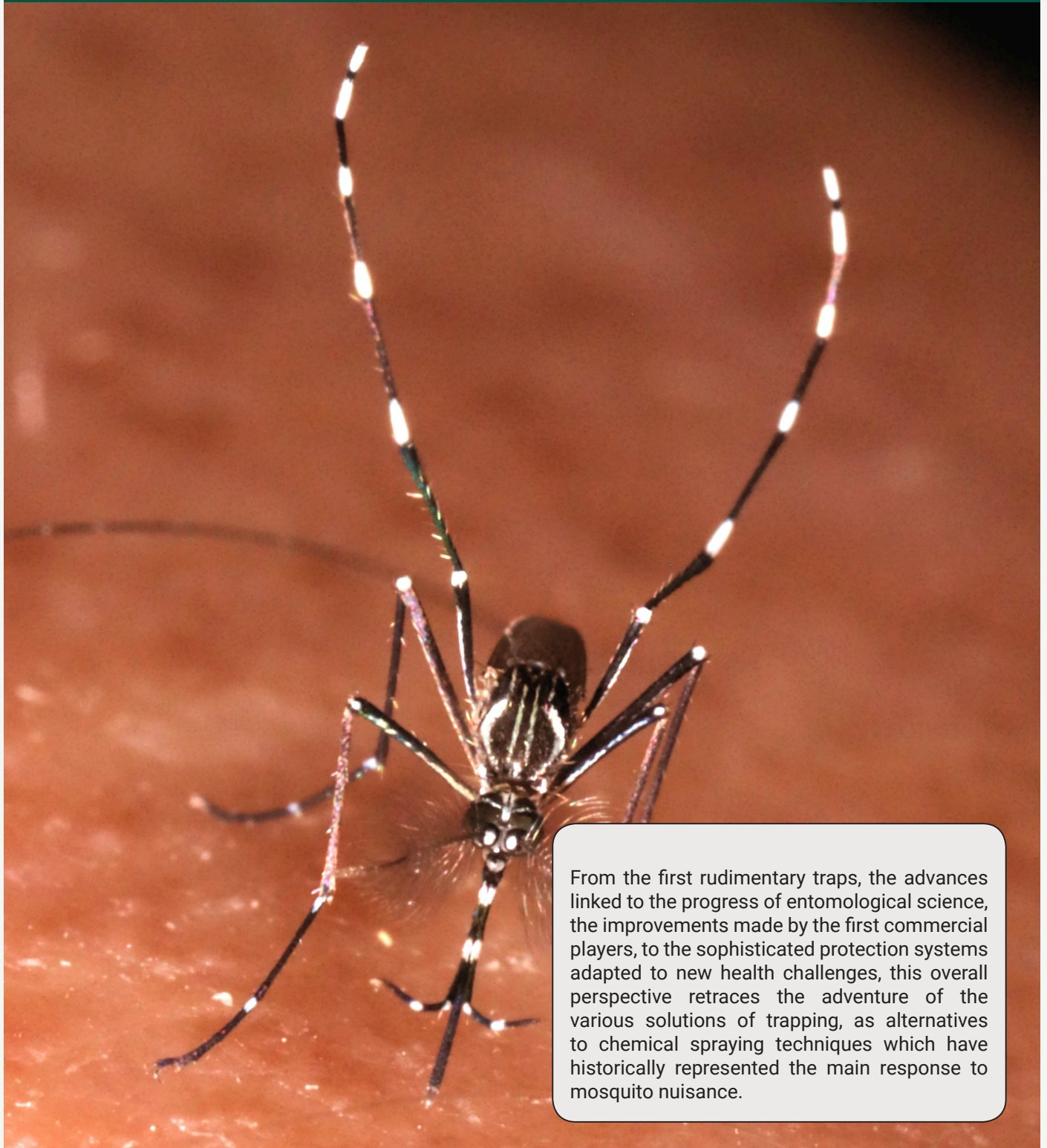


## The perspectives of different trapping solutions for capturing mosquitoes



From the first rudimentary traps, the advances linked to the progress of entomological science, the improvements made by the first commercial players, to the sophisticated protection systems adapted to new health challenges, this overall perspective retraces the adventure of the various solutions of trapping, as alternatives to chemical spraying techniques which have historically represented the main response to mosquito nuisance.

