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First observation and spread of *Popillia japonica* Newman, 1841 (Coleoptera, Scarabaeidae, Rutelinae) in Switzerland

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Abstract: The Japanese beetle (*Popillia japonica*) is one of the most dangerous pests worldwide for agriculture and ornamental plants. After its invasion in North America and the Azores, in 2014 it arrived in Italy (Piedmont and Lombardy). Since 2016, a monitoring programme with pheromone traps and visual inspections has been conducted to check for the presence and eventually the abundance of *P. japonica* in Switzerland. In particular, the study area extends to the southern part of Switzerland (Canton Ticino).
The first capture of *P. japonica* in Switzerland was registered in 2017 near the Swiss-Italian border. In 2019 the species had spread to other neighbouring sites and the number of captures had increased, with the first population notified in Stabio. During 2020, the area of occurrence extended northwards, covering large parts of southern Canton Ticino. In Stabio, after 4 years of presence, captures increased 30 fold with respect to the first year and the first larvae were found in soil samples. Adults found in Switzerland were captured from mid-June to the end of September, with a peak in the second part of July. Oviposition was observed mainly in moist soils (natural and irrigated).
In this article, we present the arrival of *P. japonica* in Switzerland and its spread in the 2016-2020 period.

Keywords: Agriculture, Invasive species, Japanese beetle, Priority quarantine pest

Primo ritrovamento e diffusione di *Popillia japonica* Newman (Coleoptera, Scarabaeidae, Rutelinae) in Svizzera

Riassunto esteso
Introduzione: Il coleottero giapponese (*Popillia japonica* Newman, 1841) è un organismo da quarantena prioritario molto pericoloso per l'agricoltura e le piante ornamentali. L'insetto ha origini asiatiche e la sua diffusione ha raggiunto il Nord America nel 1916, le Azzorre a fine anni '70 e l'Italia nel 2014 (Piemonte e Lombardia). Gli adulti si nutrono di oltre 300 specie di piante e causano danni o defogliazioni a fiori e frutti, con importanti perdite economiche nelle regioni infestate. Le larve nel suolo si nutrono delle radici, causando un danno alle superfici prative.
In questo articolo è presentato l'arrivo di *P. japonica* in Svizzera e la sua diffusione nel periodo 2016-2020.
Materiale e metodi: L'area di studio comprende la parte meridionale della Svizzera (Canton Ticino), dove è stato realizzato un monitoraggio dal 2016 da parte del Servizio fitosanitario cantonale, per verificare la presenza dell'insetto sul territorio. Il monitoraggio si è basato sull'utilizzo di trappole a feromone nei siti più a rischio, controllate settimanalmente, nel periodo da giugno a settembre. In parallelo sono state svolte ispezioni visive sulle colture sensibili, sul compost e nel suolo.
I dati raccolti sono stati categorizzati in funzione del metodo: catture (trappole) e osservazioni (ispezioni visive). Le catture sono state utilizzate per monitorare l'evoluzione del numero degli insetti durante il periodo di volo nei vari siti, mentre sia le catture che le osservazioni sono servite per rappresentare la distribuzione spaziale dell'insetto nell'area di studio.
Risultati e discussione: In Svizzera l'insetto invasivo non è mai stato osservato fino al 2016. Durante il monitoraggio del 2017 i primi 3 individui adulti di *P. japonica* sono stati catturati nella trappola di Stabio. L'anno seguente il numero d'insetti catturati è aumentato e sono stati osservati i primi individui in un vigneto di Stabio, confermando l'ipotesi di un'espansione delle popolazioni in seguito all'allargamento del focolaio presente in Italia. Nel 2019 il numero di insetti catturati a Stabio è fortemente aumentato e sono state registrate delle catture anche nei Comuni vicini: Novazzano, Chiasso e Coldrerio. Inoltre, la prima piccola popolazione di 10 individui è stata trovata a Stabio su *Parthenocissus quinquefolia*. Nel 2020 l'areale di distribuzione si è esteso verso nord occupando la parte sud del Canton Ticino. Un individuo è stato catturato anche sul Piano di Magadino, mentre a Stabio, dopo 4 anni di presenza, le catture sono aumentate di quasi 30 volte rispetto al primo anno. A Genestrerio è stato annunciato il primo focolaio vicino a un vigneto, dove sono stati trovati 2'000 adulti e una media di 5 larve/m^2. L'ovideposizione è stata osservata prevalentemente in suoli umidi (naturali o irrigati) attorno al focolaio. Dai dati raccolti durante il monitoraggio eseguito in Svizzera, risulta che i primi adulti emergono nella seconda metà di giugno, il picco di presenza si verifica a metà luglio e il volo termina a fine settembre. La rapida diffusione nella regione è probabilmente causata da differenti fattori: la vicinanza con il focolaio italiano, la diffusione attiva dell'insetto e il trasporto passivo con merci o persone.

