Social wasp (Hymenoptera: Vespidae) beer trapping in Finland 2008–2012: a German surprise

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Sorvari, J. 2013: Social wasp (Hymenoptera: Vespidae) beer trapping in Finland 2008–2012: a German surprise. — Entomol. Fennica 24: 156–164.

Beer trapping has been carried out annually in the summer in south western Finland (Turku) from 2008 to 2012 inclusive. In 2012, an additional trapping programme was conducted in southern (Helsinki), central (Kuopio) and northern (Kevo) Finland, which also included another trapping location in the south western (Turku) region. The traps were always presented for seven days in each location. While the median wasp *Dolichovespula media* (Retzius, 1783) was present in all locations, the common wasp *Vespula vulgaris* Linnaeus, 1758 was found in five out of six locations (20 traps per site). The Kevo individual represents the northernmost record for the median wasp species. The German wasp *Vespula germanica* (Fabricius, 1793) was surprisingly common in south western and southern Finland. *Vespula germanica* has a short history of occurrence in Finland and seems to have shifted its range northwards, possibly due to climate change. Some common species of the genus *Dolichovespula* Rohwer, 1916 were likely underrepresented, because they are not very attracted by beer.

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Received 4 February 2013, accepted 26 February 2013

1. Introduction

Social wasps collect protein food for their growing larvae and carbohydrate food for their own nutrition. Nectar from flowers, aphid honey-dew, sap and fermenting fruits are natural carbohydrate sources for social wasps (e.g., Witt 2009). Beer has been shown to be an effective trapping substance in social wasp monitoring studies (Dvořák 2007, Dvořák & Roberts 2007, Roberts & Dvořák 2008). However, it also seems to have some limitations since not all social wasp species are equally attracted by fermented products or carbohydrates (Seath 1999, Wegner & Jordan 2005, Dvořák & Landolt 2006).

The German wasp *Vespula germanica* (Fabricius, 1793) is a central and southern European species with a natural range between North Africa in the south and 60°N in Eurasia, extending to 64°N in Sweden (Kurzenko 1982, Witt 2009, Douwes *et al.* 2012). In Finland, the known nesting population was limited to the Åland Islands until 1998 (Söderman 1999; for location of Åland Islands see Fig. 1).

There have been only three observations of *V. germanica* in continental Finland prior to 2000; all of which were non-nesting queens (Pekkarinen & Hulden 1995, Johansson & Pekkarinen 2000). However, those queens that migrated to continental Finland have been unsuc-

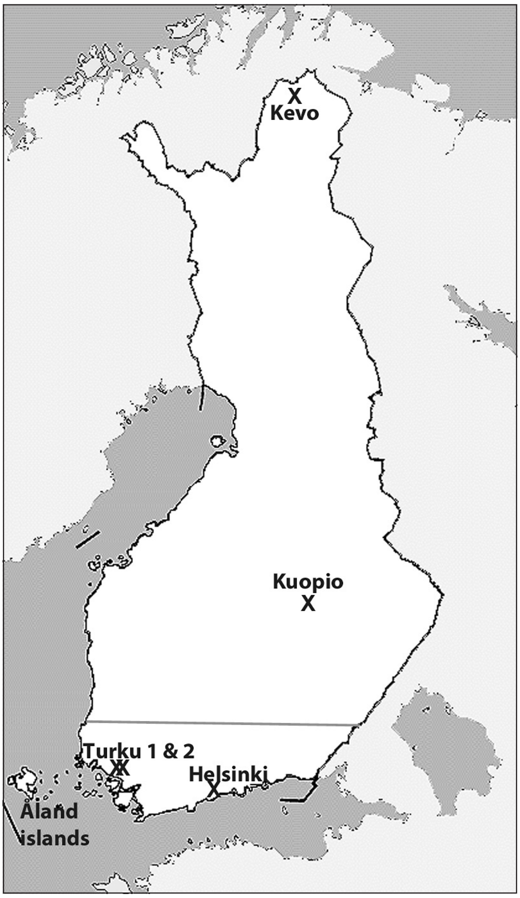

Fig. 1. The trapping locations. Turku 1 was studied 2008–2012, the others in 2012. The line across southern Finland indicates the northern limit of observations of *Vespula germanica* workers in Finland: city of Rauma in the west and Imatra in the east. The Åland Islands were the only region colonized by *V. germanica* in Finland before year 2001.

cessful in founding colonies. For example, in March 1996 a newly deceased queen was found on the snow from Turku (Johansson & Pekkarinen 2000) which is located in the southwest corner of continental Finland (see Fig. 1). It seems that the early emergence from hibernation has been the likely limiting factor for successful colonisation in northern areas (Johansson & Pekkarinen 2000).