The mosquito

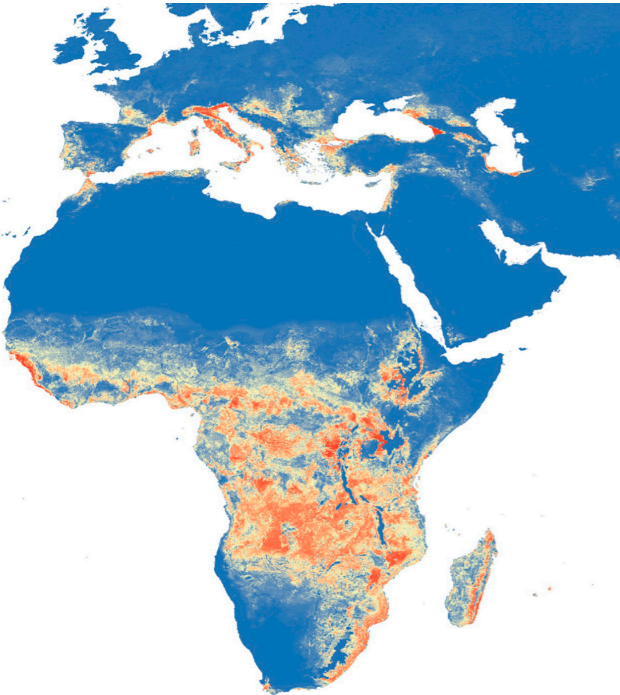
History

The mosquito has been maintaining an ambiguous relationship with humans, no doubt since the dawn of humanity. It is indeed the vector of a considerable number of diseases, historically responsible for real hecatombs and still killing more than 700,000 people per year. However, despite this dire reality, the about 3,500 existing species of mosquitoes never cease to fascinate and even surprise us. Indeed, their incredible adaptability and the extraordinary efficiency of their biological machinery impose a form of respect given this extreme sophistication that originates from a long and complex evolutionary process.



Challenges

Since the advent of globalized trade, the mosquito has taken advantage of new routes opened up by the flow of goods to spread throughout the planet except for the arctic regions that are still protected by inhospitable temperatures. Two species, in particular, are emblematic of this relentless conquest: the *Aedes aegypti* native to Africa and its “cousin” the *Aedes albopictus*, commonly known as the “tiger mosquito” native to the tropical forests of Southeast Asia. Their geographic range continues to grow at an exponential rate, stimulated by global warming, without any control strategy currently being able to oppose it.



The **Sepik masks** from **Papua New Guinea** (right) and **Tlingit masks** from **North America** (bottom) testify to the fascination that mosquitoes exert on human populations, nourishing a complex and fertile imagination.



## Control strategies

In an attempt to remedy the recent expansion of these invasive species, various strategies have been deployed by health authorities in affected countries to control the risk of epidemics.

The most common strategy is to apply chemical insecticidal agents by spraying. Used extensively since the beginning of the 20th century, this solution is very effective in the short term but causes major problems in terms of public health, the absence of targeting leading to the disruption of the localized ecosystem by the elimination of all insects, and finally, the development of multi-resistant strains.

Other solutions have also been explored, such as genetic modification and irradiation techniques that aim to make mosquitoes

infertile or the use of bacteria that contaminate the mosquito so that its offspring are no longer viable.

Experiments with the dissemination of genetically modified mosquitoes, notably those carried out in Brazil, have not demonstrated their effectiveness, but current dynamics seem to hold a promising future for these solutions.