In conclusione, questo studio dimostra che in Canton Ticino l'areale di presenza di *P. japonica* si estende di alcuni chilometri ogni anno, mentre il numero di insetti catturati nelle zone in cui è presente aumenta rapidamente in pochi anni. I risultati attestano che in Canton Ticino vi sono condizioni ecologiche favorevoli alla presenza e alla riproduzione dell'insetto. Questa informazione è cruciale per definire una strategia di gestione; dalla nostra esperienza, è essenziale tenere in considerazione la biologia dell'insetto, le vie di diffusione e la messa in atto di tutte le misure di contenimento. Per un controllo efficace e preventivo è importante coinvolgere tutte le categorie interessate tramite una campagna di sensibilizzazione della popolazione, per agire insieme nell'interesse comune.

Parole chiave: Agricoltura, Coleottero giapponese, Organismo di quarantena prioritario, Specie invasiva

INTRODUCTION

The Japanese beetle (*Popillia japonica* Newman, 1841) is considered one of the most dangerous pests worldwide for agricultural crops, fruit plants and other ornamental or forest plants. The insect belongs to the order Coleoptera, to the family Scarabaeidae and to the subfamily Rutelinae (EPPO 2022).
Originally native to northern China, Japan and to the far east of Russia, in other countries it is considered a quarantine pest (EPPO 2022). It was unintentionally introduced in North America in 1916 (Fleming 1972) and found in the Azores in the early 1970s (Martins & Simoes 1988). In 2014, it was found in northern Italy (Piedmont and Lombardy Regions), and its population size rapidly increased and expanded southward to Emilia-Romagna Region in 2020 (Pavesi 2014; EPPO 2022; Mori et al. 2022).
Fleming (1972) describes the size of adults of *P. japonica* ranging from 8 to 11 mm in length, with a metallic green body and coppery brown elytra. A characteristic trait that facilitates the species' identification is the presence of five white tufts on each side of the abdomen, and two additional ones at the lower end of the abdomen. Larvae are yellowish brown and 1.5 (L1) to 32 mm (L3) long. They are curled into a "C" shape and present a characteristic raster on the ventral side of the last abdominal segment, consisting of two rows of 6-7 spines arranged in the form of a "V" (Fleming 1972).
Adults of *P. japonica* are extremely polyphagous, feeding on more than 300 species of wild and cultivated plants with considerable impacts (defoliations, loss of harvest) and economic losses in infested areas (Potter & Held 2002). Larvae complete their development cycle in the soil by feeding on grasses' roots. In the United States, adults and larvae control costs exceed $460 million per year (USDA 2015). In Italy, damages were observed in irrigated meadows, field crops (maize and soybean), small fruit crops (raspberry, blackberry and cranberry), vineyards, private gardens, and on ornamental trees and shrubs (Regione Piemonte 2019; EPPO 2022).
Its world distribution as well as the impacts on the environment, agriculture and economy are well known; however, the spread in new areas is less reported and understood. In this article, we present the arrival of *P. japonic*a and its spread in Switzerland in the 2016-2020 period.

MATERIALS AND METHODS

The study area is located in the southern region of Switzerland (Canton Ticino), which borders the infested zone of Italy and is crossed by the main north-south trade axis through the Alps (Fig. 1).
After the first record of *P. japonica* in Italy, in 2015 the Phytosanitary Service of Canton Ticino, according to procedures for official control published by EPPO (2016), started an exploratory monitoring of the area along the border to detect any potential presence of the species in Switzerland. In 2016, 3 traps (PHEROCON Japanese Beetle, Trécé Inc., United States) were installed, including a pheromone and floral attractant (Japanese Beetle Dual Lure, Trécé Inc., United States), near sites considered as high-risk for the species' spread (airport, distribution centres, main roads near the border), and checked weekly from June to September (Fig. 1). From 2017 to 2019, 10 additional traps were installed to get a better representation of *P. japonica*'s distribution, and an awareness campaign addressed to the population was promoted. In 2020, the monitoring design was composed of 18 pheromone traps (Fig. 1) and visual inspections on sensible crops, compost and soil.
Collected data were categorized as function of the monitoring method: captures (from pheromone traps) and observations (including visual inspections on plants, compost and soil). Captures were treated as quantitative data to monitor the evolution of the number of individuals in each site and, for 2019 and 2020, the sex of insects was also determined. The whole dataset was treated as absence-presence data for a spatial representation into the study area. All data were analysed and graphically represented using R software (R Core Team 2020).

