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Social wasp trapping in north west Italy: comparison of different bait-traps and first detection of *Vespa velutina*

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Abstract

Twelve bait-traps were tested and compared in order to find the best lure for studying social wasp populations in North West Italy. *Polistes associus* Kohl, *Polistes dominula* (Christ), *Polistes gallicus* (L.), *Polistes nimpha* (Christ), *Vespa crabro* L., *Vespa velutina* Lepeletier, *Vespula germanica* (F.), *Vespula vulgaris* (L.), and *Dolichovespula media* (Retzius) were trapped for a total of 5,077 specimens in the period 2007-2012. *V. velutina* was captured at Loano (Liguria) for the first time in Italy by means of a yellow cap trap filled with beer. *V. crabro*, *V. germanica* and *V. vulgaris* were the most abundant species in the social wasp communities studied. Beer in clear, colourless and transparent, 1.5 l polyethylene bottles with yellow and white coloured caps was a good bait-trap combinations for all social wasp species, while it trapped only some *Bombus terrestris* (L.) specimens. A white cap trap filled with commercial mint syrup solution was a good combination for trapping *Bombus argillaceus* (Scopoli) and a yellow cap trap filled with a solution of vinegar, sugar and honey was the best combination for trapping *Apis mellifera* L.

Key words: *Apis*, *Bombus*, *Dolichovespula*, *Polistes*, *Vespa*, *Vespa velutina*, *Vespula*, baited traps.

Introduction

The social wasp fauna in Europe comprises 4 genera and 22 species (de Jong, 2013), among which 21 species are recorded in Italy (Giordani Soika and Borsato, 1995). A new invasive species *Vespa velutina* Lepeletier arrived in France probably in 2004 (Haxaire *et al.*, 2006), and it is now quickly spreading across south-western Europe (Rome *et al.*, 2013); Villemant *et al.* (2006) identified this social wasp as the subspecies *nigrithorax* du Buysson (Van Der Vecht, 1957).

Social wasps are generalist foragers that collect water, plant fibres and carbohydrates, hunt arthropod preys and scavenge animal proteins (Raveret Richter, 2000). For these reasons some species are pests, interfering deeply with human activities and domestic animals (Akre *et al.*, 1980; Edwards, 1980). The presence of some *Dolichovespula*, *Polistes*, *Vespa* and *Vespula* species in crop fields, orchards, urban and suburban areas, and recreational places, often results in a pest status that ranges from mild nuisance to severe hazard for workers and people, who can be stung too (Akre *et al.*, 1980; Chang, 1988; Seath, 1999). Fatalities of humans due to hymenopteran stings is a well studied phenomenon in the United States since the past century sixties (Akre *et al.*, 1980), and up to 40 deaths per year were reported by Pollyea *et al.* (2009). In Europe, circa 20 documented deaths per year were reckoned in Germany (Przybilla and Ruëff, 2012), 1.3 and 9.4 lethal stings per year during 1980-1990 and 1994-2003, respectively, were registered in Italy (Pio *et al.*, 2012). In Australia 2.4 deaths per year caused by hymenopteran stings were mentioned, but the relative proportion of deaths from wasp and bee stings are different from and opposite to those observed in USA and Europe, with about 80% for bees (McGain *et al.*, 2000).

Damage caused to fruits by hornets, yellowjackets and paper wasps are periodically reckoned (Edwards, 1980; Simmons, 1991). Losses were reported for apples, sweet cherries, grapes, peaches, pears, plums, raspberries, and strawberries in the United States (Akre, 1982; Cranshaw *et al.*, 2011), Iraq (Al-Mahdawi and Al-Kinani, 2011), and Italy (Longo, 1980).

Depredation of wasps on honey and honey bees, *Apis mellifera* L., was known at least since the sixteenth century (Edwards, 1980). The economic importance of social wasps for beekeepers has been well ascertained in some cases: an average of 8 workers of *Vespa mandarinia* Smith were enough to destroy a hive in few hours in Japan (De Jong, 1979; Matsuura, 1988); *Vespa orientalis* L., distributed in South Europe, North Africa, Near East and the Oriental Region (Carpenter and Kojima, 1997), showed a high rate of honey bee predation in Israel (Ishay *et al.*, 1967) and India (Sihag, 1992); *V. velutina* is considered a pest because the European honey bee is more vulnerable to attacks than Asiatic bee species, as the capture rates of *A. mellifera* showed (Abrol, 2006; Tan *et al.*, 2007; Perrard *et al.*, 2009); *Vespula germanica* (F.) and *Vespula vulgaris* (L.) compete heavily with *A. mellifera* for sweet honeydew, reducing a lucrative export market in New Zealand (Clapperton *et al.*, 1989; Stringer, 1989).

Nevertheless, social wasps are also beneficial to human life by pollinating flowers, becoming food for people in Eastern countries and killing many insects which we think of as pests (Edwards, 1980; Raveret Richter, 2000). *V. germanica* and *V. vulgaris* were proposed as pest control agents in New Zealand (Donovan, 2003). The management of colonies of different social wasp species was carried out in Brazilian plantations in order to control lepidopteran pests (Prezoto *et al.*, 2006; De Souza *et al.*, 2012).

The problem of social wasp invasions into sites of human activity was initially solved by the extermination of colonies with pesticides (Wagner, 1961). Studies to test the attractiveness of different chemical products, baits and lures to social wasp species started casually during field investigations for *Fannia canicularis* (L.) (Diptera Fanniidae) in Oregon (Davis *et al*., 1967); on that occasion the attraction of different species of *Vespula* to several butyrate and propionate esters was discovered. Since then, new chemical attractants (Davis *et al*., 1968; Landolt, 1998; Day and Jeanne, 2001; Landolt *et al*., 2007), and both meat-based (Ross *et al*., 1984; Spurr, 1995; Bacandritsos *et al*., 2006) and sugar-based (Spurr, 1996; Day and Jeanne, 2001; Wegner and Jordan, 2005; Dvořák and Landolt, 2006; Dvořák, 2007) food and beverage materials were tested for trapping social wasp species.

