The Asian hornet *Vespa velutina nigrithorax* was introduced in southern France in 2004. During the inventory in 2009, nests were found in the vicinity of Paris. To predict the potential occurrence in The Netherlands, a CLIMEX study has been conducted. The results show the likely geographic origin of European populations of the hornet in Yunnan province (China), and the suitability of climate in The Netherlands for support their populations.

**Keywords:** modelling, potential distribution, climate change scenarios, Hymenoptera, honeybee pest

In 2004, the Asian Hornet *Vespa velutina nigrithorax* was introduced in southern France. The suggestion is that one or several fertile females were transported in ceramic pots from Yunnan (China) origin, used for bonsai plants. By the end of 2009, this invasive species was recorded in 32 France departments (INPN 2010), covering a distance larger than 600 km, Paris being the most northern record. By the end of 2010 *V. velutina* has also been reported in the northern provinces of Spain, Navarre and Basque Country (Drs. Capdevila-Argüelles & Zilletti, Grupo Especialista en Invasiones Biológicas, pers. comm.), where it seems to have spread on its own. This means that *V. velutina nigrithorax* reaching The Netherlands could soon be a reality.

The Asian hornet is native to Southeast Asia, including northern India, China and the mountains of Sumatra and Sulawesi (Archer 1994). Apparently, the climate in those parts of the world is warmer from that in The Netherlands, so the establishment of populations in The Netherlands would be hampered by the hardiness of the Dutch climate. In France, overwintering queens where found in tree trunks (Mollet & De la Torre 2007) where frost does not penetrate. That means that also *V. velutina nigrithorax* could try to allocate places to hibernate in natural areas, similar to what the native hornet *Vespa crabro* does in The Netherlands.

To analyze the possibility of the establishment of *V. velutina nigrithorax* in The Netherlands, several experts were consulted. Professor Ken Tan (Yunnan

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Agricultural University, China, pers. comm.) Quentin Rome (Muséum National d’Histoire Naturelle, Paris, France, pers. comm.) and Dr. Wolfgang Rabitsch (Biologische Vielfalt & Naturschutz, Vienna, Austria, pers. comm.) all expect V. velutina nigrithorax would survive and reproduce under Dutch climatic conditions. Maxent (Maximum Entropy Methods) analysis based on geographic distribution records in Asia and in France predicts indeed that V. velutina nigrithorax can establish in The Netherlands and in the most areas of Europe (see figures in Rome et al. 2009). To confirm and compare Maxent results specifically in The Netherlands, a CLIMEX study has been done.

CLIMEX is a software package that contains two quite different climate-matching tools. There is the CLIMEX ‘Match Climates’ function (a tool for comparing the meteorological data of different places without reference to any particular species), and the CLIMEX model (a simulation model that enables the user to estimate the potential geographical distribution and seasonal abundance of a species in relation to climate). The CLIMEX study made for V. velutina nigrithorax includes the following subjects: Climate Matching, CLIMEX model, and study of the model under Climate Change Scenarios (+1 °C, +2 °C).

Climate matching

The Match Climates application allows the user to select a location (the ‘Home’ location) and find locations (the ‘Away’ locations) whose climate is similar to that of the ‘Home’ location. In CLIMEX, the similarity of the climate between the ‘Home’ and the ‘Away’ locations is measured by the Composite Match Index (CMI), a value between zero and one, with higher values corresponding to a greater match between locations (Sutherst et al. 2007). CMI >0.7 means good matching (0.7 is the limit of reasonable availability), and if CMI = 1, climates are exactly the same (Darren Kritikos, pers. comm.).

Mollet & De La Torre (2007) suggest that the first specimens were accidentally introduced into France with Chinese merchandise imported from Yunnan province. The original area of the introduced populations in France is still unknown, not even after the completion of a research on comparing DNA of specimens from France with specimens of Yunnan (Kunming, Wuding, Mengzi and Jianchuan) (Arca et al. 2009). In CLIMEX, four meteorological stations from Yunnan Province are included: Zhaotung, Kunming, Mengzi and Tengchong. Since 2005, V. velutina nigrithorax populations are found in southern France. It suggests that the climate in this region is suitable and comparable to the climate of their place of origin. If we use meteorological stations in southern France as Bordeaux (or Toulouse, Limoges, etc.) as ‘Home’ location, and using the Match Climates application, location Zhaotong (Fig. 1) in Yunnan (China) appears with CMI values >0.7. In contrast, the other meteorological stations in southern Asia register values <0.7. Therefore, location Zhaotong has a climate most similar to southern France and could potentially be the origin of the introduced population in France. V. velutina nigrithorax is a species that lives in...
Zhaotong (Dong & Wang 1992), and this location has not yet been taken in for a DNA compare research.