**These various solutions, although sometimes promising, are still problematic when it comes to large-scale application and have potentially uncontrolled ecological side effects.**

### Focus on Pyrethrum

Since ancient times in China, Pyrethrum has been known for its insecticidal properties. Its use was attested in the Zhou Dynasty around -1000 BC. Acting as a neurotoxicant, the fermented, dried and powdered plant helps to repel or kill mosquitoes depending on the concentration used.

### Focus on DDT

Dichlorodiphenyltrichloroethane, commonly known as DDT was first synthesized in 1874 but has only been used as an insecticide since the 1930s. Used extensively by the US army to fight malaria and typhus, DDT is nowadays banned in most countries due to its high toxicity to ecosystems.



## Ecological impact of insecticide solutions Chronology

Since the development of synthetic pesticides in the 1930s that was linked to the progress of organic chemistry necessary for the development of chemical weapons, the impact of these substances on the environment is the focus of growing concerns from the scientific community and the general public:

**1910** First legislation regulating pesticides in the United States: **the Federal Insecticide Act**

**1914** First study on insecticide resistance by A L. Melander: ***Can Insects Become Resistant to Sprays*** in the Journal of Economic Entomology

**1933** Beginning of the general public's awareness of the issues related to the use of pesticides with the publication of **100,000,000 guinea pigs: dangers in everyday foods** by Arthur Kallet and F.J. Schlink

**1962** Awareness of the environmental impact of chemicals and the beginnings of ecological movements with the publication of ***Silent Spring*** by Rachel Carson

**1970** Creation of the United States **Environmental Protection Agency (EPA)** to address growing concerns about environmental risks

**1985** Adoption of the **International Code of Conduct on the Distribution and Use of Pesticides** by the Food and Agriculture Organization of the United Nations

**2008** France adopts the first **Ecophyto plan** to reduce by half the use of pesticides

**2013** Publication of the study **Pesticides: Effects on health** by Inserm which presents a summary of the current studies on the issue of the impact of pesticides

**2021** Update of the study **Pesticides: Effects on health** with new data allowing the update of the previous collective expert report. These new developments strengthen the link between exposure to pesticides and the occurrence of serious pathologies

Link to the updated study: <https://www.inserm.fr/expertise-collective/pesticides-et-sante-nouvelles-donnees-2021/>



## Capture Traps

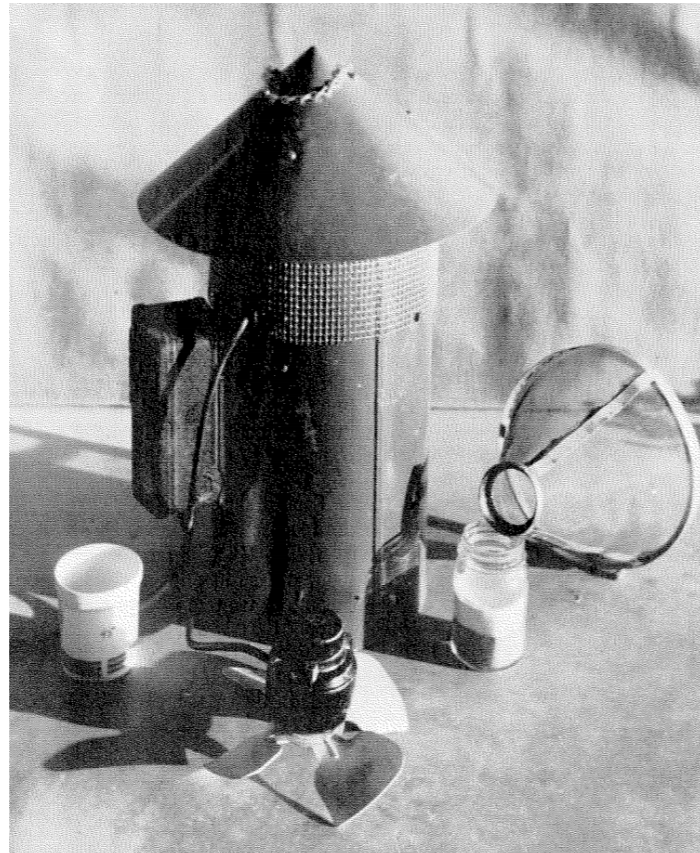
### History

Historically developed for entomological research, individual capture traps have been employed since the 1980s as an effective alternative to chemical treatments. Initially reserved for “monitoring” (collecting specimens and modeling of infestations), these traps proved their capture performance in field studies, subsequently leading to the industrial development of commercial versions intended for pest control professionals and the general public..

