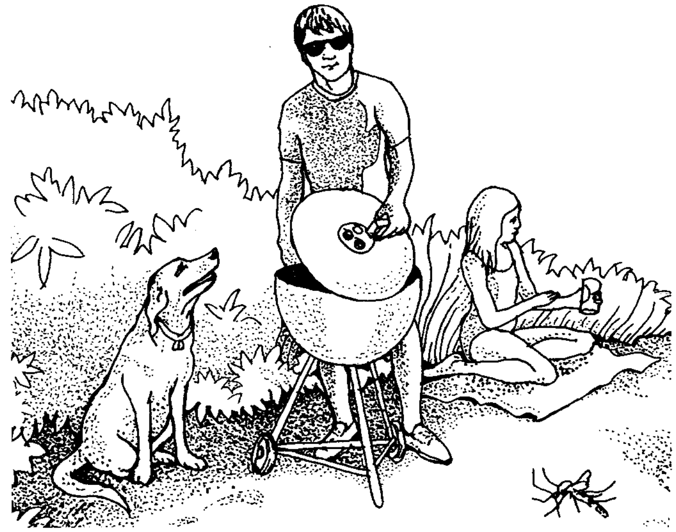
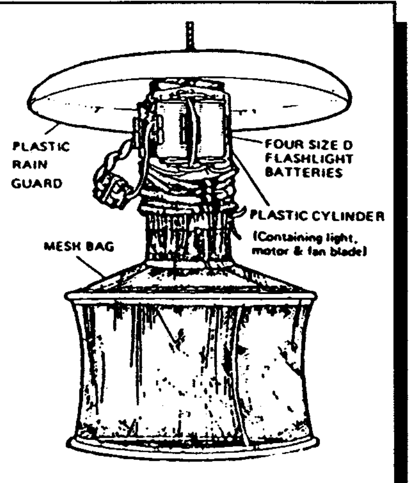
Mosquito Attractants and Traps



By William Quarles

The best way to control mosquitoes is to eliminate water sources that encourage breeding. A quick inspection of the backyard might reveal dripping outdoor faucets, birdbaths, water gardens, watering cans, buckets, saucers under potted plants, and other possible problems. Sources such as water gardens that cannot be emptied or drained can be stocked with mosquito fish or treated with the microbial insecticide *Bacillus thuringiensis israelensis* (BTI) (see Olkowski 2001). However, some mosquitoes escape the best source reduction and larval control programs to become irritating adults. Normally, an occasional mosquito bite is the cost of outdoor living, but the West Nile virus scare has driven individuals and government agencies to extremes (Quarles 2000).

In some areas, pesticide foggers are being used. Foggers may give some immediate relief, but 99.9% of the chemical never makes contact with a mosquito. Mosquitoes usually just leave a treated area, then return when the residues decay. With more persistent pesticides, they develop resistance (Quarles 2001). More and more evidence is accumulating that areawide fogging has led to more human exposure than formerly thought. Researchers at Mount Sinai in New York have just published a study on pesticides in the blood of pregnant women in New York City. Pyrethroid metabolite levels were monitored from the summer of 1998 to the winter of 2001. Blood metabolite levels were highest in the summer of 2000, a time when New York City was being fogged for containment of the West Nile virus (Berkowitz et al. 2003).



The CDC mosquito trap

Since many people are reluctant to use pesticides, but are also fearful of West Nile virus, sales of mosquito traps and repellents have soared. When *Common Sense Pest Control* reviewed mosquito traps in 1996, few options were available for the consumer market. Professionals had the CDC, New Jersey, and EVS traps. These traps use light, and sometimes CO_2 as attractants to monitor adult pest mosquito populations (Quarles 1996). (see Box A. History of Mosquito Traps)

At that time, the only option for the backyard was the zap trap—a light-baited electrocution trap that killed very few mosquitoes and eliminated many beneficial insects (Nasci et al. 1983; Frick and Tallamy 1996). Since then, mosquito traps have been vastly improved. A major advance is that most traps now use attractants that are targeted for mosquitoes and biting insects; beneficial insects are spared.

Mosquito Host Seeking Behavior

How effective are the attractants used in the new mosquito traps? Mosquitoes use a complex set of cues, long-range, midrange, and closerange to find a host. Most mosquitoes feed on sugary plant nectar or insect honeydew (Gillett 1972; Burkett et al. 1999), but the females of many species need bloodmeals to produce eggs (see Box B. Mosquito Biology). When not looking for food, mosquitoes usually rest on the underside of foliage and other discrete places. They are "activated" into flight when they receive host-recognition cues. Carbon dioxide is a mid to long-range cue. Humans emit about 250 ml of carbon dioxide a minute in breaths or pulses of about 12 per min. Concentration of CO_2 in exhaled air is 4 to 5%, while the atmosphere averages about 0.03% to 0.04%. Carbon dioxide is carried on the wind, and attracts until concentrations are diluted by a factor of 100. When mosquitoes sense CO_2, they fly slowly upwind toward the source. Commercial mosquito traps emit from 350 to 500 ml of

CO_2 per minute; the more CO_2, the greater the attraction (Kline and Mann 1998; Gillies 1980). Distance of attraction depends on the species, but traps should attract mosquitoes over a distance of at least 16 m (52.4 ft) (Clements 1963; 1999; Service 1993).

Important pest species of the genera *Culex*, *Aedes*, and *Anopheles* can be caught in CO_2 baited traps. Among these are *Culex pipiens* and *Aedes vexans* that vector West Nile fever. Mosquito species that have been caught by a combination of light and CO_2 are shown in **Table 1**.(Service 1993).