RESULTS AND DISCUSSION

In Switzerland *P. japonica* has never been observed before this monitoring program. After the first notification in Italy in 2014, visual inspections conducted by the Phytosanitary Service in 2015 and capture data from traps in 2016 confirmed the species' absence in the area (Fig. 2).
In 2017, the first observation of 3 adults of *P. japonica* in Switzerland was registered on the 21th of June, week 25, in a trap located in Stabio (Fig. 3), with 24 adults captured during the whole season. No insects were found in the remaining six traps.
During 2018, 147 adults were caught in Stabio and, on the 3rd of July, the first individuals were observed in

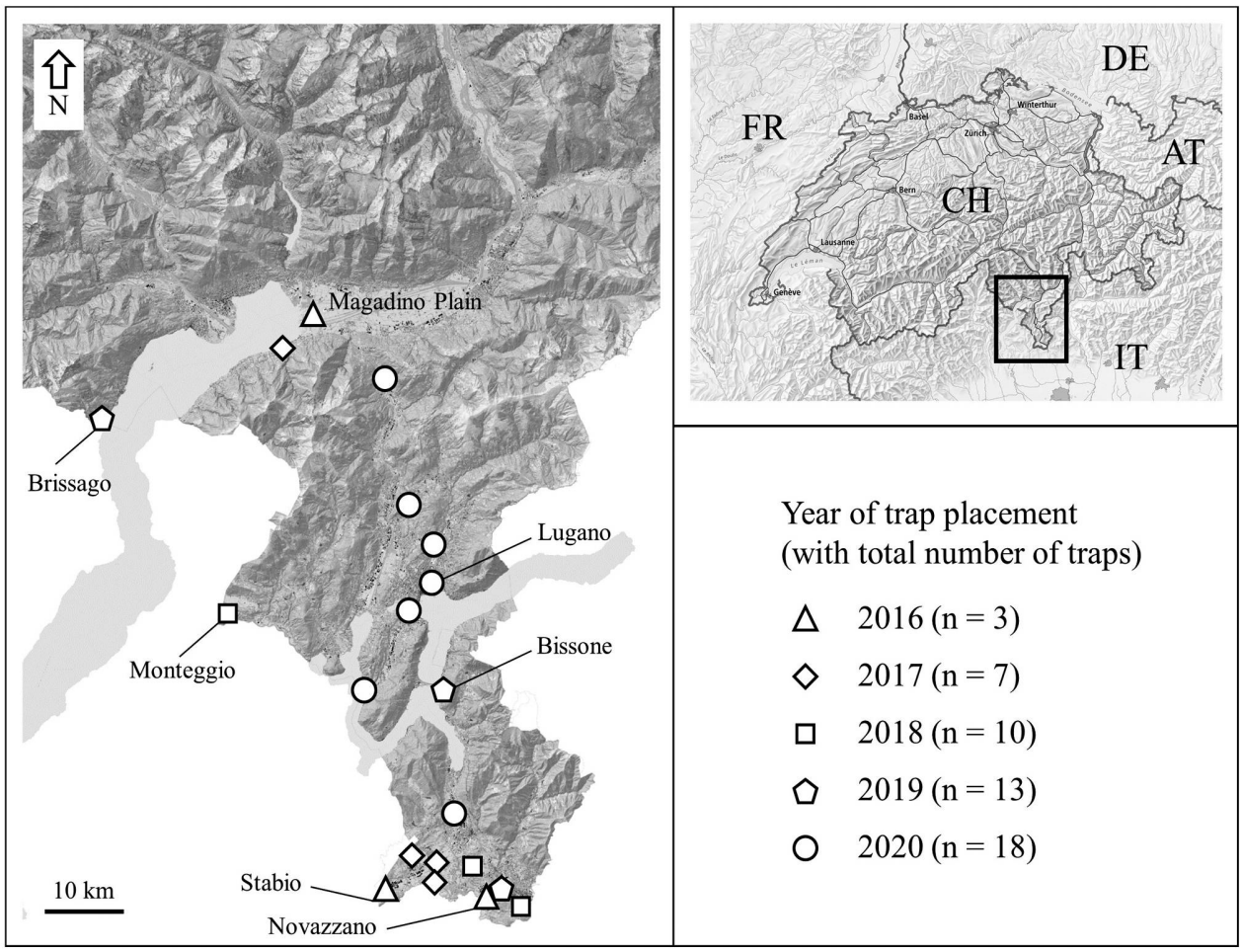

Figure 1: The study area is located in the Canton Ticino, Switzerland. Points on the map represent sites where traps were placed to monitor *P. japonica*'s presence during the 2016-2020 period. Symbols indicate the year of traps placement, and the total number of traps (n) for each year is reported in brackets.

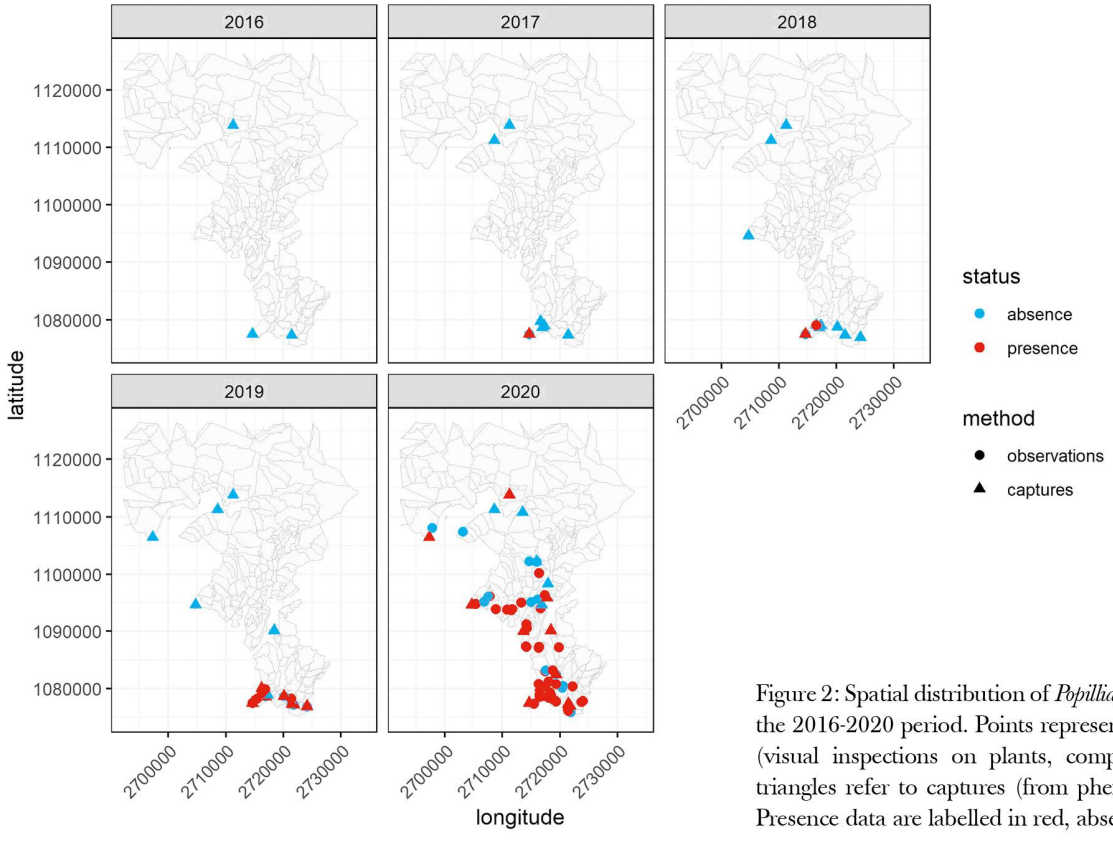

Figure 2: Spatial distribution of *Popillia japonica* during the 2016-2020 period. Points represent observations (visual inspections on plants, compost and soil); triangles refer to captures (from pheromone traps). Presence data are labelled in red, absence in blue.