Although *V. germanica* was caught in Åland Islands and along the Baltic coast in Russia, Estonia, Latvia and Lithuania, it was not captured in continental Finland during an extensive yellow trap monitoring project in 1997–1998 (Söderman 1999). Similarly, it was not caught in continental Finland in yellow and white traps in 1996 (Söderman *et al.* 1997).

Since 2001 there have been several observations of *V. germanica* workers in southern Finland, particularly around the greater Helsinki area (i.e. cities of Helsinki, Espoo and Vantaa; R. Molini, J. Paukkunen, J. Pöyry, I. Teräs & S. Väänänen, pers. comm.). One breeding colony was found in Turku in the summer of 2005 (Eeva *et al.* 2006). Earlier in the same period another colony was also found in Turku, located under the stairs of a grocery store (Sorvari unpubl.). However, it was exterminated by the management due to the nuisance caused by the high number of foragers.

It seems that since the abovementioned yellow trap monitoring projects (Söderman *et al.* 1997, Söderman 1999), *V. germanica* has become reasonably common in continental Finland, at least in the most southern part of the country. Nevertheless, studies monitoring its recent abundance have been lacking. Since beer has been shown to attract *V. germanica* (Dvořák 2007, Roberts & Dvořák 2008), it seems that beer trapping is an ideal method for monitoring.

My study questions were threefold. First, what species compositions are attracted to beer in different parts of Finland? Second, what kind of species variation occurs at one of the trapping locations over a five year period? Third, how common *V. germanica* is in traps at different parts of Finland?

2. Material and methods

2.1. Traps

A beer trap was composed of transparent disposable plastic container (0.5 litres) covered with a transparent Petri-dish lid (Fig. 2). A circular opening of 2.5 cm was made on the upper part of the container to allow wasps to enter. Trap transparency may be important for trapping efficiency; otherwise wasps can easily find their way out through the opening. Four litres of trapping liquid was needed for 20 traps (0.2 litres per trap). Trapping liquid was made from 25 g of fresh

Fig. 2. Beer trap type. Traps are made from transparent plastic containers with a hole in upper side, a transparent Petri-dish cover and steel wire for hanging the trap. Photo: J. Sorvari.

yeast and 5 tablespoons of brown sugar mixed with four litres of lager beer (alcohol 4.7%-vol.). Using steel wire, the traps were hung on trees and bushes at heights of one to four metres above the ground.

2.2. Study design

Trapping was conducted in four different regions in Finland; Turku (southwest), Helsinki (south), Kuopio (central), and Kevo (north; for locations see Fig. 1). In Turku (SW), two different sets of traps were used (i.e. Turku 1 & 2). A series of Turku 1 traps was located along the river Aurajoki (east of the city centre, ETRS89/WGS84 coordinates: N60.465°: E22.293°; 10–25 m a.s.l.). The Turku 2 trap series spread through the town from Mälikkälä in the northwest to Lauste in the southeast (Turku city centre: N60.451°: E22.267°; 10–40 m a.s.l.). The Helsinki trap series was located from Hietaniemi in the city centre to Kontula in the northeast (Helsinki: N60.170°: E24.938°; 10–50 m a.s.l.).The Kuopio trap series was located around the city centre of Kuopio (from Jynkkä in the south to Julkula in the north, Kuopio city centre: N62.892°: E27.678°; 40–120 m a.s.l.). The Kevo trap series was located northeast from the Kevo Subarctic Research Station (University of Turku) along the river valley of Gidešjohka (Kidisjoki) in Utsjoki, Lapland (N69.781°: E27.023°; 90–210 m a.s.l.). Each trap series consisted of 20 spatially separate traps. The minimum distance between the closest pairs of traps was approximately 200 m. In all locations, traps were located in bushy ecotones between open areas in forests or parks.