Host-Specific Cues

Along with CO_2, other volatile cues from respiration drift downwind and allow a mosquito to identify a host from a distance. Fortunately, not all mosquitoes are looking for humans. *Anopheles* spp. mosquitoes prefer to attack humans and carry serious human pathogens. However, some *Anopheles* species prefer to attack other mammals, and attack humans only as a last resort (Takken 1991).

Culex spp. generally prefer to attack birds, while *Aedes* spp. generally feed on mammals. These are just general rules, as *Culex nigripalpus* prefers humans and carries St. Louis encephalitis virus. *Culex pipiens* attacks birds, humans, and other mammals and carries West Nile virus from species to species (see Box D. Mosquitoes and Disease). Since some mosquitoes bite both humans and other animals, attractants associated with other species are often added as bait to backyard traps (Takken 1991).

Box A. History of Mosquito Traps

The first mosquito light traps used kerosene lamps or other such light sources. The first successful electric light trap was the New Jersey trap, which was used in the 1930s (Husbands 1976; Mulhern 1934; 1942). The basic New Jersey trap is powered by house current, and uses as an attractant a small, 20W incandescent bulb (see Resources). Underneath the bulb is an 8-inch (20.3 cm) fan, which sucks approaching mosquitoes down into the trap. To protect against destruction of non-target insects, a screen with a 1/4-inch (6.4 mm) grid is set in front of the fan. Insects larger than this grid size are thereby excluded.

Since the New Jersey trap requires line current at 110V AC for operation, it has limited usefulness for mosquito survey work, as many mosquito surveys are conducted in isolated places. Two traps that overcome this limitation are the Centers for Disease Control (CDC) trap, and the US Army Solid State (AMSS) trap. The CDC trap was developed in 1962, and the AMSS trap was developed in 1980 (Sudia and Chamberlain 1962; Driggers et al. 1980). These traps are available from commercial suppliers (see Resources), and are discussed in more detail below.

CDC Trap

The CDC trap uses a 6V battery or 4 "D" cells to operate small 3W incandescent bulb and a small fan that sucks mosquitoes into a collection bag. The trap weighs only 1.75 pounds (0.8 kg), and can be very effective, as 25,000 mosquitoes were collected in one night in Florida (Sudia and Chamberlain 1962).

The effective range of the trap is less than 5 meters (16.4 ft), and it is often used to trap mosquitoes inside dwellings as part of a sampling program. Under these conditions, the CDC trap can be very selective. In Tanzania, the light trap captured 1.23 times more anopheline (see Box B) mosquitoes than were trapped by human-bait collections. Also, the light trap preferentially trapped mosquitoes infected with the malaria organism (Davis et al. 1995)

Army Trap

The U.S. Army miniature, solid-state (AMSS) mosquito light trap is an improvement of the CDC trap. Like the CDC trap, it has a fan, a small wattage light, and is powered by a 6V battery. The trap has a daylight-activated switch that turns it on at night, and off in the daytime. The AMSS trap catches about 3.5 times as many mosquitoes, and about twice as many species each night as the CDC trap. It also catches as many *Culicoides* sp. midges as traps baited with human volunteers (Driggers et al. 1980).

A more portable version of the AMSS trap has also been developed that has a cloth body, and is totally collapsible for transportation (Collier et al. 1992).

EVS Trap

One of the simplest carbon dioxide baited light traps is the Encephalitis Vector Surveillance (EVS) light trap. The EVS trap consists of a 1 gallon (3.79 liter) paint can painted black on the outside and lined with polyurethane insulation on the inside. This can is used to hold dry ice. About 4 to 6 holes are punched in the bottom of the can to allow CO_2 to escape. This can is suspended over a vertical plastic plate holding two 1.5V dry cell batteries that power a fan that sucks mosquitoes into a simple 30 cm (12 in) long catch bag made of mosquito netting. Sometimes this trap is also used with a subminiature "grain of wheat" light bulb, but the major attraction is carbon dioxide.

A big advantage of the EVS trap is that it does not attract non-target insect species. Another big advantage is commercial availability and relatively low cost (see Resources). This trap has caught more than 10,000 *Aedes vexans* in a single night, and thus is quite effective. The EVS is very popular in California and is sometimes called the California trap. It sometimes outperforms the more expensive CDC trap, depending on the mosquito species. It is extremely effective for *Culex erythrothorax*. It has also captured effectively *Anopheles annulipes*, *Aedes vigilax*, and *Mansonia* spp. (Service 1993).

Table 1. Mosquitoes Caught with Light and Carbon Dioxide*

Aedes aurifer	Aedes abserratus	Aedes albifasciatus	Aedes alboannulatus
Aedes atalanticus	Aedes bancroftianus	Aedes canadensis	Aedes cantator
Aedes communis	Aedes excrucians	Aedes punctor	Aedes sagax
Aedes sollicitans	Aedes theobaldi	Aedes trivittatus	Aedes vexans
Anopheles annulipes	Anopheles punctipennis	Anopheles quadrimaculatus	Anopheles sp.
Anopheles walkeri	Coquillettidia perturbans	Culex inornata	Culex annulirostris
Culex australicus	Culex fuscocephala	Culex glidus	Culex modestus
Culex pipiens	Culex quinquefasciatus	Culex stigmatosoma	Culex tritaeniorhynchus
Culex tarsalis	Culex vishui	Culiseta incidens	Culiseta melanura
Culiseta morsitans	Porophor ferox		

***Information from Service 1993**

Cow's Breath and Octenol

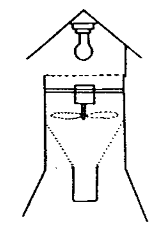
One of these attractants was discovered during research on sleeping sickness, which is carried by the tsetse fly, *Glossina* spp. The tsetse fly attacks cattle, and in some areas of Africa, cattle and flies cannot coexist. A volatile component of cow's breath, 1-octen-3-ol, hereafter referred to as octenol, is an attractant for tsetse fly and has been used in trapping programs for that insect. Since some mosquito species attack both cows and humans, USDA researchers in Florida decided to try combinations of octenol and carbon dioxide as attractants for pest mosquitoes (Kline et al. 1990a). This research, reported in Box C, is the basis for the use of octenol in the new commercial traps.