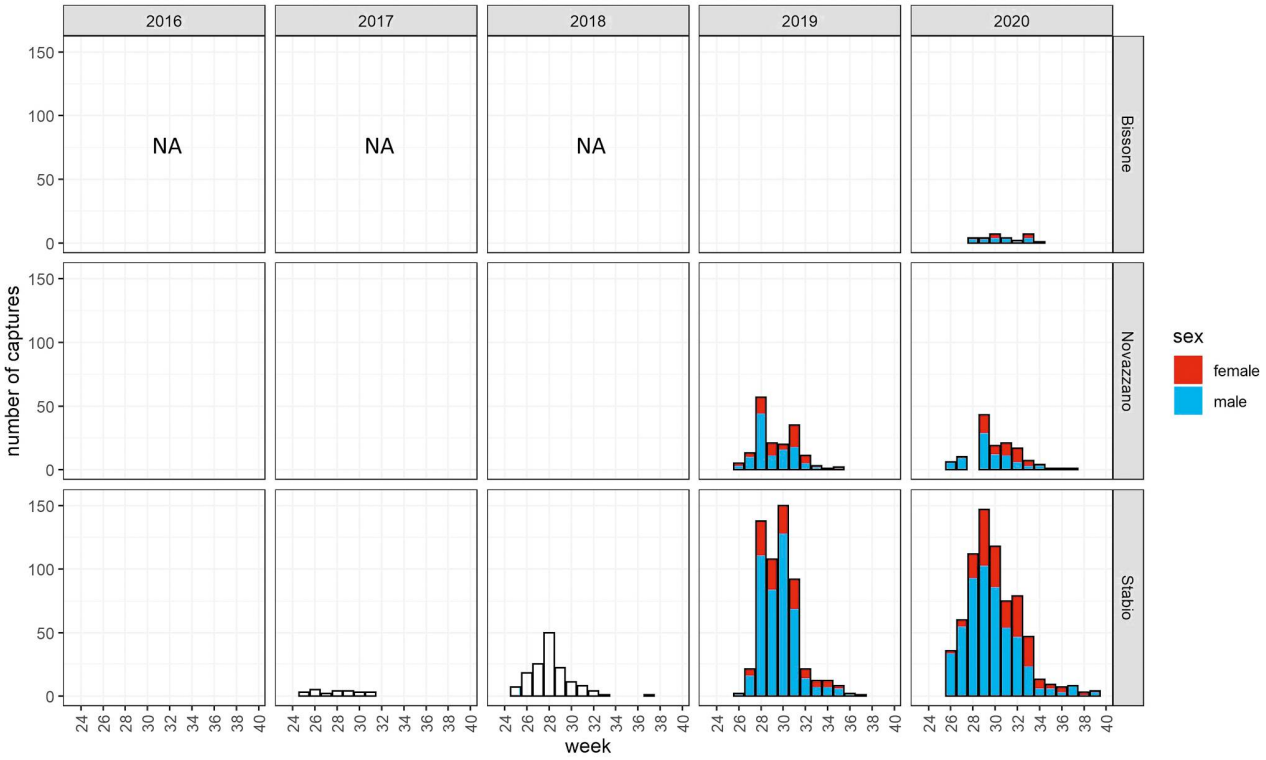

Figure 3: Number of adults of *Popillia japonica* captured weekly, from 2016 to 2020, in three sites (Stabio, Novazzano and Bissone). "NA" indicates years when no traps were installed. In 2019 and 2020 adults were distinguished between males (blue) and females (red).

Stabio in a vineyard (Fig. 3). These findings, limited to Stabio, confirm the hypothesis of a natural spread from the Italian infested area. This propagation is probably due to similarities between Swiss and Italian habitats or may be linked with the presence of major transit routes and railways (main north-south axis of the Alps), which may facilitate passive transport and act as an important vector.

In 2019 the total number of adults captured in Stabio increased reaching a total of 546 individuals (431 males and 115 females) with a peak of 150 captures during the week 30 (Fig. 3). Individuals were also caught in other traps placed in Novazzano (155 adults, of which 101 males and 54 females) and in nearby municipalities Chiasso (4) and Coldrerio (5). Again in 2019, the first small population composed of 10 specimens of *P. japonica* was observed in nature on *Parthenocissus quinquefolia* on the border of Stabio, and 3 individuals were observed in Balerna (near Novazzano).