The Turku 1 trap series was repeated in the same locations on the same trees and bushes over five consecutive years (2008–2012) during the first three weeks in August, with trapping occurring for a one week period each time. The trapping periods for the other sites were Kevo: 10.–16.VII, Kuopio: 2.–9.VIII, Turku 1 & 2: 7.–14.VIII and Helsinki: 8.–15. VIII. The traps were always presented for seven days in each location: for longer periods more attractant would have been needed. The weather was typical warm late summer weather with some showers but without the rain lasting for an entire day. Kevo was an exception to this with moderately cold weather (details below).

2.3. Statistical methods

The five year data of the Turku 1 trap series was analysed with a repeated measures generalized linear model using trap as a repeated subject (five years with same traps in same locations) in the models. While the data in other locations was analysed similarly, it was done without a repeated factor (traps used only during one year). The

Table 1. Summary of the catch of social wasp species in beer traps. For each species, number of individuals caught, mean number of individuals per trap (in parentheses) and percentage of traps occupied by the species (%) are presented. *Vvul* = *Vespula vulgaris*, *Vger* = *V. germanica*, *Vruf* = *V. rufa*, *Dmed* = *Dolichovespula media*, *Dsax* = *D. saxonica*, *Dnor* = *D. norwegica*.

Traps	Date & year	*Vvul*	*Vger*	*Vruf*	*Dmed*	*Dsax*	*Dnor*
Turku 1	13.–20.VIII.	208 (10.4)	296 (14.8)	1 (0.05)	–	–	–
	2008	100%	90%	5%	–	–	–
Turku 1	1.–8.VIII.	45 (2.25)	17 (0.85)	3 (0.15)	–	–	–
	2009	90%	40%	15%	–	–	–
Turku 1	30.VII–6.VIII.	429 (21.45)	132 (6.6)	–	39 (1.95)	2 (0.1)	–
	2010	100%	95%	–	65%	10%	–
Turku 1	4.–11.VIII.	73 (3.65)	6 (0.3)	2 (0.1)	37 (1.85)	1 (0.05)	–
	2011	95%	25%	5%	75%	5%	–
Turku 1	7.–14.VIII.	189 (9.45)	181 (9.05)	–	50 (2.5)	2 (0.1)	–
	2012	100%	100%	–	65%	10%	–
Turku 2	7.–14.VIII.	123 (6.15)	18 (0.9)	1 (0.5)	12 (0.6)	–	–
	2012	100%	30%	5%	35%	–	–
Helsinki	8.–15.VIII.	104 (5.2)	3 (0.15)	–	5 (0.25)	–	–
	2012	90%	10%	–	20%	–	–
Kuopio	2.–9.VIII.	149 (7.45)	–	–	9 (0.45)	5 (0.25)	–
	2012	85%	–	–	35%	20%	–
Kevo	10.–16.VII.	–	–	–	1 (0.05)	–	1 (0.05)
	2012	–	–	–	5%	–	5%

number of individuals per trap was analysed using the number of individuals of each species as a dependent variable with Poisson distribution (counts) and log link-function. Trap occupancy rates were analysed using the presence of species as a binomial variable (0 = not found in trap, 1 = found) with a logit link-function. Multiple comparisons were made with step-down sequential Bonferroni correction tests (*p*-values ranked from smallest to largest and sequentially removing the most significant pair-wise). The analyses were performed using the procedure GENMOD in SAS 9.2 statistical software (SAS institute, Cary, NC, USA).