Mosquito Vision and Light Attraction

As a mosquito gets closer to a host, it finally gets into visual range. If there is enough light to see a host, the mosquito swoops to attack. Mosquitoes are also attracted to light sources. The New Jersey, CDC and early light traps made use of this attraction. Lights are part of the attraction of the MegaCatch and other new commercial traps. Light intensity is often the most important environmental factor influencing mosquito activity, and a number of different light sources have been tested, but the research has been rather limited (Service 1993). For instance, a 15W fluorescent black light will catch 11 times as many biting midges, *Culicoides variipennis*, as a 40W incandescent light (Holbrook and Bobian 1989). Ultraviolet light is also attractive to *Anopheles stephensi* (Wilton and Fay 1972). Unfortunately, black light also attracts many non-target species (Wieser-Schimpf et al. 1990; Wieser-Schimpf et al. 1991).

Colored visible light has been tested. White incandescent 3W bulbs are more attractive to biting midges, *Chironomus salinarius*, than colored bulbs of the same wattage (Ali et al. 1994). However, colored LEDs are attractive to mosquitoes, and apparently each mosquito species has its favorite color (Burkett et al. 1998).

Moonlight can be a factor in light trap performance. Some mosquitoes are more active when the moon is full. For instance, *Aedes taylori* and *Anopheles sinensis* increase in numbers around human baits and bite more often during a full moon (Bidlingmayer 1964; Service 1993).



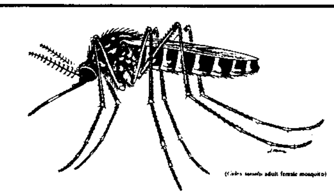
New Jersey trap

Even though more mosquitoes are flying on a moonlight night, greater numbers are caught by light traps on a dark night. The important variable is light trap intensity above background. The better mosquitoes are able to see a light trap, the more mosquitoes are caught (Wilton 1975; Rubio-Palis 1992).

Light traps are most effective for mosquitoes that are active at night. Most *Culex, Anopheles* and *Mansonia* mosquitoes bite at night. *Aedes* tends to feed in the day or early evening. *Psorophora* and *Haemagogus* bite during the daytime (see Box B Mosquito Biology) (Service 1980; Service 1993).

Heat and Moisture

As mosquitoes pass the visual threshold and draw closer to the visible target, they are attracted by heat and moisture (Kline and Lemire 1995). This attraction to heat and moisture was reported in the classic book by Gillett (1972). He used a container of hot water to draw mosquitoes away from his body. He observed *Culex fatigans*, "hovering around and even settling on warm dishes at mealtime" and "actually landing and probing warm pieces of toast with the proboscis." Many of the new mosquito traps use heat and moisture as attractants. The Dragonfly (see Resources) is designed to mimic the thermal outline of a small mammal.



Culex tarsalis

Skin Odor

At close range, blood-seeking mosquitoes are drawn to humans and other mammals by a combination of odors from their skin and their breath. Human-seeking mosquitoes such as *Aedes aegypti, Ae. albopictus* and *Anopheles albimanus* are strongly attracted to human sweat. Armpit sweat is more attractive than sweat from other parts of the body. The components of human

Box B. Biology of the Mosquito

The only area in the world where mosquitoes are absent is Anarctica. These ubiquitous, two-winged insects are part of the insect order Diptera and belong to the Culicidae family. There are 3 subfamilies—Toxorhynchitinae, Anophelinae, and Culicinae. Mosquitoes of the first subfamily are not generally pests, and their larvae actually eat pest mosquito larvae. The most important pest genera include *Anopheles, Culex, Aedes, Mansonia, Haemagogus, Sabethes* and *Psorophora.* All mosquitoes go through complete metamorphosis including egg, larval, pupal and adult stages.

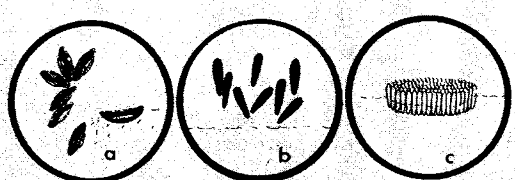
Adult mosquitoes are small, slender insects of about 4 to 6 mm (1/4 in) length. Males have feathery antennae, those with short antennal hairs are females. An important mosquito characteristic is the long, slender proboscis that is used to penetrate skin. Males do not suck blood, females feed on blood in order to produce eggs. Unfed females are slender; those with blood meals have a red, swollen appearance; those carrying eggs have a swollen, whitish appearance.

Females lay between 30 to 300 brown to blackish eggs at one time. *Anopheles* eggs are boat or oval shape, and float on the water. *Culex* and some *Mansonia* eggs are also laid on the water, but are deposited in the form of rafts. Eggs of these three species cannot survive desiccation.

