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The role of ecological infrastructures on Coccinellidae (Coleoptera) and other predators in weedy field margins within northern Italy agroecosystems

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Abstract

The insect predator complex in weedy margins adjacent to crops was studied in order to understand the ecological role of non-crop habitats on polyphagous predators in a northern Italian rural landscape. Weedy field margins at ten sites, in Bologna province, of different age and maturity which were adjacent to hedgerows, were sampled with a sweep net. Coleoptera (Coccinellidae) and Rhynchota (Nabidae) were the most abundant groups sampled in these weedy margins. *Hippodamia variegata* (Goeze) was the most abundant coccinellid species, followed by *Coccinella septempunctata* L. and *Propylea quatuordecimpunctata* (L.). Among the tribe of Scymnini, *Scymnus rubromaculatus* (Goeze) and *S. apetzi* Mulsant were the most abundant species. A consistent population of *Anthocoris* sp. was recorded at one site only, and these Anthocorids probably originated from the adjacent pear orchard. The age and maturity of the hedgerows appear to influence the abundance and distribution of predator families in the adjacent weedy margins. Nabidae were the most abundant insects within margins adjacent to old hedgerows. These old hedgerows showed generally a more uniform distribution of relative predator abundance than younger hedgerows. The margins adjacent to young hedgerows were characterised by a strong predominance of Coccinellidae. Correspondence Analysis performed on predator abundance ordinated the sites according to the age of adjacent hedgerows and the intensity of ecological infrastructure management. The phenology of Coccinellidae was studied. These predators showed two developmental peaks: the first between June and July, and the second between September and October. Particularly the first peak showed large populations of coccinellid larvae in the weedy margins. The knowledge of the phenology of these beneficial predators results in a recommendation for the rational management of ecological infrastructures in order to preserve and improve coccinellid and other predator populations.

Key words: weedy margins, ecological compensation areas, coccinellids, predators, conservation biological control.

Introduction

The maintenance and management of ecological infrastructures, or ecological compensation areas (ECAs), on rural farms is considered crucial in enhancing functional biodiversity for pest suppression (Boller *et al*., 2004). Recently these strategies have become a basic aspect for application of conservation biological control (Rossing *et al*., 2003). A number of studies and reviews have dealt with the effect of non-crop plants on populations of beneficial insects (Pimentel, 1961; Van Emden and Williams, 1974; Altieri and Letourneau, 1982; Sheenan, 1986; Russell, 1989; Van Emden, 1990; Delucchi; 1997; Altieri, 1999; Andow, 1991; Paoletti, 1999; Landis *et al*., 2000; Altieri *et al*., 2003). Improving and managing ecological infrastructures, including weedy field margins, are considered an important aspect of sustainable agriculture because of their role in enhancing functional biodiversity and for their role in supporting movement of cyclic predators between crops and environment (Landis and Wratten, 2002; Winkler 2005).

In simplified agroecosystems, many ecological services associated with the maintenance or enhancement of biodiversity, such as biological control, are compromised (Altieri, 1999). The concept of restoring these functions by managing the ecological infrastructures of landscapes shows promise in alleviating problems linked to pest management (Landis and Wratten, 2002). Undisturbed habitats in or adjacent to crop fields can enhance the overwintering survival of natural enemies. In this context "grassy beetle banks" for the conservation of ground-dwelling arthropods have been adopted in several parts of Europe (Landis and Wratten, 2002). Overwintering predator populations exceeding 1100 individuals per square meter have been reported after two years of beetle bank establishment (Thomas *et al*., 1992).

Managing the non-crop habitat of a farm to improve conservation biological control requires a detailed basic knowledge of the trophic relationships among ecological non-crop plants, phytophages and beneficials. With this knowledge we may re-activate essential "ecological services" on a farm by rational management of ecological infrastructures, and in this way we may improve conservation biological control of pests. In Italy some studies have been carried out, but a "truly ecological perspective" has not yet been widely accepted and applied within pest management, probably because ecological knowledge on functional biodiversity seems to be very fragmented. Moreover, only a few trophic systems have been studied with the specific aim to improve conservation biological control (Paoletti and Lorenzoni, 1989). A review of agroecological models as applied in Italy, including some studies on field margins, has been compiled by Altieri *et al*. (2003) and Maini and Burgio (2006).

The general aim of this research was to study the insect predator complex on weedy margins adjacent to crops in order to understand the ecological role of non crop-habitats on generalist predators in a northern Italian rural landscape. Specific aims were: i) to compare the diversity of predator populations on weedy margins characterised by different maturity of the adjacent linear features (hedgerows); ii) to measure and quantify the predator diversity in these field margins, and iii) to study and understand the phenology of the predominant predators in order to able to develop practical recommendations for farmers to improve functional biodiversity and conservation biological control of economic pests.

Materials and methods

Ten sites in the Bologna province that are characterised by different age of linear features were investigated between 1995 and 1997. Five site were characterised by old hedgerows, the others by young ones. We considered "old hedgerows" those linear features that have a minimum age of 50 years. The age of young hedgerows ranged form five to ten years. The main characteristics of the sites investigated, including the adjacent crops on the farm and the pest management strategies that were applied, are shown in table 1. Sites in the Bologna province are characterised mainly by arable crops and, to a lesser extent, pear and apple orchards. The site "Cà il Rio" is a large farm involved in an European project of sustainable agriculture (Sarno, 1995) and it included three sampling locations: area 1 (old hedgerow), 2 (young hedgerow) and 3 (young hedgerow).