3. Results

3.1. Species caught

The beer traps caught a total of 2,144 social wasp workers belonging to six species: *Vespula vulgaris* Linnaeus, 1758, *V. germanica* (Fabricius, 1793), *V. rufa* Linnaeus, 1758, *Dolichovespula media* (Retzius, 1783), *D. norwegica* (Fabricius, 1781), and *D. saxonica* (Fabricius, 1793) (Table 1). All species, except *D. norwegica*, were present in the combined five year catch of the Turku 1 trap series. Turku 2 lacked *D. norwegica* and *D. saxonica*, while the Helsinki trap series lacked *V. rufa*, *D. norwegica*, and *D. saxonica*, and the Kuopio series lacked *V. germanica*, *V. rufa*, and *D. norwegica*. By comparison, the Kevo trap series lacked all but *D. media* and *D. norwegica*. Although the only species found in all of the trapping locations was *D. media*, it was not caught in the Turku 1 trap series in the years 2008 and 2009. While *V. germanica* was present in Turku 1 (in all five years), Turku 2 and Helsinki trap series, it did not occur in the Kuopio and Kevo trap series. In addition to workers, 11 males of *V. vulgaris* and 1 male of *V. germanica* were found in the traps in 2008. In other years and trap series, all individuals were workers. The males ($N = 12$) were not used in further analyses.

3.2. Turku 1 trap series

The number of individuals caught differed between species (repeated generalized linear model: $df = 4$, $\chi^2 = 627.83$, $p < 0.0001$). The numbers of individuals differed between all species

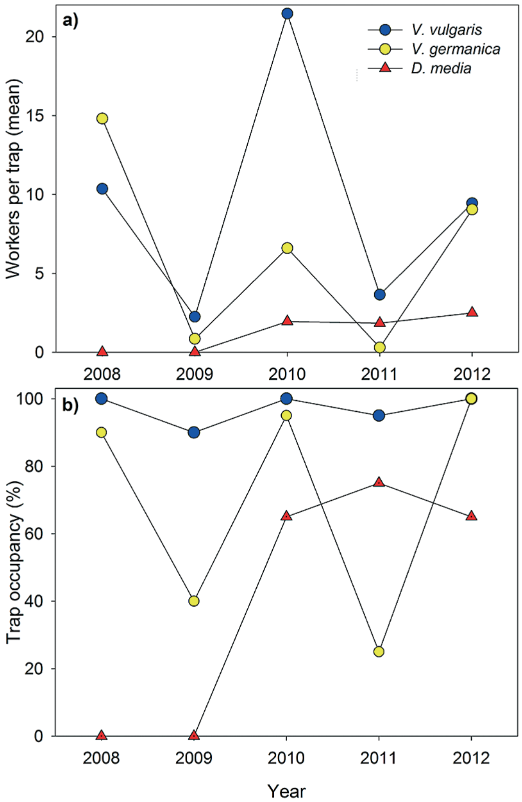

Fig. 3. Variations in numbers and occupancy rates of social wasps in Turku 1 trap series among years 2008–2012. – a. Mean numbers of individuals per trap. – b. Occupancy rates.

pairs except between *V. rufa vs. D. saxonica* (multiple comparisons with sequential Bonferroni corrections, *V. rufa vs. D. saxonica*: $p = 0.78$; all other species pairs: $p < 0.05$). The number of individuals caught varied differently between species and years (repeated generalized linear model, interaction term year × species: $df = 5$, $\chi^2 = 732.51$, $p < 0.0001$; Fig. 3a for *V. vulgaris*, *V. germanica*, and *D. media*). The trap occupancy rate (probability of occurrence of the species in traps) differed between the species (repeated generalized linear mixed model: $df = 4$, $\chi^2 = 227.73$, $p < 0.0001$). The trap occupancy rate differed between all other species pairs except between *V. rufa vs. D. saxonica* (multiple comparisons with sequential Bonferroni corrections, *V. rufa vs. D. saxonica*: $p > 0.99$; other species pairs: $p < 0.05$). The similarity in numbers of individuals in traps and trap occupancy rates between *V. rufa* and *D. saxonica* was apparently due to the very low numbers of both species in the traps. The trap occupancy rates varied between species and years (repeated generalized linear model, interaction term year × species: $df = 5$, $\chi^2 = 231.58$, $p < 0.0001$; Fig. 3b for *V. vulgaris*, *V. germanica*, and *D. media*).