Among different trapping methods, emerged the effectiveness of some bait-trap parameters and their combination for capturing social wasp species. Beer, in PET transparent bottle or plastic container, was a good lure for nine social wasp species in Europe (Dvořák, 2007; Sorvari, 2013) and it trapped also *V. velutina* in France (Dvořák, 2007). The colour preference of some *Vespula* species for yellow painted and translucent white traps, baited with meat-based food and chemical attractants, was demonstrated (Sharp and James, 1979; Chang, 1988). Acetic acid was a well known attractant for social wasp species when associated with other chemical products (Landolt *et al*., 2005; 2007). Meat and fish-based foods were good baits for trapping *Vespula* species in USA and New Zealand (Ross *et al*., 1984; Chang, 1988; Spurr, 1995), and *V. orientalis* in Greece (Bacandritsos *et al*., 2006). Longo (1980) experienced the use of a hydrolysed protein solution in yellow plastic bottle for trapping *V. orientalis* in an apiary in Sicily. Carbohydrates are important in the diet of adult social wasps (Raveret Richter, 2000). For this reason many sugar-based foods and beverages were tested over the years, demonstrating that 30% sucrose solution (Spurr, 1996) and carbonated beverages (Wagner and Jordan, 2005) trapped thousands individuals mainly of *Vespula* species, while commercial syrup added of fermented fruit was effective for trapping *Vespa*, *Dolichovespula* and *Polistes* species, in orchard in Central Europe (Dvořák and Landolt, 2006).

Since social wasps can became pests in urban areas, orchards and during beekeeping activities, the aims of this study were to compare different combinations of baits and traps for finding the best bait-trap combination for capturing social wasps, to characterize the social wasp fauna trapped, and to intercept *V. velutina* which is considered an alien invasive species in Europe (Beggs *et al*., 2011) and could arrive in Italy as expansion modelling shows (Rome *et al*., 2009).

Materials and methods

The attractiveness of different baits to social wasps (and non-target species) was investigated in some localities of northwest Italy from 2007 to 2012 (table 1). Areas of study were defined on the basis of the CORINE land cover technical guide and relative codes (Bossard *et al*., 2000).

Figure 1. Bait-trap used during the period 2007-2012 in north west Italy.
(In colour at www.bulletinofinsectology.org)

Wasps were trapped by means of a clear, colourless and transparent, 1.5 l polyethylene (PET) bottle with or without a proprietary coloured cap called Tap Trap® (www.taptrap.com), and filled with 0.33 l of bait (figure 1); traps were hung on a branch or a support approximately 1.7 m above the ground, and were checked weekly (table 1). The bait was changed at each trap check.

Analyses were made for each social wasp and bee species by using weekly data between the first and the last adult captures. On the basis of experimental design, data were analysed per week or totalled for the season.

Bait-trap combinations

PET bottles were baited and tested as follows: (BNC) beer with no cap: bottle without cap filled with beer 4.7% of alcohol; (BYC) beer with yellow cap: bottle with yellow cap filled with beer 4.7% of alcohol; (BWC) beer with white cap: bottle with white cap filled with beer 4.7% of alcohol; (MNC) mint with no cap; bottle without cap filled with a commercial mint syrup at 0.3% of mint essential oil diluted 1:10 in water; (MYC) mint with yellow cap: bottle with yellow cap filled with a commercial mint syrup at 0.3% of mint essential oil diluted 1:10 in water; (MWC) mint with white cap: bottle with white cap filled with a commercial mint syrup at 0.3% of mint essential oil diluted 1:10 in water; (PRNC) proprietary recipe with no cap: bottle without cap filled with a water solution of 7.1% vinegar (10%), sugar (4%) and honey (4%) according to a proprietary recipe made by Tap Trap®; (PRYC) proprietary

Table 1. Localities monitored in the period 2007-2012.

Region / Locality	Latitude	Longitude	Altitude	Habitat	CORINE code	Apiary	Years	Bait-Trap
Piedmont Grugliasco (TO)	45°03'58"N	7°35'33"E	286 m a.s.l.	Discontinuous urban fabric and Heterogeneous agricultural area	112 and 242	Yes	2007-2012	BNC; BYC; BWC; MNC; MYC; MWC; PYC; PRNC; PRYC; PRWC; WNC; WYC
Piedmont Montecomposto (TO)	45°07'41"N	7°22'26"E	728 m a.s.l.	Discontinuous urban fabric and Broad-leaf forest	112 and 311	No	2009	BYC; BWC
Piedmont Reaglie (TO)	45°03'28"N	7°44'46"E	355 m a.s.l.	Discontinuous urban fabric and Heterogeneous agricultural area	112 and 242	Yes	2009-2012	BYC; BWC
Piedmont Roascio Costabella (CN)	44°24'30"N	8°01'17"E	557 m a.s.l.	Discontinuous urban fabric and Heterogeneous agricultural area	112 and 242	No	2009	BYC; BWC
Piedmont Volvera (TO)	44°57'52"N	7°30'23"E	251 m a.s.l.	Discontinuous urban fabric and Non-irrigated arable-land	112 and 211	No	2009	BYC; BWC
Liguria Giardini Hanbury (IM)	43°47'04"N	7°33'11"E	115 m a.s.l.	Discontinuous urban fabric and Broad-leaf forest	112 and 311	Yes	2010-2012	BYC; BWC
Liguria Loano (SV)	44°08'09"N	8°14'39"E	63 m a.s.l.	Discontinuous urban fabric and Heterogeneous agricultural area	112 and 242	No	2011-2012	BYC; BWC
Liguria Savona (SV)	44°18'40"N	8°28'04"E	40 m a.s.l.	Discontinuous urban fabric and Heterogeneous agricultural area	112 and 242	No	2010-2012	BYC; BWC
Liguria Sanremo Valle Armea (IM)	43°49'33"N	7°49'45"E	17 m a.s.l.	Discontinuous urban fabric and Heterogeneous agricultural area	112 and 242	No	2010	BYC; BWC