At each site a weedy transect of about 100 meters adjacent to the linear structure on the farm was selected and sampled by sweep net. The investigated field margins formed a mixture of weeds with a predominance of the following species: *Urtica dioica* L., *Amaranthus ret-*

Table 1. Characteristics of the sites that were sampled by sweep net and visual counts. ECA = ecological compensation areas. The category «intensity of ECA management» includes the following typologies: i) limited (weeds were cut only one time during the sampling period); ii) intensive (weeds cut about 4-5 times during the sampling period); iii) intermediate.

Sites	Farm	Locality	Adjacent crops	Pest management	Age of adjacent hedgerows	Intensity of ECA management	Most abundant trees and shrubs within hedgerows
1	Cà il Rio-1	Castel S. Pietro (Bo)	Arable	Advanced IPM	Old	Limited	*Morus nigra*, *Ulmus* spp., *Prunus spinosa*, *Robinia pseudoacacia*, *Populus* spp.,
2	Azzoguidi	Sala Bolognese (Bo)	Orchards	IPM	Old	Limited	*Prunus spinosa*, *Ulmus minor*, *Quercus* spp., *Sambucus nigra*, *Robinia pseudoacacia*, *Euonymus europeus, Cornus sanguinea*, *Fraxinus* spp., *Crataegus monogyna*
3	Maieutica-Bora	S. Giovanni in Persiceto (Bo)	Orchards	Organic	Old	Limited	*Crataegus monogyna*, *Ulmus* spp., *Prunus spinosa*, *Acer campestre*, *Sambucus nigra*, *Rosa canina*, *Cornus sanguinea*, *Populus* spp.
4	Gubellini	Bologna	Orchards	IPM	Old	Limited	*Salix alba*, *Sambucus nigra*, *Robinia pseudoacacia*
5	Guazzaloca	Crevalcore (Bo)	Arable	IPM	Old	Limited	*Prunus spinosa*, *Populus* spp., *Fraxinus* spp., *Morus nigra*, *Ulmus* spp., *Acer campestre*
6	Breveglieri	Calderara di Reno (Bo)	Arable	IPM	Young	Intensive	*Populus* spp., *Corylus avellana*
7	Cà il Rio-2	Castel S. Pietro (Bo)	Arable	Advanced IPM	Young	Intermediate	*Euonymus europeus, Corylus avellana*, *Crataegus monogyna*, *Cornus sanguinea*
8	Cà il Rio-3	Castel S. Pietro (Bo)	Arable	Advanced IPM	Young	Intermediate	*Populus* spp., *Euonymus europeus, Crataegus monogyna*, *Cornus sanguinea*, *Pyrus pyraster*, *Corylus avellana*
9	Morisi	S. Giovanni in Persiceto (Bo)	Arable	Organic	Young	Intermediate	*Crataegus monogyna*, *Prunus spinosa*, *Cornus sanguinea, Corylus avellana*
10	Forni	S. Giovanni in Persiceto (Bo)	Arable	IPM	Young	Intensive	*Euonymus europeus*, *Crataegus monogyna*, *Prunus spinosa*, *Cornus sanguinea*

roflexus L., *Rumex* sp., *Daucus carota* L., *Plantago lanceolata* L., *Dipsacus sylvestris* Hudson, *Arctium* sp., *Cirsium arvense* (L.), *Conyza canadensis* (L.), *Crepis* sp., *Inula viscosa* (L.), *Picris echioides* L.. The composition of the weeds was relatively constant at the different sites, with some variability due to local factors. The most abundant weeds were: *U. dioica*, *D. carota*, *C. arvense*, *C. canadensis*.

Weeds were sampled every 7-10 days from April to October. The sweep net was applied in a standard way, taking 100 sweeps at each sampling date in each weed transect. Generalist predators were collected in plastic boxes, taken to laboratory and identified. Visual samples were also made on the most abundant weeds at each site by counting the number of stems infested by aphids on a total of 100 randomly selected stems.

Statistical analysis

Correspondence analysis (CA) was used to ordinate the weedy field margins at each site on the basis of the abundance of predator families. CA was calculated on a matrix ***p*** x ***n***, where ***p*** are family insects ***n*** are the sites (Manly, 1994).

The formula of Tonkyn (1980) was applied in order to convert the number of coccinellids collected by sweep net to the number of insects caught per volume unit of vegetation (cubic meters).

Biodiversity was also analysed by classic indices, like the Shannon-Weaver, Eveness and Berger-Parker index (Magurran, 1988).

Results and discussion

The predator families that were found during sampling are listed in table 2. After pooling the data collected from all sites, we may conclude that Coccinellidae (Coleoptera) form the most abundant family of predators (53.7%), followed by Nabidae (Rhynchota) (21.6%) and Anthocoridae (9.18%). Nabidae formed the most abundant family at sites characterised by weedy margins adjacent to old and mature hedgerows (sites 1-5). The lower density of Nabidae, in particular *Nabis* sp., in transects near young hedgerows might be the result of the intensive management of the weeds during the sampling period. Other abundant families near old hedgerows were Anthocoridae (16.48%) and Coccinellidae (25.75%). The weedy margins adjacent to young hedgerow (sites 6-10) were characterised by a predominance of Coccinellidae (84%). Families poorly represented at all sites were Carabidae, Staphylinidae, Chrysopidae and Syrphidae (table 2), but poor representation apparently depended on the sampling techniques used. Sampling by sweep net is able to collect only terrestrial Carabidae and Staphylinidae present in the weed canopy, and not those on the soil. Sampling by sweep net underestimated also the Syrphidae larval population because most species within this family have nocturnal activity. Moreover, sweeping net sampling is not considered the standard method to collect adult Syrphidae (Sommaggio, 1999).