### Functioning

Most individual capture traps have adopted a similar strategy, resulting from scientific work carried out since the beginning of the 20th century: they lure female mosquitoes in search of blood to feed their eggs by emitting a set of compounds, “Biological markers” imitating those emitted by the respiratory system and the skin of mammals. Mosquitoes believe they are in the presence of prey, approach to bite, and are sucked up by a reverse ventilator into a compartment where they die of dehydration.

**Almost all capture traps are based on a variation of the following association: CO2 + VOC + Reverse ventilator**



#### Focus on CO2

The CO2 produced by respiration is the main “long-distance” marker for the mosquito searching for blood, it allows it to detect and locate prey at a distance of between 50 and 70 meters. In the presence of CO2 molecules carried by air movements, the mosquito follows these corridors up to their point of emission, where it however needs, before deciding to bite, to identify VOC molecules.

#### Focus on VOCs

Volatile organic compounds or “VOCs” refer to the hundreds of biological emanations emitted by skin, attractive or repellent. The lures used by trap manufacturers generally include 1, 2, or 3 of those active compounds, reproducing to a certain extent natural attractiveness. The identification of these molecules in the air happens some meters from their point of emission and provokes the bite as soon as the mosquito has identified the biology of the transmitter.

#### Focus on other signals

Other signals are also, to a lesser extent, potential sources of attractiveness: heat, humidity, color, and for some species, light.

## Individual capture traps

### Chronology

**From the first archaic traps to the latest commercial developments, individual capture traps have gone through many developments:**

**1695** First use of “trap lanterns” to attract insects by entomologist **James Petiver**

**1866** The *New American moth trap*, first self-contained light trap powered by a kerosene reserve developed by entomologist **Townend Glover**

**1922** First research on CO2 as an attractant by **Willem Rudolfs** in *Chemotropism of Mosquitoes*

**1928** First trap incorporating an electric ventilator by **William B. Herms** and **R. W. Burgess**

**1932** The *New Jersey mosquito trap*, first standardized mosquito trap incorporating a ventilator developed at the **New Jersey Agricultural Experiment Station**

**1934** First use of CO2 in a mosquito trap by entomologist **Thomas J. Headlee**

**1960** The *Mosquito Light Trap*, first standardized mosquito trap using CO2 developed by **Dan Sudia** and **Roy Chamberlain** at the **CDC** (Communicable Disease Center)

**1983** **Flowtron** creates a trap using fuel as a source of CO2: *Apparatus for attracting insects*. Launch in 2002 of the **Mosquito Power Trap** combining CO2 by combustion, aspiration flow, and octanol-based bait

**1996** **American Biophysics Corp.** develops a trap using complex flow dynamics to attract and trap mosquitoes: the *Counterflow insect trap*. Presentation in 1999 of the **Mosquito Magnet** trap combining CO2 by combustion,

aspiration flow, and octanol-based bait

**2002** **Blue Rhino** develops a trap using fuel as a source of CO2: *Insect trap apparatus*. Launch in 2003 of the **SkeeterVac** trap combining CO2 by combustion, aspiration flow, sticky paper, and octanol-based bait

**2005** Improvement by **Biogents** of a trap concept using color contrast and circular flow: *Device for attracting insects, and system for attracting and catching insects*. Launch in 2006 of the **BG-Sentinel** trap combining a circular flow, an optional CO2 source, and a bait based on lactic acid, ammonium bicarbonate, and hexanoic acid, then in 2008 of a consumer version with the **BG-Mosquitaire** trap

**2014** **Qista** offers a trap using separate attractant and ventilation streams and a “pheromone” bait: *Device and method for trapping flying insect pests*.<sup>2</sup> Market launch in 2015 of the **Borne Anti-Moustique**

Beyond those presented above, other parties offer different traps on the market using the same lure strategies: **Coleman** with the *Mosquito Deleto System*, **Lentek** with the *Bite Shield Guardian*, **Mega-Catch** with the *Ultra Mosquito Trap*, **Biosensory** with the *Dragonfly Mosquito Trap System*.