Table 2. Social wasp communities subdivided for locality and year. Number and percentage (in brackets) for each species. TO: Turin province; CN: Cuneo province; IM: Imperia province; SV: Savona province; API: apiary site; ORC: orchard site; UCA: uncultivated area.

Locality	Year	*V. crabro*	*V. germanica*	*V. vulgaris*	*D. media*	*P. dominula*	*P. associus*	*P. gallicus*	*P. nimpha*	*V. velutina*	Total
Grugliasco (TO) - API	2007	30 (55.56)	24 (44.44)								54
Grugliasco (TO) - ORC	2007	61 (89.71)	6 (8.82)	1 (0.61)							68
Grugliasco (TO) - UCA	2007	34 (79.00)	9 (21.00)								43
Grugliasco (TO) - API	2008	136 (68,69)	33 (16.67)	11 (5.56)		16 (8.08)	2 (1.01)				198
Grugliasco (TO) - API	2009	194 (30.12)	415 (64.44)	27 (4.19)	1 (0.16)	6 (0.93)	1 (0.16)				644
Grugliasco (TO) - API	2010	266 (86.08)	36 (11.65)	2 (0.65)	2 (0.65)	3 (0.97)					309
Grugliasco (TO) - API	2011	173 (66.03)	58 (22.14)	11 (4.20)	19 (7.25)			1 (0.38)			262
Grugliasco (TO) - API	2012	125 (30.86)	241 (59.51)	26 (6.42)	2 (0.49)	9 (2.22)	1 (0.25)		1 (0.25)		405
Montecomposto (TO)	2009	60 (42.55)	2 (1.42)	76 (53.90)	3 (2.13)						141
Reaglie (TO) - API	2009	193 (48.49)	11 (2.76)	190 (47.74)	3 (0.75)	1 (0.25)					398
Reaglie (TO) - API	2010	142 (56.80)	4 (1.60)	103 (41.20)	1 (0.40)						250
Reaglie (TO) - API	2011	177 (65.07)	10 (3.68)	71 (26.10)	12 (4.41)	2 (0.74)					272
Reaglie (TO) - API	2012	238 (66.85)	13 (3.65)	104 (29.21)	1 (0.28)						356
Roascio Costabella (CN)	2009	193 (63.49)	14 (4.61)	89 (29.28)	2 (0.66)	6 (1.97)					304
Volvera (TO)	2009	62 (55.86)	44 (39.64)	2 (1.80)	1 (0.90)	2 (1.80)					111
Giardini Hanbury (IM)	2010	96 (82.76)	13 (11.21)	7 (6.03)							116
Giardini Hanbury (IM)	2011	230 (95.04)	9 (3.72)	1 (0.41)	2 (0.83)						242
Giardini Hanbury (IM)	2012	197 (91.63)	13 (6.05)	3 (1.40)		1 (0.47)		1 (0.47)			215
Loano (SV)	2011	124 (97.64)	3 (2.36)								127
Loano (SV)	2012	23 (42.59)	28 (51.85)	2 (3.70)						1 (1.85)	54
Savona (SV)	2010	123 (72.35)	36 (21.18)	10 (5.88)	1 (0.59)						170
Savona (SV)	2011	148 (81.32)	29 (15.93)	5 (2.75)							182
Savona (SV)	2012	70 (48.28)	61 (42.07)	11 (7.59)	3 (2.07)						145
Sanremo Valle Armea (IM)	2010	11 (100.00)									11
		3106 (61.18)	1112 (21.90)	752 (14.81)	53 (1.04)	46 (0.90)	4 (0.08)	2 (0.04)	1 (0.02)	1 (0.02)	5077

recipe with yellow cap: bottle with yellow cap filled with a water solution of 7.1% vinegar (10%), sugar (4%) and honey (4%) according to a proprietary recipe; (PRWC) proprietary recipe with white cap: bottle with white cap filled with a water solution of 7.1% vinegar (10%), sugar (4%) and honey (4%) according to a proprietary recipe; (PYC) protein with yellow cap: bottle with yellow cap filled with a 1% protein solution in water made with a commercial meat extract so as to meet the same protein content used by Longo (1980); (WNC) water with no cap: bottle without cap filled with water as control; (WYC) water with yellow cap: bottle with yellow cap filled with water as control.

The traps PRYC and PRWC were tested for two reasons: a) the bait was proposed in combination with a coloured cap by a commercial site for trapping hornets, b) acetic acid is a well known attractant for social wasp. WNC and WYC were used as control.

2007 trapping test

Traps were placed on the campus of the Agricultural Faculty of the University of Turin at Grugliasco. Three sites 200 m apart each other were chosen: 1) front of the Apiary (API), about 15 m apart from the hives; 2) an orchard (ORC) and 3) an uncultivated area (UCA). In each site five bait-trap treatments were placed: BYC, PRYC, PYC, WNC, and WYC; traps were set along a line about 3 m apart from each other and their positions were interchanged weekly. The experiment started on 7th September and finished on 9th November for a total of seven week observations.

