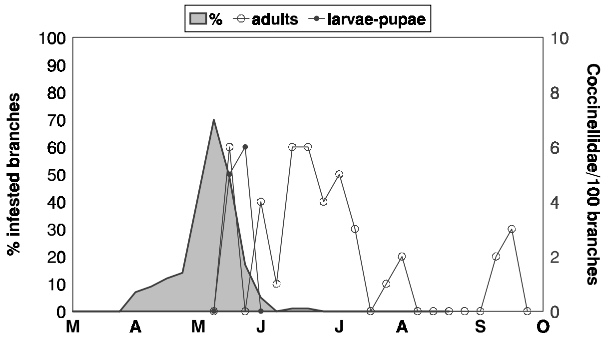

Figure 5. Trends of Coccinellid populations and branches infested by aphids on *Cornus sanguinea*.

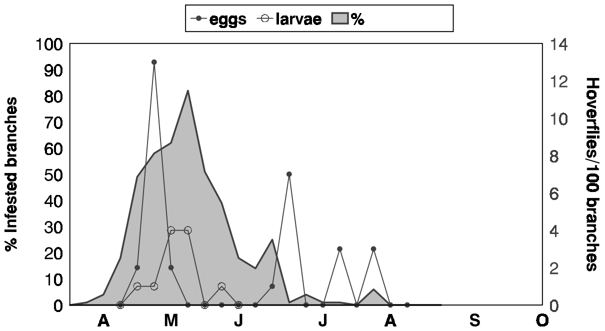

Figure 3. Trends of Syrphidae eggs and larvae, and branches infested by aphids on *Prunus spinosa*.

tribe of Coccinellini, as *Hippodamia variegata* (Goeze), *Propylaea quatuordecimpunctata* (L.), *Coccinella septempunctata* (L.), and seven species belonging to the tribe of Scymini. *Oenopia* (= *Synharmonia*) *conglobata* (L.) was less abundant in comparison to the previous species. *Coccidula rufa* (Herbst) (tribe of Coccidulini), a species that feeds mainly on aphids (Majerus, 1994), was rare and was sampled by means of MKD only on *P. spinosa* and *C. monogyna* in one site. Other species sampled were *Chilocorus bipustulatus* (L.), *Exochomus quadripustulatus* (L.) (Chilocorini), *Stethorus punctillum* (Weise) (Stethorini), *Lindorus* (= *Rhizobius*) *lophantae* (Blaisdell) (Coccidulini) and *Thea* (= *Psyllobora*) *vigintiduopunctata* (L.) (Psylloborini), a mildew-feeding species (Majerus, 1994).

Demetrias atricapillus (L.), a species common on trees, was the only carabid species collected. *Paederus* sp. was the only genus we found within the family of Staphylinidae. The species belonging to the family of Miridae were *Deraeocoris ruber* (L.)*, Heterotoma meriopterum* Scopoli, *Pilophorus cinnamopterus* Kirschbaum. The only genera of Anthocoridae sampled were *Anthocoris* Fallén and *Orius* Wolff.

Coccinellids were the dominant predators sampled also on weeds; a list of ladybird species, including the relative abundances, is shown in table 6. Among the weeds, *Cirsium* sp. (creeping thistle), *Rumex* sp. (dock) and *Urtica dioica* L. (stinging nettle) supported the multiplication of ladybirds (table 7). Only adults of Coccinellids were found on *Daucus carota* L., *Amaranthus retroflexus* L., *Dipsacus sylvestris* Hudson, *Arctium* sp.*, Crepis* sp.*, Picris* sp.. On *D. carota* adult density of *H. variegata* reached a peak between August and September, a period in which many crops of our region are harvested. Our data demonstrated that adults of ladybirds sheltered inside the flowers of *D. carota*; moreover *H. variegata* adults were observed feeding on pollen of *D. carota*, a secondary food for many aphidophagous species, as pointed out by Majerus (1994) and Triltsch (1999).