Aedes, Psorophora and *Haemagogus* lay their eggs in damp places just beyond the water line. Some *Aedes* prefer tree holes, clay pots and other containers. *Aedes* and *Psorophora* eggs can withstand weeks or years of desiccation, and can survive cold weather. Hatching is triggered by alternate cycles of flooding and drought, and not all the eggs hatch at the same time. These mosquitoes tend to be timed-release pests and never go away without good control measures.

Most mosquito larvae must come to the surface to breathe. They are most vulnerable at this time, and this is the reason that much mosquito control work focuses on the larval stage. *Anopheles* larvae lie parallel to the water surface and breathe through the holes in their sides called spiracles. Culicine larvae hang from the surface at an angle and breath through a siphon tube. Many species spend 5-7 days in the larval stage.

Mosquitoes can develop anywhere there is standing water. The range of habitats is wide. Fresh water, salt water, brackish water, ground pools, wells, cesspools, marshes, containers, tires, tree holes, and aquatic vegetation are all areas where mosquitoes can develop. *Anopheles* species generally prefer clean, unpolluted water. Many *Aedes* species develop in tree holes or containers. *Culex* tends to prefer polluted water associated with poor drainage and sanitation. *Psorophora* breeds in rice fields and marshy meadows. *Mansonia* mosquitoes are associated with aquatic vegetation. *Haemagogus* is a forest species in the U.S. (Service 1980).



Mosquito eggs

***Anopheles* spp. *Aedes* spp. and *Culex* spp.**

***Culex* lays eggs in rafts.**

Feeding Habits

Not all female mosquitoes feed on human blood. Toxorhynchitinae are all vegetarians. The two big mosquito pest groups are the anophelines and the culicines. Most pest mosquitoes are culicines that attack whatever hosts are available, feeding on humans, other mammals, birds, and even reptiles. Many *Culex* prefer to feed on birds, but will feed on humans if necessary. Species that prefer to feed mainly on animals other than humans are called zoophilic. Anophelines usually prefer to feed on humans. Mosquito species with this preference are called anthropophilic.

Many *Anopheles* species prefer to bite inside houses. *Aedes* feeds outside, and tends to rest outside before and after eating. *Culex* will feed either inside or outside.

Most *Culex, Anopheles* and *Mansonia* mosquitoes bite at night. *Aedes* tends to feed in the day or early evening. *Psorophora* and *Haemagogus* bite outside during the daytime.

Anopheles hunt, mate, bite and lay eggs at night. African anophelines tend to bite inside houses after 11 PM. South American anophelines tend to dine earlier than 9 PM, and tend to bite outside houses. When and what host any mosquito bites, though, depends on what is available. If few humans are available, anthropophilic species will temporarily become zoophilic.

Switching of hosts has implications for human disease (see Box D). *Culex* species are able to bring encephalitis virus from birds to humans. *Aedes* species bring yellow fever virus from monkeys to humans. Since *Anopheles* concentrates on humans, it will transmit at high frequency any human pathogen that it is able to incubate (Service 1980).

Box C. Carbon Dioxide and Octenol

Octenol by itself is not a very effective attractant for pest mosquitoes. Up to now, only *Aedes taeniorhynchus* and *Coquillettidia perturbans* seem to respond to octenol only. However, addition of octenol to CO_2 baited traps increases catches of many pest mosquitoes. The combination causes 2-fold or greater increases in catches for *Aedes, Psorophora, Anopheles, Coquillettidia* and *Mansonia* (Kline et al. 1991b). A synergistic effect is seen with *Mansonia* spp., *Coquillettidia perturbans*, and *Aedes taeniorhynchus* (Kline et al. 1990b; Takken and Kline 1989). The effect is so striking with *Ae. taeniorhychus*, populations of this pest might be brought below action levels with a mass trapping approach. Some *Anopheles* species show no increased attraction when octenol is added to CO_2 traps, and no increase in attraction is generally seen with *Culex* species. This is not suprising since *Anopheles* generally prefers humans, and *Culex* primarily birds. However, such generalizations sometimes fail, as the effect with *Culex nigripalpas* might be additive (Kline et al. 1990a; 1991a).

The response of *Anopheles* mosquitoes to CO_2 and octenol is especially complex. In some areas and times *Anopheles atropos, An. crucians* and *An. quadrimaculatus* seem to show an additive or even synergistic response to the combination (Takken and Kline 1989, Kline et al. 1990a; 1991a). At other times octenol does not improve the attractiveness of CO_2 (Kline et al. 1990b).

The increased effectiveness of octenol plus CO_2 over CO_2 alone is also seen with biting midges. Kline et al. (1990b) caught increased numbers of *Culicoides furens, C. mississippiensis* and *C. furens* in Florida. In Australia, Ritchie et al. (1994) found that *Culicoides* spp. were not attracted to octenol alone, but significantly more *C. histrio, C. molestus* and *C. subimmaculatus* were captured by the octenol-CO_2 combination.

In contrast to the great successes of Kline et al., Becker et al. (1995) found octenol had little attraction for *Aedes vexans, Ae. rossicus, Ae. cinereus* and *Culex pipiens* in Germany's Rhine Valley. The combination of CO_2 and octenol had no more effectiveness than CO_2 alone.

sweat that are attractive to mosquitoes are under investigation. Sweat contains amino acids, cholesterol, low molecular weight fatty acids, alcohol esters, and albumin. Some attractive compounds have been isolated, but not identified. So far, lactic acid is the only human-associated pure chemical that attracts mosquitoes in field tests. Even so, lactic acid must be combined with CO_2 to be of any use in mosquito trapping and control (Service 1993; Takken 1991; Kline et al. 1990a).