2008 trapping test

Traps were placed on the campus of the Agricultural Faculty of the University of Turin at Grugliasco in front of the Apiary (API), about 15 m apart from the hives. Nine trap treatments were tested: BNC, BYC, BWC, MNC, MYC, MWC, PRNC, PRYC, and PRWC; they were set in a square design at about 3 m apart from each other and their positions were randomly changed every week. The experiment started on 1st April and finished on 16th December for a total of 36 inspection occasions.

2009-2012 trapping test

Each year five localities were chosen on the basis of the following characteristics: two localities were heterogeneous agricultural areas in the immediate vicinity of apiaries, two localities were heterogeneous agricultural areas without nearby apiaries and one locality was a broad-leaf forest area (table 1). Traps were placed in nine localities altogether during the period 2009-2012 (table 2). Trap treatments were: BYC and BWC only; they were set about 3 m apart from each other and their position changed weekly. The experiment in each locality started on 18th March and finished at the end of December.

Data analysis

The social wasp species trapped were identified using descriptions and keys provided in Guiglia (1972), Starr and Luchetti (1993), Dvořák and Roberts (2006) and Buck *et al*. (2008); bumblebees were named using the monograph of Intoppa *et al.* (2009).

For each species, the means of individuals captured per trap per week were compared between trap-bait treatments. All analyses were performed using IBM SPSS 2.0 (SPSS, 1994), OpenStat (2013) and Jandel SigmaPlot 11.0 (Systat Software Inc, San Jose, CA, USA).

In 2007, the trapping test data were submitted to two way ANOVA with repetitions. In 2008, trapping test data were submitted to ANOVA for randomized block design with one observation per cell and weeks as blocks. In both years, the count data were transformed using log (count + 1).

In 2009-2012, the trapping test data were submitted to two way ANOVA with repetitions. Bait-trap combinations and year were considered fixed factors, with 2 and 4 levels, respectively. Each cell contained 5 repetitions, and each repetition represented the total number of individuals trapped per year per locality. Analyses was implemented for each social wasp species. In 2009-2012, the total annual number of individuals of *A. mellifera* trapped in each locality with BYC and BWC, was correlated with the number of hives present near the bait-trap position.

Differences in treatments were tested by pairwise multiple comparison procedures such as Tukey's HSD at $\alpha = 0.05$ significant level. The blank treatments were removed from the analysis and one-side confidence intervals for treatment means were used to make this decision more quantitative in accord with Reeve and Strom (2004), but using the mean square of error from the analysis of variance table. After analysis, results were back-transformed into the original units of measurement following Olsson (2005).

Dominance and diversity

Dominance classes, as defined by Engelmann (1978), were used and the following six classes were established: eudominant > 32%, dominant 10-31.9%, subdominant 3.2-9.9%, recedent 1.0-3.1%, subrecedent 0.32-0.99 % and sporadic < 0.32%.

Diversity values of the social wasp community from BYC and BWC bait-traps, and overlap between them, were calculated according to Jost (2007):

Species richness $= (\Sigma_1^{s} p_i^{q})^{1/(1-q)} \quad q = 0$

$^{q}D_{\alpha} = \exp\{[-w_1\Sigma_1^{s}(p_{i1}\ln p_{i1})]+[-w_2\Sigma_1^{s}(p_{i2}\ln p_{i2}]+...\} \quad q = 1$

$^{q}D_{\gamma} = \exp[\Sigma_1^{s}(w_1p_{i1}+w_2p_{i2}+...)\ln(w_1p_{i1}+w_2p_{i2}+...)] \quad q = 1$

$^{q}D_{\beta} = {}^{q}D_{\gamma}/{}^{q}D_{\alpha} \quad q = 1$

Overlap of q order 1 $= (\ln 2 - H_{\beta\ Shannon})/\ln 2$

where p_i is the proportion of each species, w_i is the weight of each community, q is the order of diversity measure, D_{α}, D_{β} and D_{γ} are diversities expressed as "number equivalent species" and H_{β} is the β Shannon entropy.

Results

More than 6,000 adult Hymenoptera were trapped during the period from 2007 to 2012 in 9 localities of north-western Italy for a total of 22 annual inspections (table 2). Nine species of social wasps (table 2) and three species of social bees were identified (table 3).

Table 3. Specimens of *A. mellifera* and *B. terrestris* trapped during the period 2009-2012, number of hives near bait-trap sites and ratio between honey bees and hive numbers are reported.

Locality	Years	Hive number	Honey bees / Hives	*A. mellifera*	*B. terrestris*	Total specimens trapped
Grugliasco (TO)	2009	26	3.42	89		89
Grugliasco (TO)	2010	20	1.95	39		39
Grugliasco (TO)	2011	36	5.67	204		204
Grugliasco (TO)	2012	27	8.15	220		220
Montecomposto (TO)	2009	0		1		1
Reaglie (TO)	2009	10	0.70	7	1	8
Reaglie (TO)	2010	10	3.20	32		32
Reaglie (TO)	2011	16	0.31	5		5
Reaglie (TO)	2012	15	7.40	111		111
Roascio Costabella (CN)	2009	0		2		2
Volvera (TO)	2009	0		0		0
Giardini Hanbury (IM)	2010	0		0		0
Giardini Hanbury (IM)	2011	4	0.25	1	1	2
Giardini Hanbury (IM)	2012	4	2.75	11		11
Loano (SV)	2011	0		1	1	2
Loano (SV)	2012	0		2		2
Savona (SV)	2010	0		7		7
Savona (SV)	2011	0		1	1	2
Savona (SV)	2012	0		8		8
Sanremo Valle Armea (IM)	2010	0		0		0
				741	4	745