Ordination of sites and predator groups was carried out by Correspondence Analysis (CA) (figure 1) in order to understand the similarity among sites and to correlate the abundance of families to the different weed transects within each site. 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 (in our case the "predator family") and the columns to a second type of classification (in our case the "farms"). The aim of this multivariate method is to give an ordination of both farms and insect family at the same time. By means of this analysis the sites were ordered following the age and maturity of the adjacent hedgerows (figure 1). All the weedy margins close to young hedgerows were clustered in one group and were highly correlated with coccinellid populations. All these sites were almost overlapping, indicating a very low between-site variability (figure 1). Four out of five sites characterised by old hedgerows clustered in one group and they were highly correlated with Chrysopidae, Staphilynidae, Nabidae, Syrphidae,

Table 2. Overview of families of predators that were sampled. The numbers indicate the total of specimens collected.

Sites	Anthocoridae	Nabidae	Carabidae	Staphylinidae	Coccinellidae	Chrysopidae	Syrphidae
1	26	234	22	27	167	37	44
2	31	141	6	26	70	12	54
3	13	256	40	36	95	22	51
4	310	97	5	15	133	23	13
5	34	200	53	33	183	47	36
Total	414	928	126	137	648	141	198
%	15.97	35.80	4.86	5.29	25.0	5.44	7.64
6	6	48	0	2	646	4	9
7	7	20	1	1	637	8	23
8	0	35	0	3	255	7	13
9	7	76	1	9	163	12	17
10	0	44	3	1	410	9	15
Total	20	223	5	16	2111	40	77
%	0.80	8.95	0.20	0.64	84.71	1.61	3.09
Pooled	434	1151	131	153	2759	181	275
%	8.54	22.64	2.58	3.01	54.27	3.56	5.41

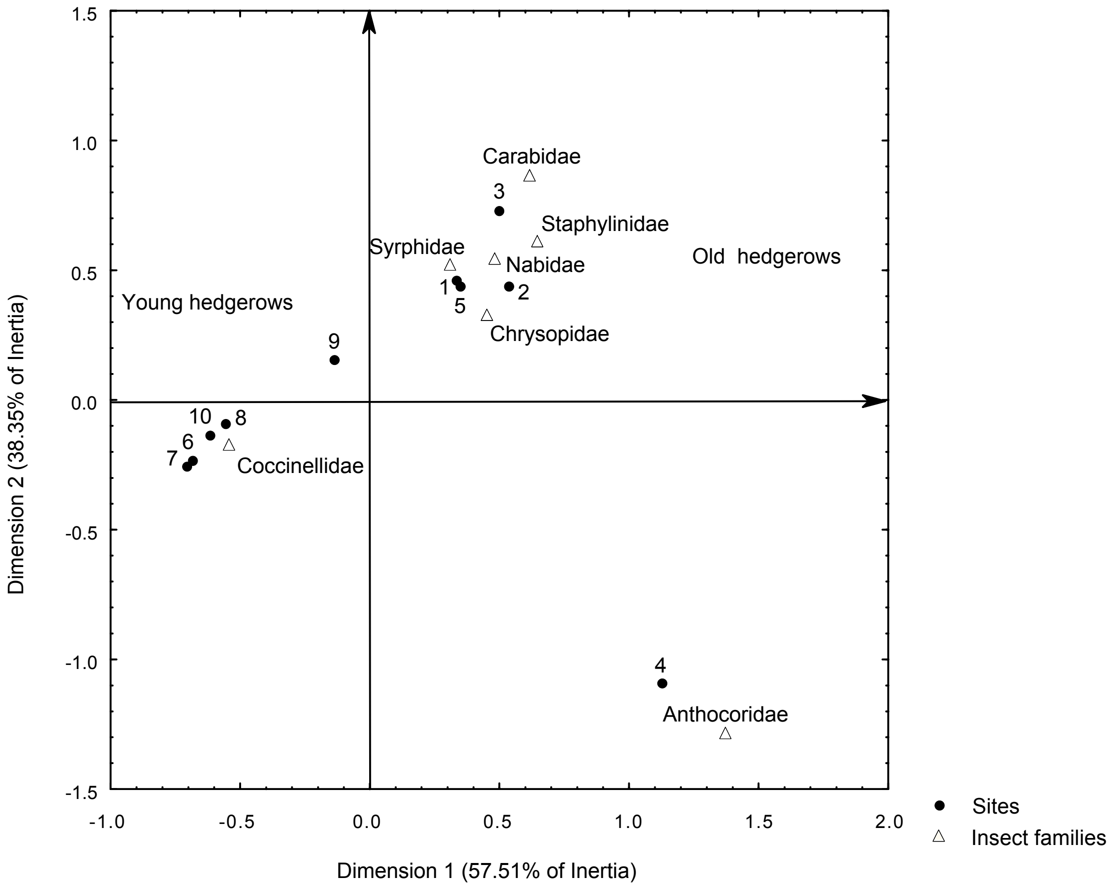

Figure 1. Correspondence analysis performed on the relative abundance of predator families on each farm.

