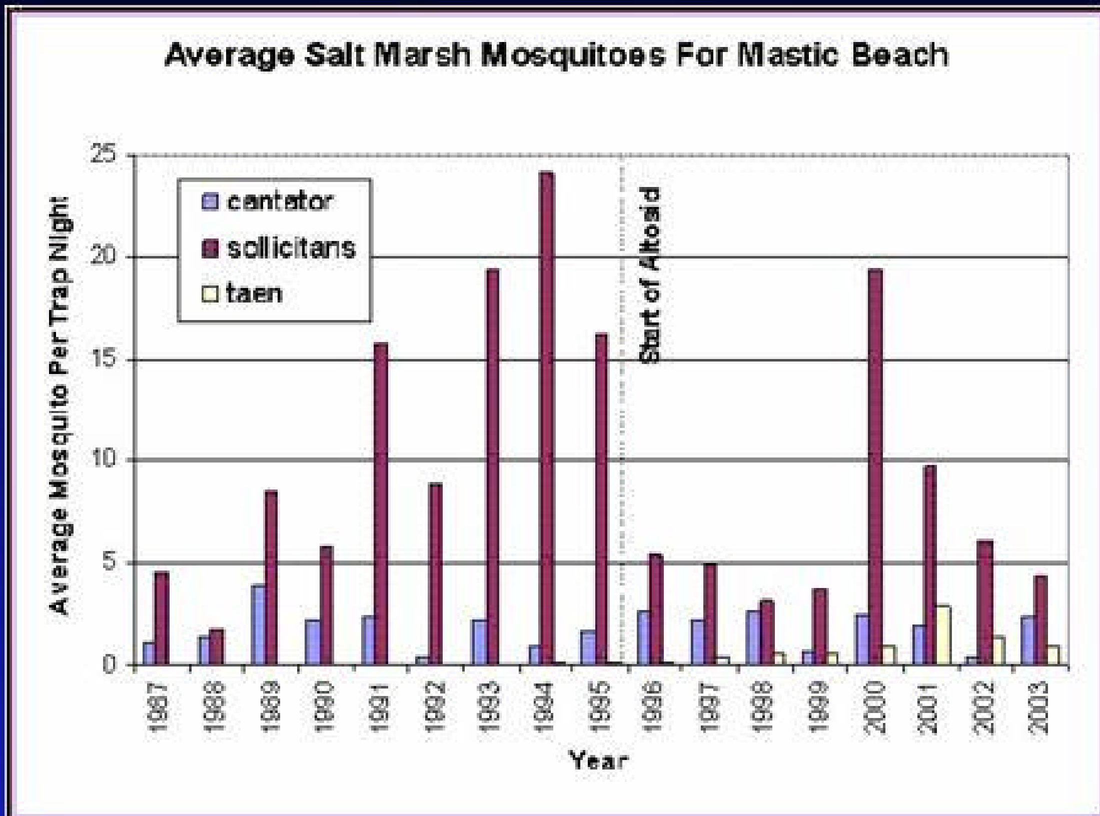
APPENDIX G

SCVC Current Operations Monitoring Pesticide Efficacy

Suffolk County Vector Control & Wetlands Management Long Term Plan & Environmental Impact Statement



Task 4: SCVC Current Operations Monitoring Pesticide Efficacy

Prepared for:

Suffolk County Department of Public Works
Suffolk County Department of Health Services
Suffolk County, New York

Prepared by:

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June 2005

SUFFOLK COUNTY VECTOR CONTROL AND WETLANDS MANAGEMENT LONG - TERM PLAN AND ENVIRONMENTAL IMPACT STATEMENT

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EXECUTIVE SUMMARY

Concerns have sometimes been raised that the use of mosquito control pesticides is ineffective. This is because mosquitoes may continue to be a problem following pesticide applications.

The problems do not generally occur because mosquito control pesticides do not kill mosquitoes. The larvicides generally used in Suffolk County, *Bacillus thuringiensis* var. *israelensis* (Bti) and methoprene are often credited with order of magnitude or more reductions in larval counts in nationwide testing. In Suffolk County, the use of methoprene in addition to Bti, which began in 1996, has been shown to have reduced salt marsh mosquito adult populations in the long term by approximately 80 to more than 90 percent at four of five locations. Adulticides, which have been shown to be capable of reducing mosquito populations by between one to two orders of magnitude, can sometimes achieve such levels of control in measurements made in Suffolk County.

However, every insecticide application can be affected by a myriad of factors, including to much or too little dispersion due to weather, blockage of the insecticide from the target mosquitoes by foliage or buildings, or misjudgements regarding the correct amount to be applied, the best way to apply the chemicals, or the best locations to release the pesticide. Professional care and conduct address the latter three sources of error in most instances, but sometimes natural conditions cannot be overcome, and the application fails to achieve its desired end.