Various parties are also present in specific markets: **Amplecta** in Sweden with the *Predator Dynamic*, **E-TND** in Korea with the *Mos-Hole*, **Valens** in China with the *Mosquito Hunter*, or even **Litmarshdetal** in Russia with the *Aero mosquito trap*.

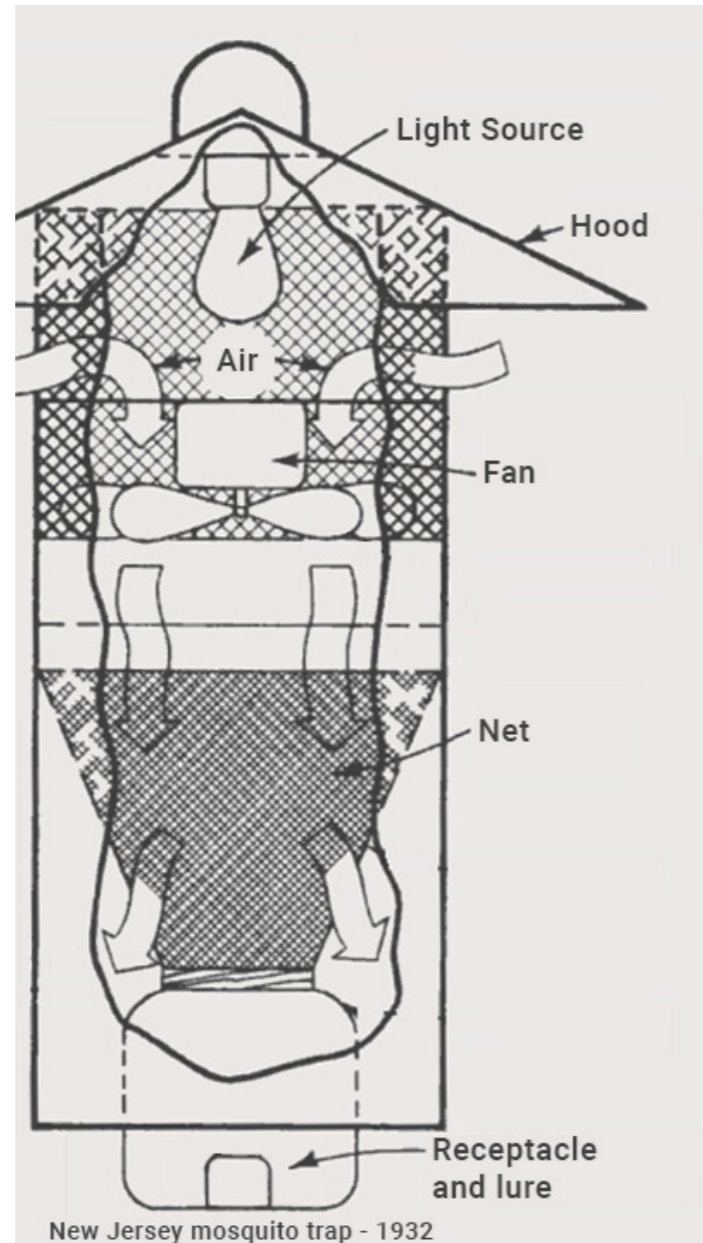
## The limits of conventional trapping strategies

### Issue: capture or protect?

“Individual” capture traps do not fully resolve the problem of mosquito bites.