Carabidae. Site 4 was an exception and formed a separate group from all the other sites adjacent to old hedgerows. This farm had a very different predator guild with a predominance of Anthocoridae [*Anthocoris nemoralis* (F.)] populations, probably due to the adjacent pear orchard. For sites 1-5 (old hedgerows) the values of the Shannon-Weaver indices were higher in comparison with the Shannon indices found for sites 6-10 (young hedgerows) (table 3). Also, eveness was in general higher in sites 1-5 in comparison to sites 6-10 (table 3).

Carabidae and Staphylinidae showed differences in abundance at the different sites: relative abundances of these families were from 4.35 to 5.45% in margins adjacent to old hedgerows. Abundance values were under 1% recorded in margins adjacent to young hedgerows. The highest abundance of Carabidae and Staphylinidae in margins near the oldest hedgerows are expected to be the result of an overall higher biological diversity of the old and mature hedgerows.

Table 3. Various biodiversity indices determined for the sampled sites. Numbers of sites are explained in table 1.

Sites	Shannon (H)	Eveness	Berger-Parker (1/d)
1	2.25	0.75	2.70
2	2.16	0.73	2.75
3	2.23	0.75	2.97
4	2.1	0.69	2.63
5	2.65	0.84	5.72
6	1.30	0.48	2.26
7	1.13	0.42	1.40
8	1.63	0.68	2.63
9	2.10	0.76	2.64
10	1.56	0.59	2.25

Weed margins close to young hedgerows showed a stronger dominance in the population structure of the predator species. Contrarily, margins adjacent to old hedgerows showed a higher uniformity of relative abundances of predator families. The weeds adjacent to old hedgerows were managed with limited intensity (see table 1) during the sampling period. We suppose that the intensity of ECA management could affect the dominance of population structure of the weed margins and it could be responsible of some differences in the composition of predatory guild between the old and the young hedgerows.

Coccinellidae formed the most abundant family among “young margins” and one of the most abundant among the “old margins”. For this reason, and for their important role in conservation biological control in northern Italy, a temporal representation of the ladybird populations for the sites is shown (figures 2 and 3). To better understand the phenology of coccinellid populations on weedy margins, the Coccinellidae populations were pooled and normalised to be able to show the trend

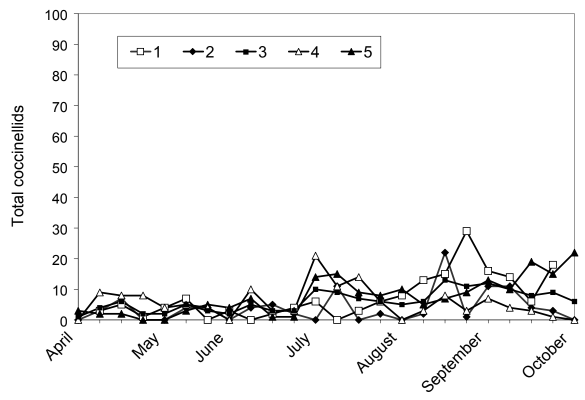

Figure 2. Numbers of coccinellids sampled on farms 1-5. (The numbers in the figure represent the sites as described in table 1).

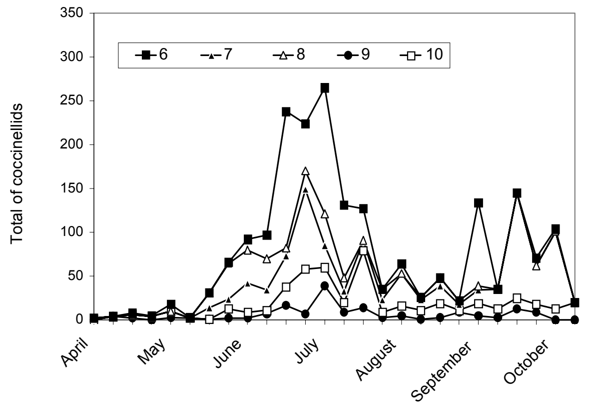

Figure 3. Numbers of coccinellids sampled on farms 6-10. (The numbers in the figure represent the sites as described in table 1).

of the percentage of presence of ladybirds during the season (figure 4). Coccinellid populations show two main peaks, the first in early summer (from early June to early July) and a second one in late summer (from the end of August to the end of September). Among the plant species of the weedy field margins, *Cirsium*, *Rumex* and *Urtica* were most infested by aphids. Aphid populations showed a very strong variability in appearance and intensity among sites, and at some sites the aphid populations occurred in a very clustered way. For these reasons data of aphid infestations on weeds are not presented. Aphids on *Cirsium*, *Rumex* and *Urtica* showed a more or less continuous presence throughout the season, with a peak infestation in May-June at some sites, and in July-August at other sites. The peaks of aphid infestations in summer occurred at the same time of the population peaks of coccinellids. The coccinellids showed an intense reproductive activity between June and July, illustrated by the presence of a mixed stage population, with a massive presence of larvae and eggs. Contrarily, the peak in September–October was represented only by adult coccinellids. These data are similar to those presented in previous studies carried out in the same region. This latter study demonstrated that *D. carota* and *A. retroflexus,* and to a lesser extent *D. sylvestris, Arctium* spp., *Crepis* spp., *Picris* spp., were the main weeds utilised by coccinellids as refuge resources in late season when the arable crops in northern Italy had been harvested.