In the 2007 trapping test, a total of 125 *V. crabro*, 39 *V. germanica*, 1 *V. vulgaris* and 63 *A. mellifera* was caught exclusively in BYC and PRYC bait traps. The difference in the mean values between the captures in the three locations was not statistically significant for all species: *V. crabro* $F_{2;\ 36} = 0.877$, $P = 0.425$, *V. germanica* $F_{2;\ 30} = 2.280$, $P = 0.120$, *A. mellifera* $F_{2;\ 36} = 2.113$, $P = 0.136$. Moreover, there was not interaction between locations and bait traps for all species analysed: *V. crabro* $F_{2;\ 36} = 2.437$, $P = 0.102$, *V. germanica* $F_{2;\ 30} = 1.195$, $P = 0.317$, and *A. mellifera* $F_{2;\ 36} = 0.0766$, $P = 0.926$. BYC and PRYC attractiveness was not statistically different for *V. crabro* ($F_{1;\ 36} = 0.276$; $P = 0.266$), while PRYC trapped more adults of *V. germanica* ($F_{1;\ 30} = 5.713$; $P = 0.023$) and *A. mellifera* ($F_{1;\ 36} = 7.902$; $P = 0.008$) than BYC. Attractiveness of BYC bait traps was not different from blank traps for *V. germanica* and *A. mellifera* (table 4).

In the 2008 trapping test, 136 *V. crabro*, 33 *V. germanica*, 11 *V. vulgaris*, 21 *Polistes dominula* (Christ), 2 *Polistes associus* Kohl, 84 *A. mellifera* and 1 *Bombus argillaceus* (Scopoli) were trapped. *V. crabro* was caught in five bait traps and a significant difference between them was observed ($F_{4;\ 76} = 2.132$; $P < 0.001$). BYC and BWC trapped more hornets than BNC, PRWC and PRYC; moreover the three last ones showed lower confidence limits near or including the zero value as blank traps (table 4). *V. germanica*, *V. vulgaris* and *P. dominula* were found in six, seven and six bait traps, respectively, and there were no differences in attractiveness between the bait traps tested in each species: *V. germanica* $F_{6;\ 72} = 1.425$, $P = 0.217$, *V. vulgaris* $F_{5;\ 35} = 0.452$, $P = 0.809$, *P. dominula* $F_{5;\ 125} = 1.174$, $P = 0.326$. Moreover, lower confidence limits were near or included the zero value as blank traps (table 4). *A. mellifera* was captured in nine bait traps and a significant difference between them was observed ($F_{8;\ 256} = 3.819$, $P < 0.001$). PRYC trapped more honeybees than all others bait traps, but it was statistically different from MWC, BNC, MNC and MYC only (table 4). *P. associus* was trapped with BWC and PRYC bait-traps. Only one *B. argillaceus* was found in a MWC bait-trap.

In the period 2009-2012, a total of 2845 *V. crabro*, 1 *V. velutina*, 1040 *V. germanica*, 74 *V. vulgaris*, 53 *Dolichovespula media* (Retzius), 30 *P. dominula*, 2 *P. associus*, 1 *P. gallicus* (L.), 1 *Polistes nimpha* (Christ), 741 *A. mellifera* and 4 *Bombus terrestris* (L.) was trapped. For all species tested there were not statistically significant differences between BYC and BWC bait-traps, years and interaction bait-trap x year (table 5). A male of *V. v. nigrithorax* (figure 2), a new invasive social wasp species for Italy, was trapped at Loano (SV) on 19th November 2012 by means of a BYC trap.

Other trapped insect specimens belonged to the following taxa in decreasing order: Diptera, Lepidoptera, Neuroptera, Coleoptera, Mecoptera, Hemiptera, Dermaptera, Thysanoptera, Orthoptera, and Blattodea.

Three social wasp species were abundant and occurred in nearly all inspections. Only *V. crabro* was nearly totally eudominant, while *V. germanica* and *V. vulgaris* mainly ranged from subdominant to eudominant categories. All other social wasp species were mainly categorized at subrecedent and sporadic levels (table 2). Among Apidae, *A. mellifera* was a nearly euconstant species and 741 adults were trapped during 20 inspections (table 3). Nevertheless, a positive correlation between the number of *A. mellifera* adults trapped in the period 2009-2012 and the number of hives present near

Table 4. Mean (adults captured per trap-bait per week), Upper and Lower Confidence Limit, number of samples analysed in 2007 and 2008. For each species, means followed by the same letter are not significantly different at $P \leq 0.05$ by Tukey's test, NT (Not Tested). Statistics are the result of back-log transformation.