The data from year 2012 was analysed separately to compare Turku 1 with other locations. The number of individuals caught differed between species (generalized linear model: $df = 3$, $\chi^2 = 113.64$, $p < 0.0001$). The numbers of individuals differed between all other species pairs except between *V. vulgaris vs. V. germanica* (multiple comparisons with sequential Bonferroni corrections, *V. vulgaris vs. V. germanica*: $p = 0.68$; other species pairs: $p < 0.05$). The trap occupancy rates of *V. vulgaris* and *V. germanica* were both 100%, whereas it was 65% in *D. media* and 10% in *D. saxonica*. The rates differed between species (generalized linear model: $df = 3$, $\chi^2 = 10.23$, $p = 0.017$). The trap occupancy rate differed between all other species pairs except between *V. vulgaris vs. V. germanica* (multiple comparisons with sequential Bonferroni corrections, *V. vulgaris vs. V. germanica*: $p > 0.99$; other species pairs: $p < 0.05$).

3.3. Turku 2 trap series

The number of individuals caught differed between species (generalized linear model: $df = 3$, $\chi^2 = 125.19$, $p < 0.0001$). The numbers of individuals differed between all species pairs except between *V. germanica vs. D. media* (multiple comparisons with sequential Bonferroni corrections, *V. germanica vs. D. media*: $p = 0.28$; other species pairs: $p < 0.05$). The trap occupancy rate differed between the species (generalized linear model: $df = 2$, $\chi^2 = 676.49$, $p < 0.0001$). The occupancy rate of *V. vulgaris* (100%) was significantly higher than in the other species having occupancy rates from five to 35%, which did not differ significantly from each other's (sequential Bonferroni corrected pair-wise differences, *V. vulgaris vs.* others: p-values < 0.05; other species pairs: p-values > 0.05).

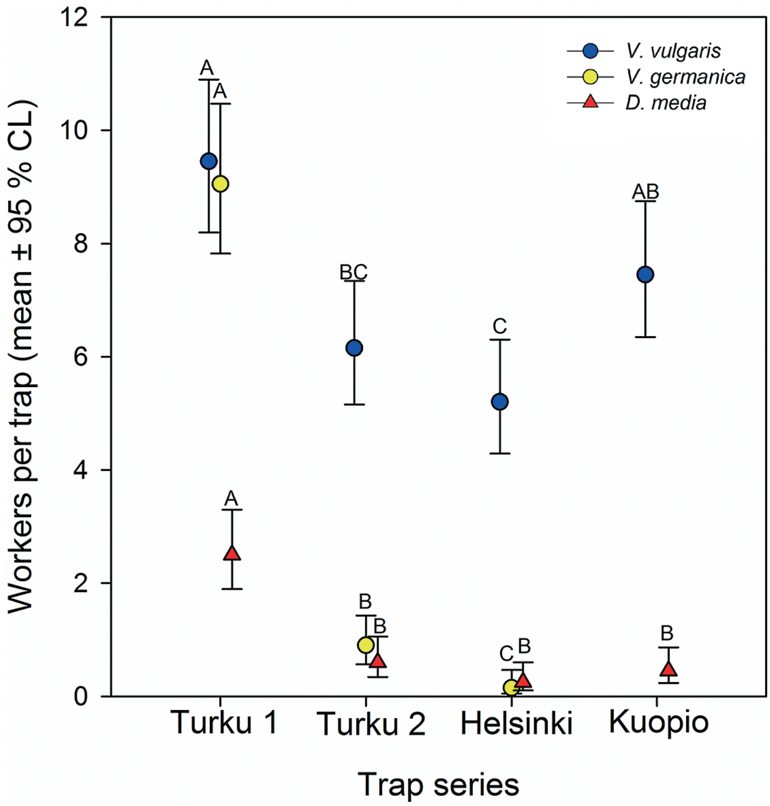

Fig. 4. Mean numbers of social wasp individuals per trap in Turku 1, Turku 2, Helsinki and Kuopio trap series in summer 2012. Symbols represent estimated marginal means and asymmetric 95% confidence limits computed with a generalized linear model. A different letter above symbols between the same species indicates statistically significant differences between trap series after a sequential Bonferroni correction.