Hippodamia variegata (Goeze) was the most abundant coccinellid species in the research, followed by *Coccinella septempunctata* L., *Propylea quatuordecimpunctata* (L.) and the *Scymnus* group, that was well represented at the sites investigated (tables 4 and 5). Among Scymnini, *Scymnus rubromaculatus* (Goeze) and *S. apetzi* Mulsant were the most abundant species. The formula of Tonkyn (1980) was applied in order to convert ladybird populations collected by sweep net to the number of specimens caught per volume unit of vegetation (cubic meters) (table 6). Considering the variability in structure and volume of weedy canopy along the seasons, the Tonkyn formula was applied for two fixed periods of the year, corresponding to the maximum canopy development (table 6). Highest population densities of coccinellids were reached for site 6 at the beginning of July: 3.6 individuals per cubic meter. Coccinellid populations peaks ranged between values of 0.17 and 2.37 specimens per cubic meter during the second peak.

Species within Nabidae family, like *Aptus mirmicoides* (Costa), *Nabis punctatus* Costa and *N. rugosus* (L.) are polyphagous predators living in herbs and bushes; other species like *Himacerus apterus* (F.), *N. ferus* (L.) and *N. pseudoferus* Remane are typical of apple and pear orchard and prey on mites, aphids caterpillars, and other small insects (Fauvel, 1999).

Among Coleoptera Staphylinidae, some *Tachyporus* species are considered important in cereal aphid control, and a study carried out in barley fields in Denmark demonstrated that *Tachyporus* spp. are present in the crop from mid May onwards and prior to the appearance of aphids (Pedersen *et al.*, 1990). In Sunderland and Vickerman's (1980) ranking of the most efficient predators, *Tachyporus* is one of the few predators that forages on the upper part of the tillers. In particular the ability of *Tachyporus* to disperse rapidly and thoroughly in cereals in early spring makes it a useful predator (Coombes and Sotherton, 1986). Faunistic notes on *Tachiporus* and other staphylinid genera in agricultural

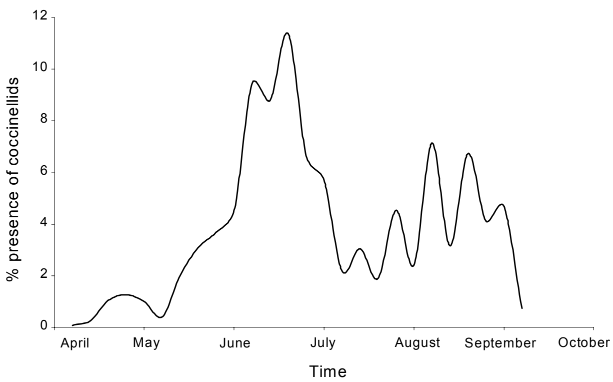

Figure 4. Coccinellid populations sampled in weedy margins represented as percentage of presence of the total population (data pooled from all years and sites).

Table 4. Predator species sampled in weedy field margins adjacent to old hedgerows. The numbers indicate the total of specimens collected.

Insect species/genus	Family	Sites				
		1	2	3	4	5
Anthocoris sp.	Anthocoridae	-	25	4	225	7
Orius sp.		26	6	9	85	27
Nabis sp.	Nabidae	192	108	158	87	90
Aptus mirmicoides		21	22	61	5	58
undetermined Nabidae		21	11	37	5	52
Demetrias atricapillus	Carabidae	21	6	37	5	52
undetermined Carabidae		1	-	3	-	1
Tachyporus sp.	Staphylinidae	8	2	3	4	6
Paederus sp.		10	24	32	11	11
undetermined Staphylinidae		9	-	1	-	16
Coccinella septempunctata	Coccinellidae	29	-	-	-	3
Hippodamia variegata		57	7	43	6	27
Propylaea quatuordecimpunctata		48	32	29	49	54
Adalia bipunctata		-	3	8	14	31
Synarmonia conglobata		-	2	2	5	9
Stethorus punctillum		11	9	-	7	6
Scymnus sp.		19	9	11	47	26
Chilocorus bipustulatus		-	-	1	-	2
Thea vigintiduopunctata		3	7	1	5	25
Chrysoperla carnea	Chrysopidae	36	11	22	23	43
Chrysopa perla		-	-	-	-	3
Mallada sp.		1	1	-	-	1
Episyrphus balteatus	Syrphidae	8	10	8	4	10
Malanostoma mellinum		16	30	35	7	21
Sphaerophoria scripta		-	6	3	1	1
Syrphus sp.		1	2	-	-	1
Meliscaeva sp.		2	-	3	-	2
Eristalis arbustorum		5	-	-	-	-
Syritta sp.		2	-	-	-	-
Eumerus sogdianus		2	-	-	-	-
undetermined hoverfly larvae		8	6	2	1	1

Table 5. Predator species sampled in weedy field margins adjacent to young hedgerows. The numbers indicate the total of specimens collected.

Insect species/genus	Family	Sites				
		6	7	8	9	10
Orius sp.	Anthocoridae	6	7	-	7	-
Nabis sp.	Nabidae	47	20	33	52	43
Aptus mirmicoides		1	-	-	5	1
undetermined Nabidae		-	-	2	19	-
Demetrias atricapillus	Carabidae	-	1	-	1	3
Tachyporus sp.	Staphylinidae	1	1	-	1	1
Paederus sp.		1	-	3	8	-
Coccinella septempunctata	Coccinellidae	69	67	90	4	23
Hippodamia variegata		318	500	119	11	67
Propylaea quatuordecimpunctata		91	35	27	37	68
Adalia bipunctata		-	-	-	-	14
Synarmonia conglobata		1	2	-	4	-
Stethorus punctillum		4	1	-	-	8
Scymnus apetzi		39	8	5	24	73
Scymnus rubromaculatus		50	14	8	52	58
Scymnus frontalis		62	4	-	7	60
Scymnus interruptus		1	1	-	-	1
Pullus auritus		9	2	-	13	6
Pullus subvillosus		-	-	-	2	6
Platynaspis luteolubra		1	-	-	-	-
Coccidula rufa		-	1	-	-	-
Thea vigintiduopunctata		1	2	6	9	26
Chrysoperla carnea	Chrysopidae	4	7	6	6	6
Chrysopa perla		-	1	1	4	3
Malanostoma mellinum	Syrphidae	6	21	11	8	2
Sphaerophoria scripta		3	2	2	9	13