Species	BNC	BYC	BWC	MNC	MYC	MWC	PRNC	PRYC	PRWC	PYC	WYC	WNC
Trapping test 2007												
Vespa crabro	NT	1.90a; 3.20; 1.00; n = 21	NT	NT	NT	NT	NT	2.70a; 4.36; 1.55; n = 21	NT	0b	0b	0b
Vespula germanica	NT	0.40b; 0.83; 0.07; n =18	NT	NT	NT	NT	NT	1.38a; 2.12; 0.82; n = 18	NT	0b	0b	0b
Apis mellifera	NT	0.44b; 0.94; 0.08; n =21	NT	NT	NT	NT	NT	1.80a; 2.76; 1.09; n = 21	NT	0b	0b	0b
Species	BNC	BYC	BWC	MNC	MYC	MWC	PRNC	PRYC	PRWC	PYC	WYC	WNC
Trapping test 2008												
Vespa crabro	0.66b; 1.05; 0.35; n = 20	2.71a; 3.56; 2.01; n =20	1.91a; 2.58; 1.37; n = 20	0c	0c	0c	0c	0.08c; 0.33; −0.12; n = 20	0.16bc; 0.43; −0.06; n = 20	NT	NT	NT
Vespula germanica	0.15a; 0.40; −0.06; n = 13	0.31a; 0.61; 0.07; n = 13	0.53a; 0.88; 0.25; n = 13	0a	0.15a; 0.40; −0.06; n = 13	0a	0.09a; 0.33; −0.11; n = 13	0.21a; 0.48; −0.01; n = 13	0.12a; 0.37; −0.08; n = 13	NT	NT	NT
Vespula vulgaris	0a	0.21a; 0.47; −0.01; n = 8	0.21a; 0.47; −0.01; n = 8	0a	0.11a; 0.35; −0.10; n = 8	0a	0.11a; 0.35; −0.10; n = 8	0.32a; 0.61; 0.08; n = 8	0.21a; 0.47; −0.01; n = 8	NT	NT	NT
Polistes dominula	0.04a; 0.12; −0.04; n = 26	0.06a; 0.15; −0.01; n = 26	0.04a; 0.12; −0.04; n = 26	0a	0.05a; 0.14; −0.02; n = 26	0a	0.14a; 0.23; 0.06; n = 26	0.12a; 0.21; 0.04; n = 26	0a	NT	NT	NT
Apis mellifera	0.09b; 0.22; −0.03; n = 33	0.28ab; 0.43; 0.14; n = 33	0.19ab; 0.33; 0.06; n = 33	0.09b; 0.22; −0.03; n = 33	0.09b; 0.22; −0.03; n = 33	0.13b; 0.26; 0.01; n = 33	0.28ab; 0.44; 0.14; n = 33	0.51a; 0.70; 0.34; n = 33	0.35ab; 0.52; 0.20; n = 33	NT	NT	NT

Table 5. More abundant species trapped in the period 2009-2012 and two way ANOVA test results. In BYC and BWC columns are reported: Means (adults per year per site), SEM, (range); in BAIT-TRAP, YEAR and YEARx-BAIT-TRAP columns are reported results of tests. N=40.

Species	BYC	BWC	Bait-trap ANOVA test	Year ANOVA test	Year × bait-trap ANOVA test
V. crabro	62.35 ± 9.23 (3-148)	75.45 ± 9.23 (4-155)	$F_{1; 32} = 1.01$ P = 0.323	$F_{3; 32} = 0.88$ P = 0.462	$F_{3; 32} = 0.32$ P = 0.810
V. germanica	28.00 ± 11.67 (0-247)	24 ± 11.67 (0-168)	$F_{1; 32} = 0.06$ P = 0.810	$F_{3; 32} = 1.38$ P = 0.268	$F_{3; 32} = 0.06$ P = 0.982
V. vulgaris	17.20 ± 5.65 (0-97)	19.80 ± 5.65 (0-59)	$F_{1; 32} = 0.11$ P = 0.747	$F_{3; 32} = 2.84$ P = 0.053	$F_{3; 32} = 0.10$ P = 0.960
D. media	0.80 ± 0.67 (0-7)	2.20 ± 0.67 (0-16)	$F_{1; 32} = 2.15$ P = 0.153	$F_{3; 32} = 3.11$ P = 0.04	$F_{3; 32} = 0.63$ P = 0.602
P. dominula	0.80 ± 0.35 (0-7)	0.85 ± 0.35 (0-5)	$F_{1; 32} = 0.01$ P = 0.921	$F_{3; 32} = 0.93$ P = 0.439	$F_{3; 32} = 1.30$ P = 0.290
A. mellifera	15.75 ± 7.95 (0-119)	21.30 ± 7.95 (0-119)	$F_{1; 32} = 0.24$ P = 0.625	$F_{3; 32} = 1.25$ P = 0.308	$F_{3; 32} = 0.09$ P = 0.967

Figure 2. Male of *V. velutina* trapped at Loano (Liguria) on November 19th, 2012. Length of right fore-wing from tegula to apex is 20 mm.
(In colour at www.bulletinofinsectology.org)

trap-bait points was showed: r = 0.86, $r^2 = 0.74$, n = 20, P < 0.01; however about 26% of variance was due to chance (figure 3).

Among the total of *V. crabro* trapped, 296 males were found in BNC, BYC, BWC, PRYC and PRWC bait-traps. More than 93% of *V. crabro* males were caught in beer bait-traps with coloured cap, almost with no difference between yellow and white cap. *V. crabro* males were trapped in the period from end July to mid November.

β-diversity calculated for all samples over the period 2008-2012 ranged from 1.000 to 1.049, so communities trapped with BYC and BWC were actually the same. But overlap values and the difference between total sample richness and common species number were less than 100% and more than zero, respectively, in 18 out 21 samples (table 6).

Discussion

Social wasps are generalist foragers on sugar and animal proteins from natural and anthropogenetic sources (Raveret Richter, 2000). Since the first casual capture of

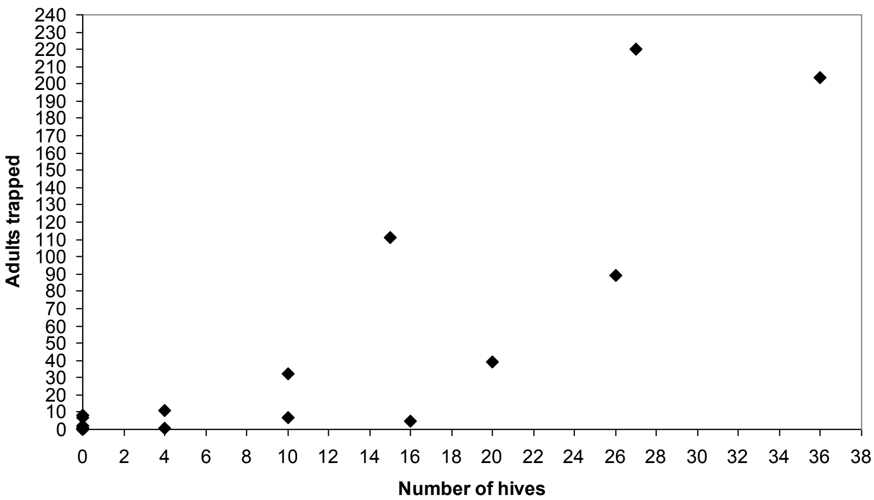

Figure 3. Scatter plot for the number of *A. mellifera* trapped and number of hives present near the bait-trap site. Data from 20 annual monitored localities in the period 2009-2012 where BYC and BWC were tested.