Although participating in the reduction of local infestation, capturing mosquitoes does not unfortunately solve the problem of the competing parallel attractiveness of people and animals that are present in a perimeter of 50 to 70 meters. The Mediterranean EID (French mosquito control government agency) thus notes that “mosquitoes always prefer a host to a trap (prefer the original to the copy)”.<sup>1</sup> According to the public vector control operator, individual traps are “useful but not sufficient”.<sup>1</sup> They are “useful” because their capturing action provides respite by reducing the presence of mosquito populations in the immediate area, but they are “insufficient” because they cannot fully protect people and animals.

**In conclusion, these “individual” traps do capture and are useful for reducing the density of local colonies, but unfortunately, they do not fully protect. The EID thus asserts that individual trapping “cannot, on its own, significantly solve the mosquito nuisance.”<sup>1</sup>**



### Focus on the Radius of action

The notion of potential radius of action is often confused with the notion of effective radius of action. In fact, a trap whose potential radius of action is several dozens of meters reduces its effective radius of action in practice to a few meters depending on the specific conditions of its installation, the presence or absence of competitive attraction in the area, air movements as well as many other factors.

### Focus on Attractiveness

Studies and experiments demonstrate the limits of currently developed commercial lures: a group of people or animals, or even a single individual are always more attractive! Ongoing work raises hope that new generations of these devices will come closer and closer to the original.



## A new concept

### The anti-mosquito belt that protects

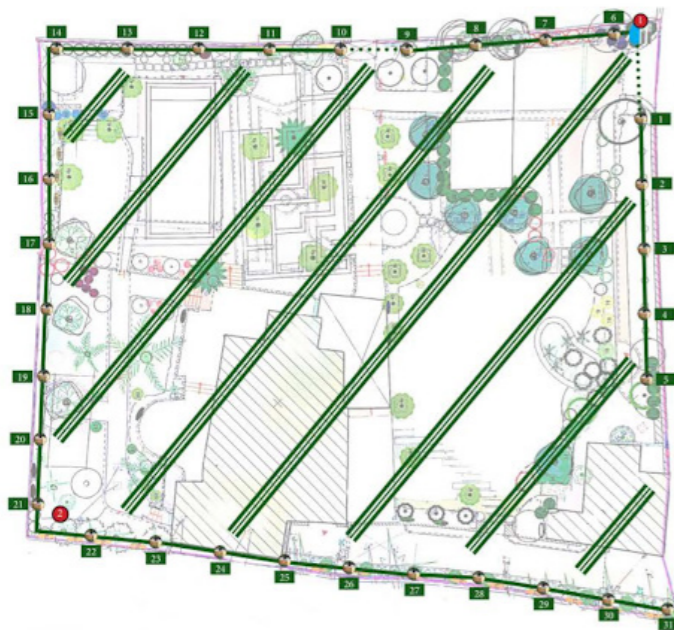
In order to reduce the biting rate observed near "individual" traps, a new concept emerged about ten years ago: a "trapping belt", consisting of a sufficient number of interconnected traps in the perimeter that needs to be protected.

These devices do not only ensure the absence of local colonies but more crucially isolate the area, preventing mosquitoes from further distances, for example from neighbors, from entering the strategic perimeter.



This concept, summarized under the name of "anti-mosquito belt", is currently the only one capable of offering a complete and highly effective solution, guaranteeing real protection and representing an actual alternative to chemical spraying.

**This solution thus makes it possible to reduce the bite rate more effectively than traditional traps by establishing a spatially uninterrupted protection, creating an enclosed space within which mosquitoes can neither penetrate nor subsist. This trapping belt concept has no theoretical protection area limit, some installations already effectively protect several hectares.**



## Anti-Mosquito Belts Chronology

In the 90s, the inadequacies in terms of protection of individual capture traps led to experiments by several companies in the world:

**1995 American Biophysics Corp.** develops a system of networked traps and CO2 diffusion: *Trap system for reducing the entry of flying insects to a defined area* which has not led to commercial development

