Detection of Asian hornet (*Vespa velutina*) colonies using harmonic radar

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The Asian yellow-legged hornet (*Vespa velutina* Lepeletier 1836) is an invasive alien species that represents a serious threat to European pollinators. Its fast expansion throughout Europe indicates that efficient restraint measures are needed.

The detection and destruction of colonies at the invasion front or outbreaks, before the emerging of reproductive individuals, actually represent the main countermeasure against the expansion of this pest, but nest detection is often difficult as they usually are well hidden in vegetation and sometimes located inside tree canopies. During summer 2017 and 2018, an harmonic radar prototype developed within the LIFE STOPVESPA Project has been successfully used in nest-detection operations in Liguria region, Italy.

The harmonic radar allows to track the flights of foraging hornets equipped with a small passive transponder (tag), in order to detect the position of the colonies they came from. The small dimension and lightweight transponder provides various advantages in terms of maintenance of flying capabilities, allowing tagged hornets to continue successfully their foraging activities, enabling operators to track both nest-returning and outgoing flights.

The rotary radar unit is equipped with two different antennas; the emitting antenna spreads a signal that is doubled by a passive transponder glued dorsally on the hornet's thorax, and successively detected by the receiving antenna. The position of tagged hornets is recorded in real time by a specifically developed software. The positions of the hornets are recorded with an accuracy of ± 2,5 m.

The detection of hornet colonies may need movements of the radar unit, particularly in order to overstep physical objects (buildings, trees, etc.) or geomorphological constraints in complex topographic contexts that limit signal reception.

Nests are easily detected when some tracks converge in a single point; subsequently a team provides for the visual identification of nests position.

Tagging operations require the following steps:

- capture of a *V. velutina* worker, generally during its hunting activity near honey bee colonies;
- insertion of the hornet in a Falcon tube;
- immobilization of the hornet, through tweezers and a cotton wad, on the edge of the tube;
- attachment of the tag on the hornet's thorax through an orthodontic adhesive and subsequent exposure to UV light for about 20 seconds, to induce polymerization.

The flying success after the tagging procedure is high and can reach values of 100%; this represent an advantage during operations in invasion fronts or outbreaks, where the number of foraging hornets in apiaries is low.

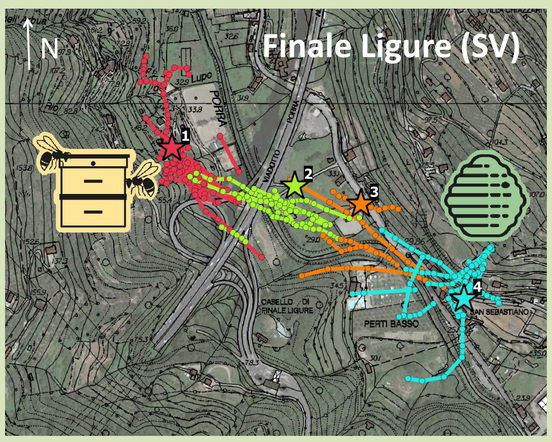
The transponder is made by a diode welded to a copper wire antenna with diameter of 0,25 mm. The tag length is 12 mm and its average weight does not overcome 20 mg.

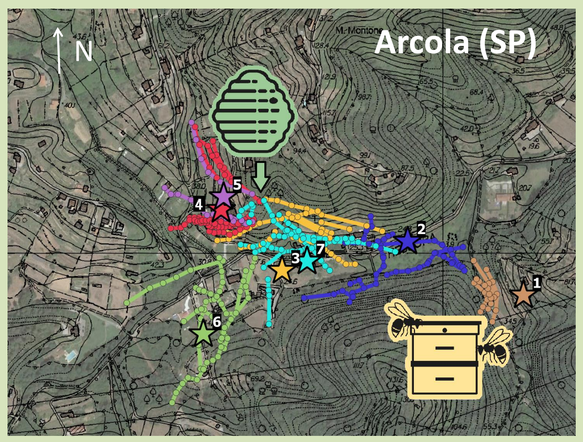
The tag is able to receive the electro-magnetic signal sent by the radar at a frequency of 9,41 GHz and to retransmit it back at a doubled frequency (18,82 GHz). In this way the signal emitted by the tag can be isolated in a univocal way from other returning-signals. A paper support is also added, in order to enhance the contact surface between the tag and the hornet's thorax, thus facilitating the adhesion between the two surfaces.

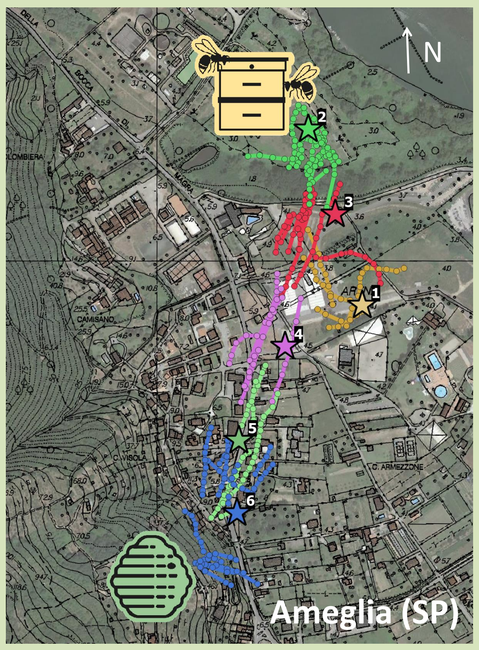
The functionality of each of the tags is preventively verified in the lab with a spectrum analyzer, to maximize the efficiency in the field.

The finding of 3 previously undiscovered nests in invasion front (Finale Ligure - province of Savona) and outbreaks zones (Ameglia and Arcola - province of La Spezia) demonstrates the high potential of harmonic radar in containing *V. velutina* spread. In La Spezia province, volunteers from local beekeeper associations ALPA Miele, ApiLiguria and Toscana Miele provided support in hornet capture operations and in visual research of nest positions.

Locality	Distance between beehives and hornet nest (m)	N° of radar movements	N° of Operators	N° tagged hornets	Radar detection time (h)
ARCOLA (SP)	448	7	4 + 7 volunteers	14	23
AMEGLIA (SP)	786	6	3 + 8 volunteers	21	12
FINALE LIGURE (SV)	561	4	4	21	10,5







The table and the figures show harmonic radar operational performances in invasive outbreaks zones in La Spezia (Arcola e Ameglia) and Savona provinces (Finale Ligure). The cartographic representations are reproduced at 1:5000 scale; the yellow symbols represents the apiaries where the Asian hornet were captured while the green symbols indicates the position of the discovered nests. The radar locations are indicated by a star and progressively numbered with the same color of the tracks obtained in that location, in order to correlate the radar position with hornets' tracks.

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