If we use the application with Zhaotong as ‘Home location’, the resulting map (Fig. 2) shows CMI > 0.7 in Europe from the Pyrenees to the middle of The Netherlands (Vlissingen: 0.70; Rotterdam: 0.71; Gilze-Rijen: 0.70; De Bilt: 0.70; Maastricht: 0.70). Netherlands CMI values for weather stations are similar to

![Figure 1. Location Zhaotong (Yunnan) in China.](image1.png)

![Figure 2. Zhaotong (Yunnan, China) Match Climate Europe. Green triangles indicate the locations of Vespa velutina nests until 2009 (INPN 2010), blue dots indicate stations where CMI >0.7, and crosses indicate stations where CMI <0.7. The red circle and blue lines indicate the current distribution in Europe and the area with a climate similar to Zhaotong.](image2.png)
that in the locations in France, where the Asian hornet has settled populations (CMI Bordeaux: 0.76; CMI Limoges: 0.72).

Fig. 3 shows the result of comparing the climate of a location where the Asian hornet has a registered population in Europe (for instance Limoges in France), with the climate of the rest of Europe. CMI >0.7 (good matching) shows in almost all Europe including all weather stations in The Netherlands: Den Helder, Leeuwarden, Groningen, Amsterdam, De Bilt, Winterswijk, Rotterdam, Gilze-Rijen and Maastricht.

**Climex model**

CLIMEX enables the user to estimate the potential geographical distribution and seasonal abundance of a species in relation to climate, and is applied to a species by selecting values for a set of parameters that describe its response to temperature, moisture and light (Sutherst *et al.* 2007). The biology of *V. velutina nigrithorax* remains poorly documented, and very few studies have been conducted on the insect in its natural range of distribution (Perrard *et al.* 2009; Claire Villemant, pers. comm.). Parameters such as threshold temperatures, degree days per generation, etc. are still not available to build a CLIMEX model.

Perrard *et al.* (2009) describes that the activity of *V. velutina nigrithorax* can occur under rainy, cloudy and clear weather conditions. They also describe that the nests of *V. velutina nigrithorax* observed under natural conditions in France showed a rhythm of activity similar to the trends observed also in France on *Vespula vulgaris* (L. 1758), and *Vespula germanica* (Fabricius 1793). In the CLIMEX software Version 3, a full set of parameter values is available for the

![Figure 3. Limoges (France) Match Climate Europe. Green triangles indicate the locations of Vespa velutina nests until 2009 (INPN 2010), blue dots indicate stations where CMI >0.7, and crosses indicate stations where CMI <0.7.](image-url)
latter species. The model parameters of *V. germanica* (Fig. 4) were manually slightly adjusted until the simulated potential geographical distribution indicated by the Ecoclimatic Index (EI) values agreed with the *V. velutina nigrithorax* known native distribution in Yunnan and Southern Asia (Fig. 5).
The EI describes the overall favourability of any location for that particular organism. The EI is scaled between 0 and 100. EI scores of 1-5 are generally interpreted as marginally climatically suitable habitat, 6-25 suitable, and >25 represents a very favourable climate for a species (Kriticos & Leriche 2010). The reference climate dataset (1961-1990) used by CLIMEX was used to project the threat posed by *V. velutina nigrithorax* in Europe (Fig. 6). Under the current climate *V. velutina* is projected to be capable of establish in the most part of Europe, including The Netherlands. EI value around Limoges (Central France) where populations of *V. velutina nigrithorax* are present is 18. EI values in The Netherlands range from 16 in South (Limburg) until 11 in North (Groningen), indicating that Dutch climate conditions would be suitable for *V. velutina nigrithorax*.

**Climate change scenarios**

Under the reference climate dataset (1961-1990) *V. velutina nigrithorax* is projected to be capable of establishing in the most of Europe. In the last 10 years, average temperature in The Netherlands raised around +1 °C compared with temperature between 1971-2000 (KNMI 2010). The CLIMEX software enables users to consider the potential implications of climate change (setting new temperature and rainfall parameters) on the potential geographical distribution and seasonal phenology and survival of species (Sutherst *et al.* 2007). The projected geographic distribution of *V. velutina nigrithorax* under +1 °C climate change scenario provides a better indication of the current risk (Fig. 7). The future risk was gauged using a climate change scenario of +2 °C (with an increase of the rainfall in summer and a decrease during the winter months). This scenario makes The Netherlands more suitable for establishing of populations of the hornet (Fig. 7).

Figure 6. Model *Vespa velutina nigrithorax* (0.5° world grid meteorological data) Europe. Triangles: Locations *V. velutina*, Red gradation: EI values.
DISCUSSION

Similar to the Maxent analysis (Rome et al. 2009), the CLIMEX analysis indicates that V. velutina nigrithorax would be able to establish in The Netherlands under the current climatic conditions. An incursion of V. velutina nigrithorax in The Netherlands could have an important impact on beekeeping, ecosystems and biodiversity. The CLIMEX model analysis, based on the species parameter values of Vespula germanica, is validated by the presence of V. velutina nigrithorax.
in its natural range of distribution in Asia and in the locations in France. According to the Match Climates analysis, location Zhaotong in Yunnan province (China) would most likely be the place where the first specimens came into France with the pottery.

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**REFERENCES**