In addition, some mosquito species have a very quick generation time when the weather is warm and conditions are right; other mosquitoes are capable of migrating miles from their breeding sites in search of blood meals. So it is also possible to have an application of pesticides that kills the larvae or adults in a particular area, but still have a mosquito problem soon after that application.

1. Introduction

Mosquito control pesticides are developed because they are intended to kill mosquitoes. Sometimes they act to directly kill the organisms, and sometimes adult mosquitoes are prevented by ensuring the larvae do not develop.

It is important to understand the effectiveness of larval and adult controls at their intended tasks. Suffolk County Department of Public Works, Division of Vector Control (SCVC) uses Bti, a biological control, and methoprene, an insect growth regulator mimic, as larval controls. At this time, SCVC relies primarily on two pyrethroids, resmethrin and sumithrin, for adult control. Malathion, an organophosphate pesticide, was last used in 1999 in Suffolk County, but is being considered as a potential adulticide by the Long-Term Plan. Therefore, these chemicals will be the focus of this report on the effectiveness of pesticides for mosquito control.

2. Larvicides

2.1 Background

Two larvicides commonly applied by Suffolk County are Bti and methoprene. As reported in the Literature Search for the project, Bti is a naturally occurring soil bacterium used as a microbial pesticide. Microbial pesticides are comprised of microscopic living organisms (e.g., bacteria, fungi, protozoa) or the toxins produced by these organisms. Bti is used to control the filter feeding stages of mosquito, black fly, midge, and fungus gnat larvae. Granular and liquid formulated products can be applied through ground or aerial application. Commercial Bti products may consist of the endotoxins and spores, or just the endotoxins. The endotoxins must be ingested by larvae before they act as poisons (and are therefore referred to as "stomach" poisons). After ingesting Bti, enzyme activity and alkaline conditions in the larvae's gut activate the endotoxins, which rapidly bind to the cells lining the midgut membrane and create pores in the membrane, upsetting the gut's ion balance. This results in paralysis of the gut, thus interfering with normal digestion and feeding (Cashin Associates and Integral Consulting, 2004).

Bti is selective for larvae of certain insect species, particularly mosquitoes and black flies. The active endotoxins of Bti range in size from 27 to 138 kilo Daltons, require alkaline conditions of pH 7 or greater, and specific enzymes must also be present in the gut to cause activation. In addition, distinct chemical receptors must be present in the plasma membrane of the gut to encourage binding of the endotoxins. Different mosquitoes have varying susceptibility to Bti, with *Aedes* and *Psorophora* being affected at lower application rates and *Anopheles* and *Culex* requiring greater applications (Cashin Associates and Integral Consulting, 2004).

The length of time that Bti remains effective against insect larvae is a function of the species and behavior of the larvae, environmental conditions, and water quality. Bti is generally effective from one to seven days after application. Light waves from 300 – 400 nanometers can inactivate both spores and endotoxins of Bt. Bti can last for months in soil, and has an above-ground half-life of 1-4 days on plant surfaces. Bti has a tendency to bind to particulate matter in the water column and settle out on the bottom. When adsorbed to particulates in the water column, Bti is too large to be ingested by target insects, and once on the bottom, Bti is not available for consumption by larvae of the open water column or water surface, such as the targeted mosquitoes and flies. Thus, the efficacy of Bti may be limited in aquatic systems with a large amount of particulate matter (Cashin Associates and Integral Consulting, 2004).

Bti, as is the case with Bt strains in general, does not colonize or cycle (reproduce and persist to infect subsequent generations of pests) in the magnitude necessary to provide continuing control of target pests. The bacteria may multiply in the infected host, but bacterial multiplication in the insect does not result in the production of abundant spores or endotoxins. Once larvae die, few or no infective units are released into the environment (Cashin Associates and Integral Consulting, 2004).

Methoprene is a biochemical pesticide found in two formulations (methoprene and methoprene sustained release formula). Methoprene is used to control mosquitoes, beetles, horn flies, tobacco moths, sciarid flies, fleas (eggs and larvae), fire ants, pharoah ants, midge flies, and Indian meal moths. It is also registered for use on a number of foods including meat, milk, eggs, mushrooms, peanuts, rice, and cereals. There are also uses in food processing plants and eating establishments; along with non-food uses such as for tobacco, ornamentals, golf courses, pet products, uses in and around the home, and boxcars (Cashin Associates and Integral Consulting, 2004).