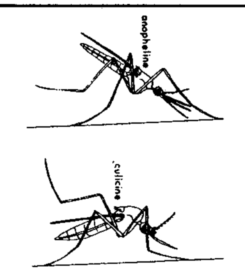
Chemical attraction can be quite specific. Field tests have shown that mosquitoes are able to discriminate between potential hosts. Some people are more attractive to mosquitoes than others, and the key to differential attraction is odor. This kind of gourmet activity is shown by mosquitoes such as *Anopheles stephensi*. Exactly why one person is more attractive than another is a rich topic of further research (Takken 1991). There is also an "invitational effect." When mosquitoes bite, the feeding mosquitoes apparently release volatile pheromones that attract yet more mosquitoes (Service 1993).

None of the new traps make use of these short range cues, but these short range attractants are effective in traps. For instance, Kline (1998) found that the odor of dirty socks combined with a CO_2 baited trap attracted larger numbers of mosquitoes than CO_2 alone. The dirty socks were effective for 8 consecutive days!

New Commercial Traps

Most of the new traps use CO_2 as an attractant. The CO_2 is usually generated by catalytic burning of propane, or it is released from a CO_2 gas cylinder. In some models, it is generated chemically or photocatalytically. Mosquito attractants other than CO_2 include octenol, heat, moisture, lights, and even the sound of human heartbeats. Mosquitoes attracted to the traps are usually captured by fans that pull them either into a net, sticky trap, catch basin or electric grid.

The Mosquito Magnets, Lentek MK01, Skeeter Vac, and Flowtron Power Trap generate CO_2 from propane. The Megacatch, Terminator, and the Dragonfly use CO_2 gas cylinders. The advantage of propane is that heat and moisture are produced simultaneously, and these are also mosquito attractants. Propane has the advantage of convenience and portability when these machines are used in remote areas. About 20 lbs of propane generates 60 lbs of CO_2 and lasts about 3 weeks in continuous operation (Kline 2002). For the case of the Mosquito Magnet Pro and the Skeeter Vac, a thermoelectric generator powers the fans, and no batteries or line current is needed. (See Table 2 Comparison of the New Traps)



Culicine and anopheline biting styles

Mosquito Magnets and most of the others have a good reputation for safety. Coleman, however, produced a relatively inexpensive propane trap called the Mosquito Deleto that had to be recalled. The connection between the propane tank and the trap was prone to leakage. The device has been redesigned and is currently available (Coleman 2003).

The advantage of CO_2 gas cylinders over propane is that releases of CO_2 are easier to program. In the case of the Dragonfly, there are several release settings and trap operation is also controlled by a photocell. The MegaCatch releases CO_2 in programmed pulses. Host-seeking mosquitoes react more strongly to pulses of CO_2 that suggest respiration (Clements 1999).

Table 2. Comparison of Mosquito Traps and Attractants

Name	Attractant	CO2 Source	Power	Catch Mode	Price*
Flowtron	light, octenol	none	110 AC	fan, electrocution	$53
Insectivoro	light	none	110 AC	fan, net	$89
Black Hole	heat, UV, CO2,	photocatalytic	110 AC	fan,net	$99
Gobblin	CO2, heat, moisture	methanol flame	thermoelectric	fan electrostatic grid	$195
Sonic Web	sound, heat, octenol, UV	none	110 AC	fan, sticky trap	$199
Mosquito Deleto	CO2, heat, octenol	propane	none	sticky trap	$199
Lentek Eco-Trap	CO2, heat, moisture	chemical cartridge	110AC	sticky trap	$199
Mosquito Magnet Defender	CO2, heat, moisture, octenol	propane catalytic	110 AC	fans, net	$295
Flowtron Power Trap	heat, moisture, CO2	propane catalytic	110 AC	fan, chamber	$299
Lentek MKOI	CO2, heat, light, moisture	propane catalytic	110 AC	fan, net	$369
Mosquito Terminator	CO2, heat, light	CO2 cylinder	110 AC	fan, net	$450
Skeeter Vac	CO2, heat, octenol	propane catalytic	thermoelectric	fan, net	$495
Mosquito Magnet Liberty	CO2, heat, moisture, octenol	propane catalytic	110 AC	fans, net	$495
MegaCatch	pulsed CO2, heat, programmed lights	CO2 cylinder	110 AC	fans, net, wet catch	$599
Dragonfly	adjustable CO2, heat, octenol	CO2 cylinder	110 AC, photocell activated	electrocution	$795
Mosquito Magnet Pro	350 ml CO2, heat, moisture, octenol	propane catalytic	thermoelectric	fans, net	$1295

*The price of these traps may vary according to distributor. Prices are listed only to estimate costs.

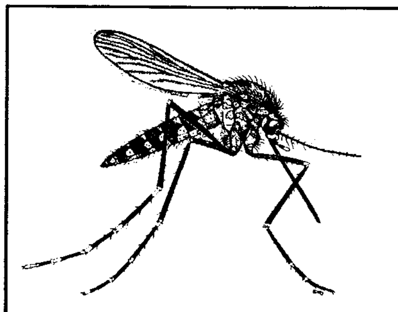
Traps such as the Mosquito Magnet that collect mosquitoes in nets are more useful for professionals because species identification is easier. Watching the net fill up may also be more rewarding to the backyard trapper. Glueboards and electric grids make identification and estimation of the numbers caught or destroyed more difficult.