Table 6. Peaks of coccinellid numbers sampled as number of specimens per cubic meter. A volume of 0.4 cubic meters was estimated for each sweep net sample according to Tonkyn (1980).

Sites	Coccinellids per cubic meter	
	First peak	Second peak
1	0.15	0.72
2	0.22	0.27
3	0.27	0.55
4	0.52	0.17
5	0.37	0.47
6	3.60	2.37
7	2.27	2.20
8	0.90	0.22
9	0.97	0.32
10	1.17	0.32

fields are reported by Andersen (1991). A similar searching behaviour is shown by the Carabid *Demetrias atricapillus* (L.). In Italy this species is linked to field margins and grassy canopy characterised by high humidity and to the mulches within crops (Drioli, 1987; Vigna Taglianti, 2001). *D. atricapillus* is typical of soils with *Phragmites* spp. and has a good dispersal capacity.

Data of the present research were critically analysed taking into account also the earlier studies performed in northern Italy on coccinellid dynamics on ecological compensation areas and crops (Nicoli *et al*., 1995; Cornale *et al*., 1996; Ferrari *et al*., 1996; Molinari *et al*., 1998; Burgio *et al*., 1999; Burgio *et al*., 2000; Celli *et al*., 2001; Burgio *et al*., 2004). We summarise the current hypothesis about the cyclic movement of ladybirds between arable crops, ecological compensation areas, fallow and open field vegetable crops in figure 5 (Maini and Burgio, 2006). In agroecosystems of northern Italy, the period between late May and early July is crucial for the maintenance of predator populations because at that time many coccinellid species are in their reproductive period. Our data seem to demonstrate that in early summer coccinellid populations are migrating to and settling in weeds. These ladybirds originate from harvesting alfalfa and wheat (Burgio *et al*., 1999). Moreover, high coccinellid larval populations were recorded on weeds between May and July, thus demonstrating the role of field margins for recruiting and reproduction of these beneficials. In September a second peak of coccinellid populations is registered on weeds, mainly represented by adults. Although we expect that in this period mowing might be less destructive for the beneficial fauna, weeds like *D. carota* and *A. retroflexus* still collect high populations of coccinellids that come from the last two alfalfa cuttings (Burgio *et al*., 1999). Further, during this part of the season arable crops are already harvested and weeds within ecological infrastructures become crucial for these cyclic colonisers. Besides coccinellids, also other young instars of other beneficial predators including Nabidae, Anthocoridae, Chrysopidae and Syrphidae were recorded on weeds in similar studies (e.g. Burgio *et al*., 2004), confirming literature

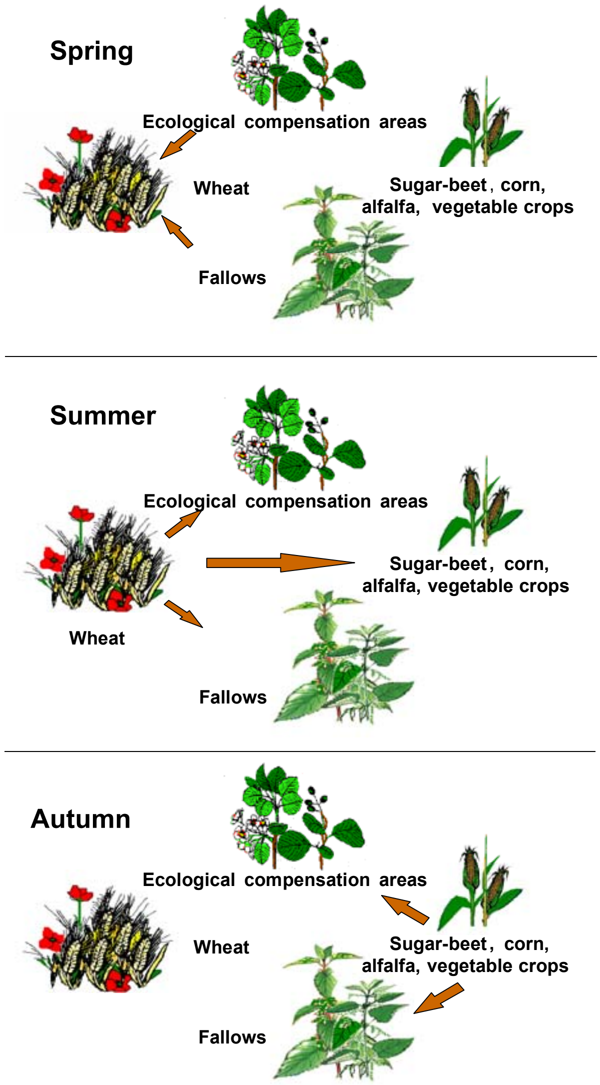

Figure 5. Diagram showing the cyclic colonisation of coccinellids between crops and non-crop areas (from Maini and Burgio, 2006).

data of Sommaggio (1999) and Boller *et al*. (2004) and providing new phenological data for agroecosystems of northern Italy.