**1997 Joseph Paganessi, an engineer at Air Liquide** develops a line of traps coupled with a control unit and a CO2 tank: *Method and delivery system for the carbon dioxide-based, area specific attraction of insects* and initiates a commercial development without follow-up

**2000 The Bugjammer** company creates a

system of attractive workstations linked to a control room and centralized aspiration: *Blood-sucking insect barrier system and method* but focuses its activity on individual traps

**2003 Skeeter Bagger** conceptualizes a network of traps coupled with an attractant and CO2 nebulization system: *Insect trap system*. This development does not lead to sustainable market development

**2005 Akhil Garland of Biting Insect Technologies** offers a system for distributing CO2 and attractant in a network of traps: *Flying insect management system* but its commercial development is quickly interrupted

**2010 Attempt by Biogents** to market a networking system of 3 traps associated with a CO2 source and a programming tool: *Eisenhans Protection Belt*

**2011 Launch of the Anti-Mosquito BioBelt System to effectively protect large areas by combining a network of traps and a monitoring system**



The Mediterranean EID, a historical vector control player, attests to the effectiveness of the anti-mosquito belt concept in its documentary dossier "Mosquito traps":

"A very recent test has shown the effectiveness of a CO2 trap barrier in reducing the nuisance of the tiger mosquito, with one trap every 5 m or so." <sup>1</sup>

## Parasites & Vectors

"We have shown the barrier trap system to be effective in reducing to almost zero the biting rate of *Ae. albopictus* with semi-individual protection in an enclosed environment. At a time where there is evidence of the low effectiveness of some *Aedes* control strategies, this method could represent a promising controlling tool of *Ae. albopictus* for specific areas (...) We are optimistic that once it is improved and combined with other tools, this strategy will contribute to the panel of new methods that will open a new era of successful *Aedes* control, and consequently the control of arboviruses and other vector-borne diseases."

### The anti-mosquito belt concept

#### Scientific validation

A study published in the scientific journal *Parasites & Vectors* by the Medical Entomology Service of the University Hospital (CHU) of Nice in partnership with the Service of Infectious Diseases and Vectors - Ecology, Genetics, Evolution and Control (MIVEGEC) of the Institute of Research and Development (IRD) of Montpellier demonstrates the effectiveness of the anti-mosquito belt concept.

The conclusion of the study indeed attests to the relevance of the notion of traps network to allow effective protection of a given perimeter:

#### Focus on future developments

The trapping adventure is a real solution for the future, given the dead-end represented by chemical solutions. At this time, the anti-mosquito belt concept appears to be the most promising if the main objective is, of course, to capture, but more essentially to protect. This adventure remains largely to be completed, in particular concerning lures for which the understanding of bacteria's role in the generation of VOCs is still very incomplete. Mosquitoes are not only a terrible source of discomfort, but they are still responsible for a considerable number of deaths, and the development of effective solutions to replace insecticide spraying methods is a great challenge.

There are different methods to assess the effectiveness of trapping solutions. The most common method is to count the number of mosquitoes captured. However, this methodology makes it impossible to assess the impact of these captures on the protection capacity of an anti-mosquito solution. It is indeed possible to still be bitten despite a high number of captures. Thus, to measure a degree of protection, the HLC (Human Landing Catch) protocol appears more appropriate. It consists of sampling mosquitoes landed on a person and thus makes it possible to assess the number of potential bites. A variant of this method consists in counting the number of effective bites. However, ethical and technical constraints most often lead researchers to favor raw counting of catches, despite the limitations of this approach.

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The study "Effectiveness of a field trap barrier system for controlling *Aedes albopictus*: a "removal trapping" strategy" published in the American entomology journal "Parasites & vectors" which highlights the effectiveness of the anti-mosquito belt concept uses the HLC (Human Landing Catch) protocol to assess the level of performance in terms of protection. This study shows a 50% reduction in the bite rate after one week and a reduction to almost zero after 6 weeks. It is one of the rare publications demonstrating the effectiveness of protection and not just the quantification of a capture rate.