Traps such as the Mosquito Magnet, Flowtron Zap, Sonic Web, Skeeter Vac and the Dragonfly have octenol as an added attractant (see Box C). The Dragonfly releases more octenol than the other traps.

More exotic traps include the Sonic Web that emits human heatbeats, the Gobblin that is powered by methanol, and the Black Hole, that produces CO_2 by a photocatalytic process. The MegaCatch has a UV source and programmed flashing multicolored light emitting diodes (LEDs).

Mosquito Magnet

The Mosquito Magnet made by American Biophysics, and the Dragonfly produced by BioSensory were the first of the new traps (see Resources). The Mosquito Magnets produce CO_2, water and heat by catalytically burning propane. Octenol is added as an additional attractant, and mosquitoes that approach the trap are sucked into a net by vacuum fans. There are three models of the Mosquito Magnet. The more expensive Mosquito Magnet Pro produces its own electricity with a thermoelectric generator. The Liberty and Defender models use AC line current to power the fans. New models use counter flow geometry, which increases effectiveness (Kline 1999). One fan blows CO_2 downward through a tube away from the trap, while another more powerful fan produces a counter flow into the trap and net. Mosquitoes flying at less than 3.5 m/sec (11.5 ft/sec) are swept into the trap (Kline 2002).



Treehole mosquito, *Aedes* sp.

Mosquito Magnets have generally done well in comparison tests. Mosquito Magnets with counterflow geometry captured more mosquitoes in a tropical area of Korea than a number of other standard traps including the New Jersey and the CDC trap (Burkett et al. 2001; Burkett et al. 2002).

Wheeler (2003) tested the Mosquito Magnet (Liberty), Mosquito Deleto and Sonic Web traps in areas of high mosquito density in the Cayman Islands. In 9 days the Mosquito Magnet caught about 7000 mosquitoes, the Mosquito Deleto caught 37 and the Sonic Web caught 5. About 60% captured were *Culex*, and about 30% were *Aedes*.

Culicine mosquito and larvae

Consumer Reports

Consumer Reports (2003) tested the Mosquito Magnet (Liberty), the Lentek MK01 and the Sonic Web in closed room tests. *Culex quinqefasciatus* and *Aedes aegypti* were released. About 75% of the mosquitoes were recaptured by the CO_2 traps within 20 hours. The Sonic Web, which relies on heat, sound, and octenol, caught only 25%. More of the *Aedes aegypti*, which is an aggressive biter, were recovered than the *Culex quinquefasciatus*. The testers found the Liberty was quieter and easier to use than the Lentek.

MegaCatch

The MegaCatch uses programmed flashing lights from LEDs, carbon dioxide, heat, and vacuum fans as attractants. The carbon dioxide is released in pulses to

Box D. Mosquitoes and Disease

Throughout the world, mosquitoes vector arborviruses [**ar**thropod-**bor**ne viruses] such as yellow fever, encephalitis, and dengue. They also carry nematodes and the malaria protozoa. Malaria, caused by *Plasmodium* sp., is still one of the most serious diseases in the world today. There are an estimated 300 to 500 million cases worldwide, leading each year to 1.4 to 2.6 million deaths and much human misery. The malaria organism is resistant to treatment with drugs such as quinine. Alternate drugs are more expensive and often have adverse effects. Malaria is carried by the *Anopheles* mosquito, and is primarily a problem in tropical countries.

About 80 million people in the world are infected with lymphatic filariasis caused by the nematode, *Wucheria bancrofti.* This disfiguring disease causes parts of the human body to grotesquely swell, a condition called elephantiasis. This disease and the similar filariasis caused by *Brugia malayi* is carried by *Anopheles.*

In terms of numbers, dengue and dengue haemorrhagic fever are the most important arborviral diseases worldwide. Dengue threatens nearly two-fifths of the world's population, ranging over 100 countries infecting millions and killing thousands each year in Africa, the Americas, Asia, the Pacific Islands and Eastern Europe. In many countries, it is the major cause of death among young children. Dengue is spread mainly by *Aedes aegypti* and the tiger mosquito, *Aedes albopictus.*

Japanese encephalitis is mainly an Asian disease. About 45,000 cases and 4,300 deaths were reported in 1990. Increased rice cultivation has caused increased breeding of the vector, *Culex tritaeniorhynchus.* Increased production of pigs has also increased the problem, as pigs act as alternate hosts, and amplify the virus.

Unlike many mosquito-borne diseases, yellow fever is on the decline. Yellow fever is carried mainly by *Aedes* spp. mosquitoes, especially *Aedes aegypti.* About 2,500 cases were reported in Africa in 1991, and only 50-250 cases were seen in the Americas (WHO 1995).

Disease in the U.S.

The principal malaria mosquito in the U.S. is *Anopheles quadrimaculatus*, which is prevalent in the east and southeast. *Anopheles freeborni* is the western malaria mosquito. Transmission rates are extremely low, and malaria is not a public health problem in the U.S. (Swan and Papp 1976). However, malaria remains a threat due to worldwide travel and immigration of infected individuals from abroad.

Yellow fever is no longer a problem in the U.S. Yellow fever in the U.S. is carried only by *Aedes aegypti*, which can also carry dengue and encephalitis. This mosquito is a serious pest of dogs as it carries the canine heartworm, *Dirofilaria immitis.* (See *Common Sense Pest Control Quarterly* 3(2):5-17.)

Since yellow fever and malaria are no longer health problems in the U.S., encephalitis has become the most important mosquito-vectored disease. There are currently 5 different forms of encephalitis caused by 5 different viruses. Eastern equine encephalitis (EEE), Western equine encephalitis (WEE), California encephalitis (CE) and Venezuelan equine encephalitis (VEE).