Proper management of mowing, including timing, is recommended during the whole season in order to preserve and stimulate the development of insect predators, including coccinellid populations. Field margins play a crucial role in regulating the cycle of ladybirds and other predators, contributing to the cyclic movements from weeds to crop and *vice versa*. Mowing of weeds, wildflower strips and grassland strips in this period could be destructive for coccinellid populations, and the management procedures of field borders should take into account the phenology of beneficials (Honek, 1982; Leather *et al*., 1999; Hodek and Honek, 1996). The negative impact of mowing techniques on faunistic diversity is treated by Boller *et al*. (2004). They provide a list of recommendations to augment faunistic diversity, including level, direction, period and frequency of mowing. For example, the first cut should be made as late as possible using a procedure that is least harmful to the fauna (Boller *et al*., 2004). This conclusion is in agreement with our results. Our data seem to demonstrate that in a multifunctional agriculture context, a rational management of ecological infrastructures is crucial for conservation of beneficial fauna, thus contributing to the implementation of conservation biological control. Considering the local variability of the beneficial fauna cycles, due to geographical, climatic, environmental variations among countries and regions, recommendations on the maintenance and management of ecological infrastructures should be suggested at local scale, considering the characteristics of each geographic area and the specific knowledge of each agroecosystem.

In conclusion, an abundant predator insect fauna was recorded on weeds within field margins, confirming the key role of ecological infrastructures within rural landscape. A rational management of ecological infrastructures is considered very important for the temporal and spatial dynamics of cyclic colonisers predators (Boller *et al*., 2004) and our study, improving the knowledge of the phenology of ladybirds on field margins in our region (see figures 4 and 5), can contribute to a better management of ecological compensation areas.

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References

ALTIERI M. A., 1999.- The ecological role of biodiversity in agroecosystems, pp. 19-31. In: *Invertebrate biodiversity as bioindicators of sustainable landscapes. Practical use of invertebrates to assess sustainable land use* (PAOLETTI M. G., Ed.).- Elsevier, Amsterdam, NL.

ALTIERI M. A., LETOURNEAU D. K., 1982.- Vegetation management and biological control in agroecosystems.- *Crop Protection*, 1 (4): 405-430.

ALTIERI M. A., NICHOLLS C. I., PONTI L., 2003.- *Biodiversità e controllo dei fitofagi negli agroecositemi*.- Accademia Nazionale Italiana di Entomologia, Firenze, Italy.

ANDERSEN A., 1991.- Carabidae and Staphylinidae (Col.) frequently found in Norwegian agricultural fields. New data and review.- *Fauna norvegica Ser. B*, 38: 65-76.

ANDOW D. A., 1991.- Vegetational diversity and arthropod population response.- *Annual Review of Entomology*, 36: 561-586.

BOLLER E. F., HANI F., POEHLING H.-M., 2004.- *Ecological infrastructures. Ideabook on functional biodiversity at the farm level*.- IOBC/wprs, Lindau, Switzerland.

BURGIO G., VAN LENTEREN J. C., FERRARI R., 1999.- Indagine sui parassitoidi e predatori di afidi su colture erbacee dell'Emilia-Romagna.- *Italus Hortus*, 6 (4): 43.

BURGIO G., FERRARI R., BORIANI L., 2000.- Spazi preziosi ai margini del campo.- *Il Divulgatore* (Provincia di Bologna), 23 (12): 13-22.

BURGIO G., FERRARI R., POZZATI M., BORIANI L., 2004.- 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.- *Bulletin of Insectology*, 57 (1): 1-10.

CELLI G., MAINI S., FERRARI R., CORNALE R., POZZATI M., RADEGHIERI P., BURGIO G., 2001.- Studio dell'entomofauna utile presente in aziende agricole del Parco del Delta del Po: dinamica delle popolazioni e interazione con le aree coltivate.- *Informatore Botanico Italiano*, 33 (1): 279-281.

COOMBES S, SOTHERTON N. W., 1986.- The dispersal and distribution of polyphagous predatory Coleoptera in cereals.- *Annals of Applied Biology*, 108: 461-474.

CORNALE R., POZZATI M., CAVAZZUTI C., BURGIO G., 1996.- Trattamenti insetticidi al grano: influenza su afidi e loro antagonisti naturali.- *Informatore Agrario*, 52 (22): 35-39.

DELUCCHI V., 1997.- Una nuova frontiera: la gestione ambientale come prevenzione, pp.35-57. In: *Atti della Giornata sulle strategie bio-tecnologiche di lotta contro gli organismi nocivi*, Sassari, 11 aprile 1997. CNR, Sassari, Italy.

DRIOLI G., 1987.- *Tipi e tempi di sviluppo dei Coleotteri Geoadefagi presenti sul basso Carso triestino*.- Tipografia Adriatica, Trieste, Italy.

FAUVEL G., 1999.- Diversity of Heteroptera in agroecosystems: role of sustainability and bioindication, pp. 275-303. In: *Invertebrate biodiversity as bioindicators of sustainable landscapes. Practical use of invertebrates to assess sustainable land use* (PAOLETTI M. G., Ed.).- Elsevier, Amsterdam, NL.

FERRARI R., BURGIO G., CORNALE R., CURTO G., 1996.- Difesa biologica-integrata di cocomero e melone.- *Colture Protette*, 12: 33-36.