Table 7 shows that a group of ten plant species, including trees, shrubs and weeds, provided multiplication sites also for Syrphidae, while thirteen plant species supported multiplication of Neuroptera Chrysopidae.

In figure 6 is shown the plot of plant and Coccinellid species against the first two axes found by applying correspondence analysis to the data from the 10 x 36 matrix (see material and methods). The matrix was created by all the data collected by VIS. Ordination by correspondence analysis involves using the plant and Coccinellid values for the first few largest eigenvalues that are less than 1, because these are the solutions for which the correlations between rows and columns are strongest (Manly, 1994). Correspondence analysis gives an ordination of both plant and Coccinellid species at the same time. The arch or "horseshoe" that appears in the ordination is a common feature in the results of correspondence analysis (Manly, 1994). Coccinellid species that are typical of trees and shrubs [*A. bipunctata, S. conglobata*, *Scymnus rubromaculatus* (Goeze), *C. bipustulatus*] are clustered in the same group; all these species were absent on weeds. Also *Pullus auritus* Thunberg, *L. lophantae, T. vigintiduopunctata* and *S., punctillum* were sampled only on trees and shrubs but they were less abundant and their presence was not regular. *H. variegata*, *C. septempunctata*, *P. quatuordecimpunctata* were found both on trees and weeds, with a different pattern: *H. variegata* was the dominant species on weeds and the only Coccinellid species found on *D. carota*, *A. retroflexus*, *D. sylvestris*, *Conyza canadensis* (L.) Cronquist*, Crepis* sp., *Picris* sp.. This Coccinellid species colonised also trees and shrubs. In general *H. variegata* was the most abundant Coccinellid sampled in our study. *Platynaspis luteorubra* Goeze was rare and it was recorded only on *Rumex, Pullus subvillosus* (Goeze) only on *Salix* (see figure 6 for the correspondence between plant and Coccinellids). *C. septempunctata* was present on *Cirsium* and *Rumex* but it was absent on the other weeds; this species was recorded also on trees and shrubs by VIS with high variability. *P. luteorubra* was recorded on *Rumex* and *L. lophantae* only on hazel. In general Coccinellids showed some variability in the relative abundance among the plant sampled in the different sites, probably reflecting local differences due to the microclimate, prey composition and physical environment.

In our study relative abundance of *A. bipunctata* on *U. dioica* was very low (4.8%). This Coccinellid species was found on nine weed species sampled and was the dominant species on trees and shrubs, confirming data of Nedved (1999).

The importance of Coccinellidae in conservation biological control is pointed out by Hodek and Honek (1996) and Iperti (1999). Hodek *et al*. (1966) described the Coccinellid species on *Euonymus*, taking into account the importance to increase the population level of the natural enemies by rational management of weeds, trees and shrubs; in this study, *C. septempunctata* and *A. bipunctata* were the most abundant Coccinellid species and *Adalia decempunctata* (L.) and *P. quatuordecimpunctata* were rare. Stechmannn (in Hodek and Honek, 1996) studied the Coccinellid fauna of some shrubs and trees (*Crataegus* sp., *Rosa* sp. and *Prunus* sp.) in Germany. Three species*, Calvia quatuordecimpunctata* (L.), *A. bipunctata* and *Adalia decempunctata* (L.) were present as both larvae and adults, whereas only the adult of *Anatis ocellata* (L.), *C. septempunctata* and *P. quatordecimpunctata* were found. Bode (in Hodek and Honek, 1996) studied Coccinellid communities on *Prunus padus* L. in spring; *A. bipunctata*, *C. septempunctata* and *P. quatuordecimpunctata* were dominant, but only the former species produced larvae on *P. padus*. Honek (1985) studied the habitat preferences of aphidophagous Coccinellids in Central Bohemia and Southwest Slovakia, reporting the mean abundance of seven species of different host plants, including trees and shrubs typical of hedgerows. Honek's study revealed