Of the five diseases, EEE is the most serious. Human mortality rates are 50-75%. WEE and SLE have fatalities of 5-20%. CE has fewer than 1% mortalities, and VEE is a mild non-fatal disease in humans.

The common house mosquito is *Culex pipiens.* It is primarily interested in birds and poultry, but also attacks humans and other mammals. It has caused at least one epidemic of St. Louis encephalitis in the U.S. It also vectors the canine heartworm and filariasis in humans. A related species *Culex tarsalis*, is the principal vector of western equine encephalitis. Eastern equine encephalitis is spread to man and horses by *Aedes* species (Mulhern 1975).

The biting midge, *Culicoides varipennis* is a common vector of bluetongue virus in the U.S. (Holbrook and Bobian 1989).

West Nile Encephalitis

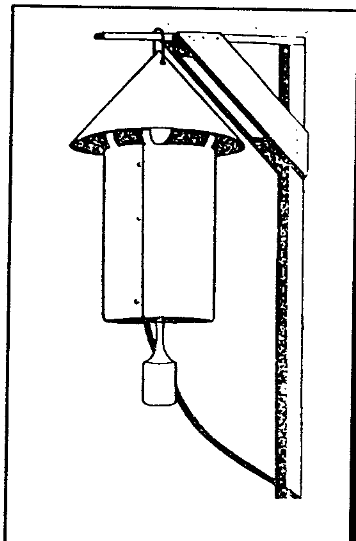
West Nile encephalitis attacked New York City in 1999 (see Quarles 2000). *Culex pipiens* and *Aedes vexans* were the primary vectors in the initial outbreak. Since large numbers of birds were infected, the disease has remained endemic. Sporadic outbreaks occur each year. Of 20,000 people that get infected, 4000 will have symptoms. Mild symptoms include fever, headache and an occasional body rash. About 132 of the 20,000 develop encephalitis or severe symptoms, including stiff neck, high fever, tremors, muscle weakness, convulsions or coma. The death rate is about 9 of each 20,000 infected or 6.8% of the severe cases (CDC 2003).

Mosquito Magnet Liberty model

produce CO_2 gradients fluctuating in time. Line current at 110 AC is used to power the machine. There are two catch modes: a dry mosquito net, and a wetcatch water tray. In cage studies, the MegaCatch with CO_2 caught about 73% of the female *Aedes aegypti* released within 24 hours. Without CO_2, the trap caught about 52%. The wet catch mode captures more biting midges than dry operation (Kline 2003).

Dragonfly

The Dragonfly takes up much less space than the other CO_2 traps. It uses bottled CO_2 with programmed releases. Photocell operation insures that CO_2 is not wasted, but this feature reduces captures of daytime feeders. If daytime catches are desired, photocell operation can be disabled, and the machine can be operated on a timer. The Dragonfly uses more octenol than the other traps. A wax matrix contains the octenol, which is slowly released as the wax is heated. Heat is produced to fit the thermal profile of a small mammal, such as a rabbit. When mosquitoes try to land, they encounter an electrocution grid. Dragonfly prototypes have been used for mass trapping mosquitoes in Florida (Kline and Lemire 1998).



New Jersey light trap

Magnets and MegaCatch

Kline (2003) compared the Mosquito Magnet (Pro) and residential models with the MegaCatch trap in laboratory cages, in a suburban backyard, and in a Florida swamp. In these tests, the Mosquito Magnets were at a disadvantage because Kline eliminated the octenol attractant. Under these conditions, the MegaCatch generally caught more mosquitoes.

In competitive cage studies, the MegaCatch caught about twice as many *A. aegypti*, as the Mosquito Magnet. The traps caught about the same numbers of *Ochlerotatus (Aedes) taeniorhynchus or Culex quinquefasciatus*. In a Florida backyard, the MegaCatch without CO_2 caught about the same number of mosquitoes as the Mosquito Magnet. When CO_2 was added, the MegaCatch caught about 3x as many as the Magnet each night. In various swamp tests, the MegaCatch caught from 2-24 times more mosquitoes. The Mosquito Magnet caught many more biting midges than the MegaCatch (Kline 2003).

Other Florida Tests

John Smith of Florida A&M University reported on comparison tests at the 2002 ESA Annual Meeting in Fort Lauderdale, FL. He compared seven commercial traps and one model under development in terms of numbers and species caught on a northwest Florida peninsula surrounded by a salt marsh. The MegaCatch and the Mosquito Magnet Liberty captured 2.5x to almost 3x more mosquitoes than the next best trap, the Lentek MK01 Mosquito Trap, and 4x to 6x more than the Mosquito Deleto, Mosquito PowerTrap and the Dragonfly. The SonicWeb collected considerably fewer mosquitoes than any of the other traps, which shows the importance of CO_2 as an attractant. The Mosquito Magnet Liberty was able to attract and capture 16 different mosquito species, more than any of the other traps.

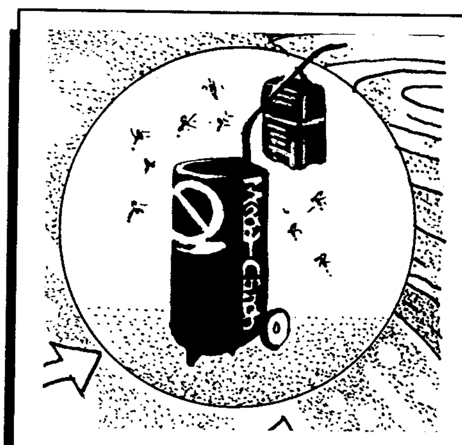
Trap Placements

Trap placement is one of the keys to success with the new traps. If a CO_2 baited trap is placed improperly, it could make mosquito problems worse. Traps should be put 30-40 feet (9-12 m) away from porches or patios and other human congregation areas. If traps are placed too close, mosquitoes will see hosts and track them visually or thermally. Traps may also attract ticks, another reason to put them at a distance.