3.4. Helsinki trap series

The number of individuals caught differed between species (generalized linear model: $df = 2$, $\chi^2 = 77.82$, $p < 0.0001$). The numbers of individuals were significantly higher in *V. vulgaris* than in the other species, whereas the number of individuals did not differ between the others, i.e., *V. germanica* and *D. media* (multiple comparisons with sequential Bonferroni corrections, *V. vulgaris vs. D. media* and *V. vulgaris vs. V. germanica*: both $p < 0.05$; *V. germanica vs. D. media*: p=0.48). The trap occupancy rate differed between the species (generalized linear model: $df = 2$, $\chi^2 = 20.64$, $p < 0.0001$). The occupancy rate of *V. vulgaris* was 90% (18 out of 20 traps) and was significantly higher than in *V. germanica* and *D. media*, which did not differ significantly from each other (occupancy rates 10 and 20%, respectively; multiple comparisons with sequential Bonferroni corrections, *V. vulgaris vs. D. media* and *V. vulgaris vs. V. germanica*: both $p < 0.05$, *V. germanica vs*. *D. media*: $p = 0.38$).

3.5. Kuopio trap series

The number of individuals caught differed between species (generalized linear model: $df = 2$, $\chi^2 = 112.32$, $p < 0.0001$). The numbers of individuals were significantly higher for *V. vulgaris* than for other species, whereas the number of individuals did not differ between the others, *D. media* and *D. saxonica* (multiple comparisons with sequential Bonferroni corrections, *V. vulgaris vs. D. media* and *V. vulgaris vs. D. saxonica*: both $p <$ 0.05; *D. media vs*. *D. saxonica*: p=0.09). The trap occupancy rate differed between the species (generalized linear model: $df = 2$, $\chi^2 = 15.20$, $p =$ 0.0005). The occupancy rate of *V. vulgaris* was 85% (17 out of 20 traps) and was significantly higher than in *D. media* and *D. saxonica*, which did not differ significantly from each other (occupancy rates 35 and 20%, respectively; multiple comparisons with sequential Bonferroni corrections, *V. vulgaris vs. D. media* and *V. vulgaris vs. D. saxonica*: both $p < 0.05$; *D. media vs*. *D. saxonica*: $p = 0.13$).

3.6. Kevo trap series

The June–July mean temperature was about 1°C colder than usually in Kevo region in Lappland in summer 2012 (Finnish Meteorological Institute 2013). Possibly due to the cool weather only two wasp individuals were caught (one *D. media* and one *D. norwegica*). Therefore, further analyses were unnecessary and data from Kevo is not used in analyses of between sites comparisons. The small catch, however, was surprisingly interesting since the *D. media* individual caught was the northernmost record of the species (distribution in, e.g., Pekkarinen & Huldén 1995, Witt 2009, Douwes *et al.* 2012).

3.7. Between sites comparison

Of the wasp species *V. vulgaris*, *V. germanica*, and *D. media* were the most common species contributing together over 99.1% of the individuals (*V. vulgaris*: 61.5%; *V. germanica*: 30.5%; *D. media*: 7.1%) and the results remain almost the same when data from years 2008–2011 (of Turku 1) are removed: the species triplet constitutes 98.9% of the individuals (*V. vulgaris*: 66.2%; *V. germanica*: 23.7%; *D. media*: 9.0%). Because these three species were clearly the most abundant, their relative abundance was compared between the sites (excluding Kevo).

The trap series (locations) differed significantly for all of the three most abundant species (generalized linear models, *V. vulgaris*: $df = 3$, $\chi^2 = 28.20$, $p < 0.0001$; *V. germanica*: $df = 3$, $\chi^2 = 131.97$, $p < 0.0001$; *D. media*: $df = 3$, $\chi^2 = 51.86$, $p < 0.0001$; Fig. 4). The number of *V. vulgaris* workers was highest in Turku 1 trap series, followed by Kuopio, Turku 2 and Helsinki, respectively (Fig. 4). The number of *V. germanica* workers was highest in Turku 1 followed by Turku 2 and Helsinki (not in Kuopio). The number of *D. media* workers was also highest in Turku 1, followed by Turku 2, Kuopio and Helsinki.