Methoprene is an insect growth regulator that acts by interfering with maturation and reproduction in insects by mimicking the activity of natural juvenile insect hormone, ecdysone. Ecdysone is a hormone in insects, secreted by glands near the brain, that controls the retention of juvenile characteristics in larval stages. If present, ecdysone (or methoprene acting as an insect growth regulator controlling ecdysone) leads to a suppression of adult characteristics. Although applied at the larval stage, response to methoprene usually occurs in the last instars of the larval or nymph form, or pupae form. In the case of mosquitoes, larvae are the target stage, but the effect is not seen until lack of adult emergence (Cashin Associates and Integral Consulting, 2004).

Methoprene degrades rapidly in sunlight, so that within three days of application, 90 percent will degrade via photolysis and microbial metabolism; without microbial metabolism, photolysis will degrade 80 percent in 13 days. Overall, methoprene has a half-life ranging from 30 hours to 14 days, depending on environmental conditions. Higher temperatures and salinity lead to higher degradation rates. The effects of methoprene last up to a week, but it reaches undetectable levels in ponds within 48 hours of application. After four days, only 1 percent of the original application concentration will persist in the top two inches of soil. Methoprene is tightly adsorbed to soil and is rapidly broken down, therefore it is not likely to be transported to ground water. Methoprene sustained release formulation does not produce residual concentrations greater than those produced with the application of a liquid formulation (Cashin Associates and Integral Consulting, 2004). Sampling in association with the development of the long-term plan seems to have shown that methoprene may bind to particles and reach aquatic sediments. It was detectable in sediment samples seven days after application, but despite repeated applications, concentrations did not increase, suggesting its sediment half-life is a week or less (Brownawell et al., 2005).

2.2. General Efficacy Studies

Bti applications in Rhode Island resulted in reductions in light trap counts (the trap was a quarter-mile from the marsh) of between 40 and 60 percent for salt marsh mosquitoes (*Ochlerotatus. sollicitans*) from one year to the next; when Bti was applied at spots where breeding persisted after an OMWM project that constructed tidal creeks and fish ponds, the decrease from baseline conditions was from 85 to 95 percent (except on one occasion where the Bti was not applied in a timely fashion, and a brood resulted) (Christie, 1990). The reductions for *Oc. cantator* were not consistent. Bti was found to kill half of exposed *Anopheles quadrimaculatus* larvae in a liquid formulation applied at 7.6 ug/l (Milam et al., 2000) (note the standard application rate is an area formulation – lbs/acre). Bti killed half of exposed *Culex spp*. mosquitoes from California at concentrations ranging from 0.006 to 0.017 ug/l, and 95 percent of the mosquitoes at concentrations ranging from 0.022 to .085 ug/l. Cx. Pipiens mosquitoes from Cyprus had a 50 percent mortality at concentrations from 0.005 to 0.05 ug/l, and a 95 percent mortality rate for concentrations ranging from 0.026 to 0.325 ug/l (Wirth et al., 2001), illustrating that there is a great variability in the susceptibility of particular mosquito populations, even with one species. In Australia, mosquitoes from the genera *Aedes*, *Ochlerotatus*, and *Culex* were all controlled, with 48 hour mortalities exceeding 96 percent, even in highly organic waters, using a water-dispersible formulation of Bti. *Ochlerotatus* mosquitoes were slightly more tolerant of the pesticide. No residual effect was found one week after application (Russell et al., 2003).

Bti was found to be ineffective for most application means for the control of *Coquillettidia perturbans* in Minnesota, as only one formulation resulted in statistically significant differences between pre-treatment and post-treatment larvae means (the one application type reduced mean numbers by more than 50 percent) (Sjrogen et al., 1986). It also was not effective in Indiana against *Cq. perturbans* (Walker, 1987).

Methoprene reduced numbers of *Cq. perturbans* in Minnesota, with treatment areas having 60 percent fewer adults than untreated areas, and the difference being statistically significant, as measured using emergence cages. The dosage applied was less than five percent of the label rate (Sjrogen et al., 1986). It was also found to be reduce Cq. perturbans in Indiana, with a more than 80 percent reduction in emergence (Walker, 1987).

2.3 Suffolk County Efficacy Tests

The County tests the efficacy of selected larval applications by testing for live larvae after Bti applications, and conducting fly-up testing for methoprene. These results have not been cataloged, but anecdotal information confirms that the larvicides, by and large, achieve their purpose. An example of the effectiveness of Bti was shown when duplex applications (Bti and methoprene) was made to salt marshes at Timber Point and Johns Neck. No live larvae could be found to test for methoprene effectiveness on one date.