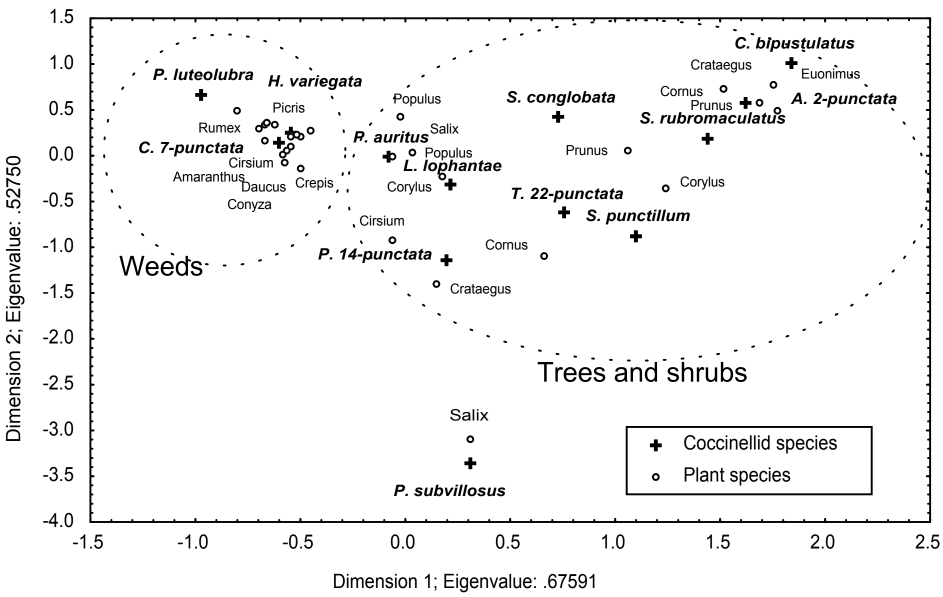

Figure 6. Ordination of the plant species on the basis of the abundance of Coccinellid species recorded by visual inspection, by correspondence analysis; data analysed by a matrix ***p*** x ***n***, where ***p*** are Coccinellid species and ***n*** are plant species (***10*** x ***36*** matrix).

that the habitat diversification shown by adults of these species may be explained in terms of different preferences for three environmental factors: aphid abundance, insolation and type of plant cover. The species composition and abundance of adult Coccinellidae and Chrysopidae were investigated by Honek (1981) on some weed/aphid systems. Trophic and microclimatic requirements of adults and geographic and temporal distribution of populations were considered important factors affecting the composition of aphidophagous species complex. Nedved (1999) recorded twenty-one predatory species of ladybirds collected from a range of habitats in Central Bohemia and provided a list of aphid/plant host complex on which the development stages were found. Leather *et al*. (1999) presented data on the distribution and abundance of ladybirds in non–crop habitats. Coccinellid abundance appeared to be most strongly correlated with the percentage ground cover of *Cirsium* sp., grasses and *U. dioica*. Leather *et al*. (1999) found frequently larvae and pupae of *C. septempunctata* and *A. bipunctata* on *Rubus* and *U. dioica*, and Honek (1981) found a high relative abundance of *A. bipunctata* on *U. dioica*.

Other studies have pointed out that ladybird population size is correlated with plant density, landscape and time of the year (Evans and Youssef, 1992).