Traps should be placed between mosquito breeding areas and areas where people will congregate. Mosquitoes should encounter the trap before they encounter hosts. Traps should be placed upwind from human activities, preferably in shady, open locations. Vegetation interferes with dispersal of trap CO_2 (ABC 2003).

Are They Effective?

Can mosquito traps baited with CO_2 and octenol successfully reduce backyard mosquito populations? Or better yet, can they



MegaCatch trap

reduce the number of bites? Mass trapping with attractants and traps has certainly been successful in some cases. USDA scientists D.L. Kline and D.R. Barnard were able to trap an estimated 90% of the pest salt marsh mosquitoes, *Aedes taeniorhynchus*, that plagued a 63-acre (25.5 ha) country club on Key Island at the northern end of the Florida Everglades. Kline and Barnard used mosquito traps baited with cylinders of CO_2 and octenol. They used 52 traps set about 20 feet (6 m) apart, and traps were harvested every 30 days. After one intense 30-day period, more than 2 billion mosquitoes were collected—nearly 23 gallons (87 liters) of mosquitoes (Adams 1996; Kline and Lemire 1998).

Dispensers of citronella or essential oils (Mosquito Incognito) (see Resources) that conceal human odors can be used where humans congregate to give added protection. Citronella candles might be less useful, because mosquitoes are attracted to light and moisture, which might overcome the repellent effect of citronella oil. Traps and repellents could work together as part of an IPM program. Repellents would probably be effective longer, if the mosquito density was lowered by traps. Traps would be more effective if hosts were disguised by repellents.

Overzealous Advertising

These traps are great improvement over the Zap traps that were commercially available when *Common Sense Pest Control Quarterly* reviewed this field in 1996. Traps with targeted attractants do not kill beneficial insects and can capture large numbers of mosquitoes. However, claims of removing all the mosquitoes from an acre are probably exaggerated.

These claims result from measurement of CO_2 dispersal and extrapolations of cage capture tests. If CO_2 can be detected 118 ft (36 m) away, and the wind keeps shifting in a 360 degree pattern, the CO_2 gradient covers an acre. If no mosquitoes are breeding, and the acre is covered with a cage, sooner or later all the mosquitoes either die or find the trap.

However, open space is not caged. Mosquitoes fly into and out of defined areas all the time. Dry weather suppresses breeding; wet weather and successful bloodmeals encourage it. Wind conditions determine movement, and only populations downwind from the trap are affected (Gillett 1972, Service 1993). Complex steady state kinetics develop between mosquito sources and the trap. The steady state equilibrium is complicated by surges and crashes of breeding populations.

Testimonials

Cage tests and comparison field tests show that these traps can catch large numbers of mosquitoes. Other than cage tests and comparison field tests, the only information confirming efficacy of the new traps are the testimonials of consumers. Some of these testimonials are on the American Biophysics website (ABC 2003). Many customers are happy with them, and it is unlikely that the results in all these different situations are coincidence or a result of dry weather.

Resources

Black Hole—www.1mosquito-control.com

CDC, EVS, New Jersey—BioQuip, 2321 Gladwick St., Rancho Dominguez, CA 90220; 310/667-8800; Fax 310/667-8808; www.bioquip.com

Dragonfly, Mosquito Incognito—Biosensory, Windham Mills Technology Center, 322 Main St., Bdlg 1, Willimantic, CT 06226; 860/423-3009; Fax 860/423-3009

Flowtron MT 50, Power Trap—Flowtron, 2 Main St., Melrose, MA 02176; 781/321-2300; www.mosquito-zapper.com

Gobblin—www.mosquitoeater.com

Lentek—Lentek Intl., 407/857-8786, Fax 407/857-4045; www.lentek.com

MegaCatch—Envirosafe,120 Albert St., Westpac Trust Tower, 7th Floor, Aukland, NZ. +64 9416 1544; www.megacatch.com; Mosquito Wizard, 4800 District Blvd., Vernon, CA 90058; 866/339-4927

Mosquito Deleto—Coleman, 800/835-3278; www.coleman.com

Mosquito Magnets—American Biophysics, 2240 South County Trail, East Greenwich, RI 02818, 401/884-3500; Fax 401/884-6688; www.mosquitomagnet.com

Skeeter Vac—Blue Rhino; www.bluerhino.com; www.northlineexpress.com

Sonic Web—Applica Inc., 5980 Miami Lakes Drive, Miami Lakes, FL 33014; www.applicainc.com

*A number of these traps are sold by www.amazon.com and other Web distributors. Significant savings can be made by shopping around.

Conclusion

Published comparison tests show that CO_2 traps catch more mosquitoes than those without CO_2. Mosquito Magnets and MegaCatch models generally have outperformed other traps in comparison tests. Many consumers are happy with the traps, and they should give relief in many situations. However, traps should not be considered magic bullets that destroy all the biting mosquitoes by themselves. But, as one part of an IPM program including source reduction, larval control, and the judicious use of repellents, mosquito traps can help reduce dependence on sprays of toxic pesticides.

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