In 2020, the area of occurrence of *P. japonica* extended northwards (Fig. 2). For the first time adults were found by visual inspections on compost sites and the presence of larvae in soil was attested. The first infestation on crops was identified in Genestrerio (near Stabio), in a one-hectare vineyard, where approximatively 2'000 adults were captured manually and an average of 5 larvae/m^2 was calculated from soil sampling on a transect. Trap monitoring resulted in captures of *P. japonica* adults in 14 out of 18 traps (Fig. 2), with the first captures in the central part of Canton Ticino: Brissago (3), Lugano (5), Monteggio (2) and Bissone (29) (Figg. 2 and 3). Furthermore, an individual was captured on the Magadino Plain, a region with significant agricultural activity. In Stabio, 718 adults (522 males and 196 females) were trapped, showing an increase of approximatively 30 times in captures after four years since the first detection (Fig. 3). Concerning the phenology of the flight, the first individuals were captured at the end of June (week 26) with a peak in the second half of July (week 29), and ended in late September (week 39). During the first two weeks of captures, the percentage of females was less than 10%, while during the peak this proportion was about 30%. In August, during the egg deposition period, it reached 50% approximatively (Fig. 3).

The rapid spread of *P. japonica* within the region is likely the result of several factors: the presence of a large outbreak close to the Swiss-Italian border with a high population density; the active diffusion by flying; and the consequence of passive transport. From our results, we suppose that active diffusion may reach between 2 to 4 km per year, ranging 8 km or more with passive transport related to commercial goods, tourism, or soil and plants transportation. Land relief is probably limiting the active diffusion and we suppose that mountains may act as a physical barrier slowing down the species' spread.

In terms of population density, during the early stages of the species' colonisation the population increased rapidly, reaching hundreds of individuals in a few years. Traps are an efficient method to detect the arrival of *P. japonica*, but once a population is established, host plants (such as those listed in table 1) may exert greater attractiveness and the number of individuals captured by pheromone traps may not reflect the actual number of adults present on site. Further studies are needed to compare the catching capacity of different trap types, their attractiveness in relation to gender and the range of pheromone action.

Insect biology arising from our monitoring seems to confirm the observations carried out in Italy (Regione Piemonte 2019). Results show that in the southern Swiss Alps, insects emerge as adults in the second part of June and the flight period ends in late September. The flight peak is around mid-July and varies between week 28 and week 30 depending on the year and on the location. Oviposition was observed in moist soils environments such as meadows close to water bodies, or irrigated gardens. With respect to native species, it is important to highlight that only 1% of captured individuals (excluding the trap in Stabio) belong to species other than *P. japonica*, which shows the high specificity of the pheromone traps (Tab. 1).

In conclusion, this study demonstrates that in Canton Ticino the range of presence of *P. japonica* extends by some kilometres every year, while the number of insects caught in the areas where it is present increases rapidly within a few years. This fact indicates that large parts of the Canton Ticino provide favourable ecological conditions for the presence and reproduction of the insect. On the other hand, no significant damage has yet been reported after 4 years from the first observation. This information is crucial to define a proper management strategy; from our experience, it is essential to take into account insect biology, the possible ways of spread and to implement all possible containment measures by regulating and controlling the transport of plant material, compost, living vegetables and soil. To achieve effective control it is fundamental to approach the problem in advance by involving all stakeholders and acting for the common good through a public awareness campaign.

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Table 1: Number of captures per insect species and host plants registered during the 2016-2020 period.

	Species	Number per year						Notes
		2016	2017	2018	2019	2020	Total	
Insects	*Popillia japonica*	0	24	147	743	1366	2280	
	Oxythyrea funesta	0	0	56	107	2	165	Only trap in Stabio
	Tropinota hirta	0	0	7	0	0	7	
	Cetonia aurata	0	0	1	2	2	5	
	Mylabris variabilis	0	0	2	0	0	2	
	Apis mellifera	0	0	0	1	0	1	
	Bombus sp.	0	0	0	0	1	1	
	Cantharis livida	0	0	1	0	0	1	
	Malachius bipustulatus	0	0	0	1	0	1	
	Palmar festiva	0	0	1	0	0	1	
	Pyrrhocoris apterus	0	0	1	0	0	1	
	Sehirus bicolor	0	0	1	0	0	1	
	Vespula vulgaris	0	0	0	0	1	1	
	Xylocopa violacea	0	0	1	0	0	1	
Plants	*Vitis vinifera*	0	0	1	2	35	38	
	Rosa spp.	0	0	0	1	2	3	
	Corylus avellana	0	0	0	0	2	2	
	Diospyros kaki	0	0	0	1	0	1	
	Parthenocissus quinquefolia	0	0	0	1	0	1	
	Rubus ulmifolius	0	0	0	0	1	1	
	Salvia rosmarinus	0	0	0	0	1	1	
	Trifolium pratense	0	0	0	0	1	1	
	Urtica dioica	0	0	0	0	1	1	