Paoletti and Lorenzoni (1989) identified three impacts of hedgerows on invertebrate dynamics: 1) during spring and autumn the hedgerows can support some specialized predators of *Tetranychus urticae* Koch, such as *Oligota flavicornis* Boisduval and Lacordaire, and *Stethorus punctillum* Weise which in summer depressed spider mites moving into corn fields or soybean fields; 2) polyphagous predators like spiders, carabids, staphylinids, syrphids and ants are also affected by the vicinity of hedgerows; 3) migration of a few predators such as *Orius majusculus* Reut. in the fields is more effective in the vicinity of hedgerows and some predators such as Phytoseidae mites are at times more abundant near hedgerows. Inter-relationships between pear and hedgerow tree species were studied by Rieux *et al*. (1999). Ash tree (*Fraxinus angustifolia* Vahl.) and ivy (*Hedera helix* L.) displayed a diversified fauna that was correlated with the pear tree community. Their influence on pear tree fauna was different. Ash trees host specific psyllids and gall midges, providing food for beneficial pear arthropods. Ivy acts as a shelter species for beneficial pear arthropods. The spider community of hedgerows located in Northern Italy is reported by Groppali *et al*. (1995) and biological and phenological data about some species are given. Pantaleoni (1982) and Pantaleoni and Sproccati (1988) studied the composition of Neuroptera fauna related to herbs, shrubs and conifers in Northern Italy.

Several authors have stressed that reintroducing a mosaic structure into the agricultural landscape composed of woodlots, hedgerows and wetlands can lead to the creation of multiple habitats for reproduction, feeding and sheltering of a number of beneficial arthropod species (Paoletti and Lorenzoni, 1989; van Emden, 1990; Andow, 1991; Delucchi, 1997; Altieri, 1999). Studies on habitat manipulation within agricultural landscapes, such as "island" habitats in cereal crops, have concentrated on polyphagous predators like the carabid beetle, spiders (Thomas *et al*., 1992; Kromp and Steinberger, 1992; Lys and Nentwig, 1994) and hoverflies (Lövei *et al*., 1993; Hickman and Wratten, 1996; Frank, 1999). Leather *et al*. (1999) suggested that only a slight modification of the various proposed island habitats would be required to elevate Coccinellid levels in crop ecosystems, and that habitat preferences of Coccinellids, which are more abundant on grasslands and margins, may be related to the fact that these habitats are more exposed to the sun than wooded habitats.

Vegetal biodiversity in ecological conservation areas of farm can be considerable. In Northern Italy (Mongardi, 1999) 255 plant species belonging to 53 different families were recorded in a non-crop areas of about 9 hectares in a farm in rural landscape. These data show that a rational management of natural vegetation area within farm can allow the conservation of a large amount of plant diversity, comparable to that of semi-natural landscapes.

In conclusion our data demonstrated that *P. spinosa*, *Populus* spp., *C. monogyna*, *C. avellana*, *S. alba*, *C. sanguinea*, *E. europaeus*, *Ulmus minor* Miller (elm), among the trees and shrubs, and *C. arvense*, *Rumex* spp., *U. dioica*, *D. sylvestris*, *Crepis* spp. (among the weeds) supported reproduction of ladybird populations. Furthermore, some trees, shrubs (i.e. *P. spinosa, C. monogyna* and *E. europaeus*) and weeds species (*D. sylvestris*, *D. carota*, *C. canadensis*, *A. retroflexus*, *Crepis* spp., *Picris* spp.) can supply a shelter site for adult ladybirds when aphids and/or crops are not present. Some weeds, like *D. carota*, supplied a feeding-site for *H. variegata*, providing pollen and refuges to Coccinellids in late summer, a period in which many crops are harvested in Northern Italy. The knowledge of the cycle and phenology of Coccinellids is crucial to manage ECA, in particular to preserve Coccinellid populations during cultural practices like grass cutting in agroecosystems. Considering the importance of Coccinellids in aphid control in Northern Italy, low impact cutting techniques like strip harvesting of crops and natural vegetation should to be considered (Iperti, 1999).

The role of the plants on the beneficial populations can be also helpful to select trees and shrub species within hedgerows, or to choose the key-weeds, in order to restore degraded agroecosystems.

Further studies are needed to implement knowledge of crop/non-crop habitats relationship (i.e. to study the mutual influences between vegetal association and crops), the role of hedgerows as overwintering site of beneficials, and the rational management of weeds and vegetal associations to make possible a reductions of pesticides.

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