HODEK I., HONEK A., 1996.- *Ecology of Coccinellidae*.- Kluwer Academic Publishers, Dordrecht, NL.

HONEK A., 1982.- Aphidophagous Coccinellidae (Coleoptera) and Chrysopidae (Neuroptera) on three weeds: factors determining the composition of populations.- *Acta entomologica Bohemoslovaca*, 78: 303-310.

LANDIS D., WRATTEN S., 2002.- Conservation of biological controls, pp. 138-140. In: *Encyclopedia of Pest Management* (PIMENTEL D., Ed.).- Marcel Dekker, New York, USA.

LANDIS D., WRATTEN S. D., GURR G., 2000.- Habitat manipulation to conserve natura lenemies in arthropod posts in agriculture.- *Annual Review of Entomology*, 45: 173-199.

LEATHER S. R., COOKE R. C. A., FELLOWES M. D. E., ROMBE E., 1999.- Distribution and abundance of ladybirds (Coleoptera: Coccinellidae) in non-crop.- *European Journal of Entomology*, 96: 23-27.

MAGURRAN A. E., 1988.- *Ecological diversity and its measurement*.- Chapman and Hall, London, UK.

MAINI S., BURGIO G., 2006.- Aree di compensazione ecologica per il potenziamento del controllo naturale dei fitofagi.- *Atti dell'Accademia Nazionale Italiana di Entomologia, Rendiconti*, 53: 243-268.

MANLY B. F. J., 1994.- *Multivariate Statistical methods*.- Second edition, Chapman & Hall, London, UK.

MOLINARI F., BAVIERA C., DI PARDO M., 1998.- Attività degli antagonisti degli afidi nei pescheti, p. 241. In: *Atti XVIII Congresso nazionale italiano di entomologia*, Maratea, 21-26 giugno 1998. Scientific Press, Firenze, Italy.

NICOLI G., LIMONTA L., CAVAZZUTI C., POZZATI M., 1995.- Il ruolo delle siepi nell'ecologia del campo coltivato. I. Prime indagini sui Coccinellidi predatori di afidi.- Informatore fitopatologico, 45 (7-8): 58-64.

PAOLETTI M. G., 1999.- *Invertebrate biodiversity as bioindicators of sustainable landscapes. Practical use of invertebrates to assess sustainable land use*.- Elsevier, Amsterdam, NL.

PAOLETTI M. G., LORENZONI G. G. 1989.- Agroecology patterns in Northern Italy.- *Agriculture Ecosystems & Environment,* 27: 139-154.

PEDERSEN M., PEDERSEN L. T., ABILDGAARD K., 1990.- Annual and diurnal activity of some *Tachyporus* species (Coleoptera: Staphylinidae) in two spring barley fields and a hedge.- *Pedobiologia*, 34: 367-378.

PIMENTEL D., 1961.- Species diversity and insect population outbreaks.- *Annals of the Entomological Society of America*, 54: 76-86.

ROSSING W. A. H., POEHLING H. M., BURGIO G., 2003.- Landscape management for functional biodiversity. Proceedings of the 1st Meeting of the study group, Bologna, Italy, 11-14 May 2003.- *IOBC/wprs Bulletin*, 26 (4): 1-220.

RUSSELL E. P., 1989.- Enemies hypothesis: a review of the effect of vegetational diversity on predatory insects and parasitoids.- *Environmental Entomology*, 18 (4): 590-599.

SARNO G., 1995.- La rete europea dei «sistemi integrati».- *Agricoltura*, 23 (11): 56-58.

SHEENAN W., 1986.- Response by specialist and generalist natural enemies to agroecosystem diversification: a selective review.- *Environmental Entomology*, 15 (3): 456-461.

SOMMAGGIO D., 1999.- Syrphidae: can they be used as environmental bioindicators?, pp. 343-356. In: *Invertebrate biodiversity as bioindicators of sustainable landscapes. Practical use of invertebrates to assess sustainable land use* (PAOLETTI M. G., Ed.).- Elsevier, Amsterdam, NL.

SUNDERLAND K. D., VICKERMAN P., 1980.- Aphid feeding by some polyphagous predators in relation to aphid density in cereal fields.- *Journal of Applied Ecology*, 17: 389-396.

THOMAS M. B., WRATTEN S. D., SOTHERTON N. W., 1992.- Creation of 'island' habitats in farmland to manipulate populations of beneficial arthropods: predator densities and species composition. *Journal of Applied Entomology*, 29 (2): 524-531.

TONKYN D. W., 1980.- The formula for the volume sampled by a sweep net.- *Annals of Entomological Society of America*, 73: 452-454.

VAN EMDEN H. F., 1990.- Plant diversity and natural enemy efficiency in agroecosystems, pp 36-80. In: *Critical issues in biological control* (MACKAUER M., EHLER L. E., ROLAND J., Eds).- Intercept Ltd, Andover Hants, UK.

VAN EMDEN H. F., WILLIAMS G. F., 1974.- Insect stability and diversity in agro-ecosystems.- *Annual Review of Entomology*, 19: 455-475.

VIGNA TAGLIANTI A., 2001.- I Carabidi delle isole circumsarde (Coleoptera Carabidae).- *Annali del Museo Civico di Storia Naturale Giacomo Doria*, 93 (2000): 305-428.

WINKLER K., 2005.- Assessing the risks and benefits of flowering field edges, 118 p., *PhD thesis*, Wageningen Agricultural University, NL.

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