4. Discussion

4.1. General

The species composition of the present study closely resembles those of previous beer-trapping studies made by other researchers in Europe (Dvořák 2007, Dvořák & Roberts 2007, Roberts & Dvořák 2008). The only real difference is the absence of the European hornet *Vespa crabro* Linnaeus, 1758 which was very commonly found in other studies. In addition, the catches of *V. rufa* and *Dolichovespula* species other than *D. media* were similarly marginal in those beer trapping studies. Although beer trapping cannot be used to monitor populations of all social wasp species, it is useful in monitoring the four species (*V. vulgaris*, *V. germanica*, *D. media*, and *V. crabro*). While *V. crabro* has recently been found in several places in southern Finland (Teräs *et al.* 2003) its absence in the beer traps may indicate its rareness around cities, possibly because it is strongly associated with forests (Dvořák 2007, Roberts & Dvořák 2008).

Yearly fluctuations in the abundance of *V. vulgaris* and *V. germanica* may be caused by weather conditions, especially those of spring (and perhaps summer and autumn) or by endogenous factors affecting queen quality or survival (Archer 1985). It has been observed that when the number of colony founding queens is high in the spring, the following summer shows either a decreased or at least, no increase in the number of workers (Archer 1985). This is explained by the poorer quality of mass-produced queens and/or by competition for nesting places, resulting in a high mortality of queens due to fighting during frequent colony usurpations (Archer 1985). Warm spring weather has been shown to shift the phenology of *V. germanica* earlier (Tryjanowski *et al.* 2010). Therefore, the colonies may be bigger in summers after a warm spring due to shifted phenology. In addition, parasites, pathogens and predators may also cause variations in wasp abundances (Spradbery 1973). Migration of queens can be important, especially in *D. media* (see Fig. 3b), which undergo mass migrations occasionally (see Mikkola *et al.* 2007). The mass migrations of queens are possibly caused by unfavourable weather conditions. In early summer

2007, *D. media* displayed a mass migration in southern Finland, which resulted in a population crash at the end of the summer (Mikkola *et al.* 2007). The absence of *D. media* in traps in both 2008 and 2009 (Turku 1) may have been caused by the observed population crash.

4.2. *Vespula germanica*

Bearing in mind the recent colonization of continental Finland by *V. germanica*, it was surprisingly common in southern Finland. It has apparently shifted its range rapidly northwards, likely due to climate change. Climate driven range shifts have been observed earlier in butterflies (Parmesan *et al.* 1999, Crozier 2003, Pöyry *et al.* 2009). The northernmost record of *D. media* found in this study may indicate that other social wasps may also respond to climate change with a similar northward shift.

According to the results of beer trapping of this study, *V. germanica* has been on average the second most common social wasp in the Turku region (SW-Finland) since the summer 2008, second only to its sister species *V. vulgaris*. Thus far, the northernmost records of breeding *V. germanica* colonies (indicated by the presence of foraging workers) in western Finland are from Rauma (N61.129°: E21.505°; J. Sorvari, summer 2012) and in eastern Finland from Imatra (N61.198°: E28.769°; J. Jantunen, pers, comm. & photographs, summer 2011) (see Fig. 1).

Vespula germanica has been accidentally carried outside its native range by human activities and has become a serious invasive species in Australia, New Zealand, Argentina, Chile, Canada, USA, South Africa, Malta, Canary Islands (Spain) and Madeira (Portugal) (Spradbery & Dvořák 2010). It has also been introduced to Iceland but is not considered there as an invasive species (Spradbery & Dvořák 2010). This species has several ecological characters that make it potentially a highly invasive species, e.g., it has wide native range, it is highly adaptable to different environments, it is tolerant to anthropogenic disturbance and it has fast colony growth and a broad spectrum of diet (Spradbery & Dvořák 2010). These ecological characters are also likely to affect its successful and rapid range expansion in southern Finland.

Further studies and additional locations are needed to monitor the actual range of the species in Finland. In addition to *V. germanica*, the spread of *V. crabro* in its northern limits could likely be monitored with beer trapping.

Acknowledgements. Two anonymous referees gave valuable comments on the previous draft of the manuscript. T. Andersson (Kevo Subarctic Research Station, University of Turku) carried out the beer trapping in Kevo and gave comments on the manuscript. In addition, I'm grateful for J. Jantunen, R. Molini, J. Paukkunen, J. Pöyry, I. Teräs and S. Väänänen for their information concerning observations of *V. germanica* in Finland. The study was funded by Kone foundation and Emil Aaltonen Foundation.

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