Table 6. Diversity values of social wasp communities trapped by means of BYC and BWC trap-baits in each locality in the period 2008-2012. Beta diversity (D_β), overlap between BYC and BWC, total species richness (SR_{TOT}), common species (CS), species richness in BYC (SR_{BYC}) and species richness in BWC (SR_{BWC}).

Grugliasco	2008	2009	2010	2011	2012
D_β	1.021	1.004	1.022	1.024	1.035
Overlap (%)	96.99	99.45	96.85	96.38	95.20
SR_{TOT}	5	6	5	5	7
CS	4	4	3	4	3
SR_{BYC}	4	5	4	4	5
SR_{BWC}	5	5	4	5	5
Reaglie	2008	2009	2010	2011	2012
D_β		1.049	1.005	1.024	1
Overlap (%)		93.16	99.61	96.37	99.75
SR_{TOT}		5	4	5	4
CS		3	3	4	3
SR_{BYC}		4	3	4	3
SR_{BWC}		4	4	5	4
Montecomposto	2008	2009	2010	2011	2012
D_β		1.013			
Overlap (%)		97.27			
SR_{TOT}		4			
CS		3			
SR_{BYC}		3			
SR_{BWC}		4			
Roascio	2008	2009	2010	2011	2012
D_β		1.008			
Overlap (%)		98.88			
SR_{TOT}		5			
CS		4			
SR_{BYC}		4			
SR_{BWC}		5			
Volvera	2008	2009	2010	2011	2012
D_β		1.030			
Overlap (%)		99.70			
SR_{TOT}		5			
CS		2			
SR_{BYC}		5			
SR_{BWC}		2			
Giardini Hanbury	2008	2009	2010	2011	2012
D_β			1.000	1.000	1.014
Overlap (%)			99.86	99.71	97.68
SR_{TOT}			3	4	5
CS			3	3	3
SR_{BYC}			3	3	5
SR_{BWC}			3	4	3
Savona	2008	2009	2010	2011	2012
D_β			1.029	1.000	1.046
Overlap (%)			96.35	99.71	93.42
SR_{TOT}			4	3	4
CS			3	3	3
SR_{BYC}			4	3	3
SR_{BWC}			3	3	4
Loano	2008	2009	2010	2011	2012
D_β				1.009	1.045
Overlap (%)				99.60	93.63
SR_{TOT}				2	4
CS				1	2
SR_{BYC}				1	3
SR_{BWC}				2	3
Sanremo	2008	2009	2010	2011	2012
D_β			1.000		
Overlap (%)			100		
SR_{TOT}			1		
CS			1		
SR_{BYC}			1		
SR_{BWC}			1		

yellowjackets with synthetic chemicals (Davis *et al*., 1967), also meat and sugar based food and beverage material were tested across the world for trapping and controlling social wasp species in an effective, economic and selective manner, relatively to Apidae (Wegner and Jordan, 2005). Beer, indicated as anecdotal lure for yellowjackets (Wegner and Jordan, 2005), is well known as a total of 10 social wasp species were caught in Europe using it (Dvořák, 2007; Roberts and Dvořák, 2008; Sorvari, 2013). During this trapping investigation 9 species were caught with beer bait-traps and among them 3 sporadic species (*P. associus*, *P. gallicus* and *P. nympha*) which were absent in previous European studies; moreover, beer allowed also the catching of *V. velutina*, as it already happened in France (Dvořák, 2007). To date, 13 social wasp species have been trapped with beer in Europe over the period 2006-2012, while 8, 5 and 2 social wasp species were trapped with syrup (Dvořák and Landolt, 2006), chemical attractants (Landolt *et al*., 2007) and fish and meat proteins (Bacandritsos *et al*., 2006), respectively. When bait-traps were compared one to another in experimental groups, beer bait-traps with coloured caps resulted the best lures for *V. crabro*, and to a lesser extent for *Vespula* and *Polistes* species which were trapped in the same statistical quantity also by MYC, PRNC, PRYC and PRWC bait-traps. The preference showed by each social wasp species or genus for different attractants is a well known phenomenon: synthetic organic compounds, such as esters of butyric, isobutyric and propionic acids, acetic acid, and isobutanol, trapped more *Vespula* species than *Dolichovespula*, *Polistes* and *Vespa* species (Landolt, 1998; Day and Jeanne, 2001; Wegner and Jordan, 2005; Landolt *et al*., 2007); animal proteins, such as meat- and fish-base food products trapped a great number of *Vespula* species (Ross *et al*., 1984; Spurr, 1995) and *V. orientalis* (Bacandritsos *et al*., 2006); sugar based food was an effective attractant for either *Vespula* species (Spurr, 1996; Wegner and Jordan, 2005; Dvořák and Landolt, 2006) or *V. crabro* (Dvořák and Landolt, 2006). But these associations could change because the same attractant works in different manners on the basis of the geographical location as demonstrated by Grothaus *et al*. (1973). In our study the same attractants set up in different sites, such as apiary, orchard and uncultivated area, showed the same attractiveness for each species analysed; indeed in the 2007 experimental design there was no interaction between the site and bait-trap tested.

The four most abundant and constant social wasp species trapped in north-western Italy seem to characterize the majority of European social wasp communities present in bait-traps, but the relative percentages change in each study (Dvořák and Landolt, 2006; Dvořák, 2007; Landolt *et al*., 2007; Roberts and Dvořák, 2008; Sorvari, 2013). In our samples *V. crabro* was mainly eudominant and euconstant, while *V. vulgaris* was so in other countries (Dvořák, 2007), except in Greece where *V. orientalis* was the only eudominant species (Bacandritsos *et al*., 2006). Instead, the subrecedent and sporadic species trapped in Italian localities were taxonomically different respect to the results obtained in other European countries. In our samples we found only *Polistes* species, while in other localities *Dolichovespula norwegica* (F.), *Dolichovespula saxonica* (F.), *Dolichovespula sylvestris* (Scopoli) and *Vespula rufa* (L.) were trapped too (Dvořák, 2007; Landolt *et al*., 2007; Roberts and Dvořák, 2008; Sorvari, 2013). Differences in the relative abundance and species composition are probably due to factors, such as geography, habitat, altitude, and climatic conditions (Dvořák, 2007), but also the length of the monitoring period could play a role, characterising social wasp communities trapped: indeed, we monitored 20 times over a year and in 5 localities for more than 1 year consecutively.

One remarkable result was the first individual of *V. v. nigrithorax* trapped at Loano (SV) in the Liguria region. This species arrived in Italy 7 years after the first yellow-legged hornet was caught in France at Nérac, Lot-et- Garonne (Haxaire *et al*., 2006). So, it is confirmed that *V. velutina* spreads at around 100 km per year in Europe (Rome *et al.*, 2013), while it has spread at a rate of 10-20 km per year in South Korea (Choi *et al*., 2012). Following monitoring activities will show if this sample is an isolate incidental introduction away from the invasion front, as it happened in Belgium (Rome *et al*., 2012), or *V. velutina* is well established at Loano. The presence of the yellow-legged hornet in localities very far from the invasion front (Rome *et al.*, 2013) seems to confirm that a good dispersal way of *V. velutina* is by human transport, probably on freight vehicles.

On the other hand, *A. mellifera* was trapped by all bait-traps tested except PYC, a protein bait, but the best attractant was PRYC containing about 0.8% of acetic acid, sugar and honey. Some *B. argillaceus* and *B. terrestris* were trapped with MWC and BYC bait-traps, respectively. In experimental designs across the world, the number of honey bees and bumble bees present in bait-traps ranged from zero, when synthetic organic compounds and food volatile products were used (Davis *et al*., 1968; Landolt, 1998; Day and Jeanne, 2001), to few specimens when sugar-based food (Spurr, 1996), fruity carbonated beverage (Wegner and Jeanne, 2005), syrup with fermented fruits (Dvořák and Landolt, 2006) and meat- and fish-based food (Bacandritsos *et al*., 2006) were used. In Europe no honey bees and bumble bees were caught with beer as bait (Dvořák, 2007; Roberts and Dvořák, 2008; Sorvari, 2013). Our results apparently demonstrate a high presence of honey bees, mainly in beer bait-traps with coloured cap, but the highest captures of *A. mellifera* were near the largest apiary and the number of honey bees trapped per hive and per year ranged from 0.25 to 8.15, so very few individuals relatively to the hive population were trapped; moreover, our experimental design lasted all the entire active season, while generally in other works the trapping period was of few days, weeks or months.

Odour and visual stimuli together are well known to stimulate the foraging activity of *V. germanica* mainly when bait and conspecific adults are present in the same container (D'Adamo *et al*., 2000; 2003). For *V. vulgaris*, *V. rufa*, and *D. sylvestris*, Mazokhin-Porshniakov (1960) demonstrated that they distinguish green, yellow and orange coloured paper sheets of various shades. Also *Polybia occidentalis* (Olivier) was demonstrated to be able to recognise different colours after a training period with food reward (Shafir, 1996). Spectral sensitivity of single photoreceptors, measured in *P. gallicus*, *V. germanica*, *V. vulgaris*, *V. crabro*, and *D. norwegica*, showed three major peaks at UV, blue and green wavelengths (Peitsch *et al*., 1992). In our 2008 experimental design for the first time bait-traps with and without coloured cap were tested together and the results seem to demonstrate that *V. crabro* preferred bait-traps with coloured cap, while *V. germanica*, *V. vulgaris*, and *P. dominula* chose indifferently bait-traps with and without coloured cap although the absolute number of adults trapped was higher in coloured bait-traps than in others. Instead, there was no difference in the number of adults trapped between yellow and white bait-traps for all social wasp species tested in the 2009-2012 experimental design, while it has been demonstrated that the two bait-traps used together trapped a social wasp community richer than a single coloured bait-trap.

In conclusion, among the bait-trap combinations tested, BYC and BWC were relatively good lures on the basis of requisites proposed by Wegner and Jordan (2005). The beer bait-trap was an effective and economic lure, trapping social wasp species independently from habitat and geographical position; moreover it caught social wasp species all along the year and the capture of honey bees and bumblebees was incidental. Nevertheless, BYC and BWC seemed to be more useful for monitoring activity than for mass trapping activity, as the rather modest number of individuals captured in each locality and year demonstrated. The trapping effectiveness of BYC and BWC was highest when they were used together. Finally, BWC trapped *V. velutina* at Loano (SV), exactly in an highly probabilistic area as defined by the provisional model elaborated by Rome *et al*. (2009).

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