Methoprene efficacy was shown in the testing at Johns Neck and Timber Point. Following a duplex application, 32 larvae and 75 pupae were collected; only one adult emerged, suggesting efficacy greater than 95 percent. When methoprene alone was applied, approximately 275 larvae were collected along with 20 pupae. Four adults emerged, again suggesting better than 95 percent mortality.

The County added methoprene to its larvicide program in 1996. Bti, as suggested above, was shown to be effective for specific applications, but did not seem to be providing an overall reduction in mosquito counts. The addition of methoprene did provide major reductions in counts, as measured using annual trap counts at six sites (five treatment areas and one control).

overall, four of the traps showed counts reductions between 79 to 99 percent for salt marsh mosquitoes (*Ochlerotatus cantator*, *Oc. sollicitans* and *Oc. taeniorhynchus*), comparing eight years of data pre-methoprene to eight years of data following its addition to the program (Figures 1-4). The fifth site, overall, had a 23 percent reduction in mosquitoes, but the trend was also sharply down for the first four years of the treatment before reversing itself in 2000 (Figure 5). The County attributes this to the proximity of untreated National Seashore marshes. The control site had essentially unchanged populations (Campbell et al., 2005).

3. Adulticides

3.1 Background

is a broad spectrum pyrethroid insecticide used for control of flying and crawling insects in homes, greenhouses, indoor landscapes, mushroom houses, and industrial sites, insects that infest stored products, and for mosquito control. It is also used for fabric protection, pet sprays, and shampoos, and it is applied to horses and in horse stables (Cashin Associates and Integral Consulting, 2004).

Resmethrin is classified as relatively insoluble in water, but it is highly soluble in organic solvents. It binds tightly to soil and is not expected to be mobile in soil or to contaminate ground water. In addition to binding to soil, resmethrin may sorb to sediments, suspended particles, and plants. Biodegradation, hydrolysis, and photodegradation are the rapid degradation pathways for resmethrin, with environmental half-lives ranging from 15 minutes to just over a month, depending on the environmental setting. Resmethrin's photodegradation half-life on surfaces is approximately three hours, while half-lives in soil and sediment have been reported to be 30 and 36.5 days, respectively. Environmental degradation products reported for resmethrin are chrysanthemic acid, benzaldehyde, benzyl alcohol, benzoic acid, phenylacetic acid, and various esters (Cashin Associates and Integral Consulting, 2004).

Sumithrin (also called phenothrin) is a broad spectrum pyrethroid insecticide registered for use against mosquitoes in swamps, marshes, and recreational areas. Sumithrin can also be used to kill pests in transport vehicles such as aircraft, ships, railroad cars, and truck trailers, and for institutional non-food use, use in homes, gardens, and greenhouses, and on pets (Cashin Associates and Integral Consulting, 2004).

Sumithrin degrades readily, with a half-life of less than one day, on plants and other surfaces. In soil, sumithrin degrades rapidly, with a half-life of 1-2 days under dry, sunny conditions. Under flooded conditions, the half-life increases to 2-4 weeks for the trans isomer and 1-2 months for the cis isomer. Half-life is longer in the absence of light — sumithrin has been found to remain almost intact on grains stored in the dark for up to 12 months In general, the degradative processes that occur in the environment lead to less toxic products (Cashin Associates and Integral Consulting, 2004).

The pyrethroids are synthetic pyrethrin-like materials widely used for insect control. Pyrethrins are natural pesticides harvested from some chrysanthemum plants (mainly *Chrysanthemum cinerarnaefolium*). Chemically, pyrethroids are esters of specific acids (e.g., chrysanthemic acid, halo-substituted chrysanthemic acid, 2-(4-chlorophenyl)-3-methylbutyric acid) and alcohols (e.g., allethrolone, 3-phenoxybenzyl alcohol). Pyrethrins and pyrethroids have a similar mode of action — they work on the nerve axons by keeping open sodium channels used to propagate signals along a nerve cell. Initially, they cause nerve cells to discharge repetitively; later, they cause paralysis. These pesticides affect both the peripheral and the central nervous systems. When applied alone, pyrethroids may be swiftly detoxified by enzymes in the insect. Thus, some pests will recover. To delay the enzyme action so a lethal dose is accomplished for pest control, a synergist (e.g., piperonyl butoxide) is generally added to pyrethroid formulations to improve efficacy (Cashin Associates and Integral Consulting, 2004).

Ester hydrolysis and oxidation at various sites on the molecule are the major degradation processes. As a chemical class, pyrethroids have very low volatility, are all very poorly soluble in water, and have a tendency to bind very tightly to organic particles in soil, and so pyrethroids are not expected to leach to groundwater or surface water bodies. In aquatic settings, pyrethroids strongly adsorb on sediments (Cashin Associates and Integral Consulting, 2004).

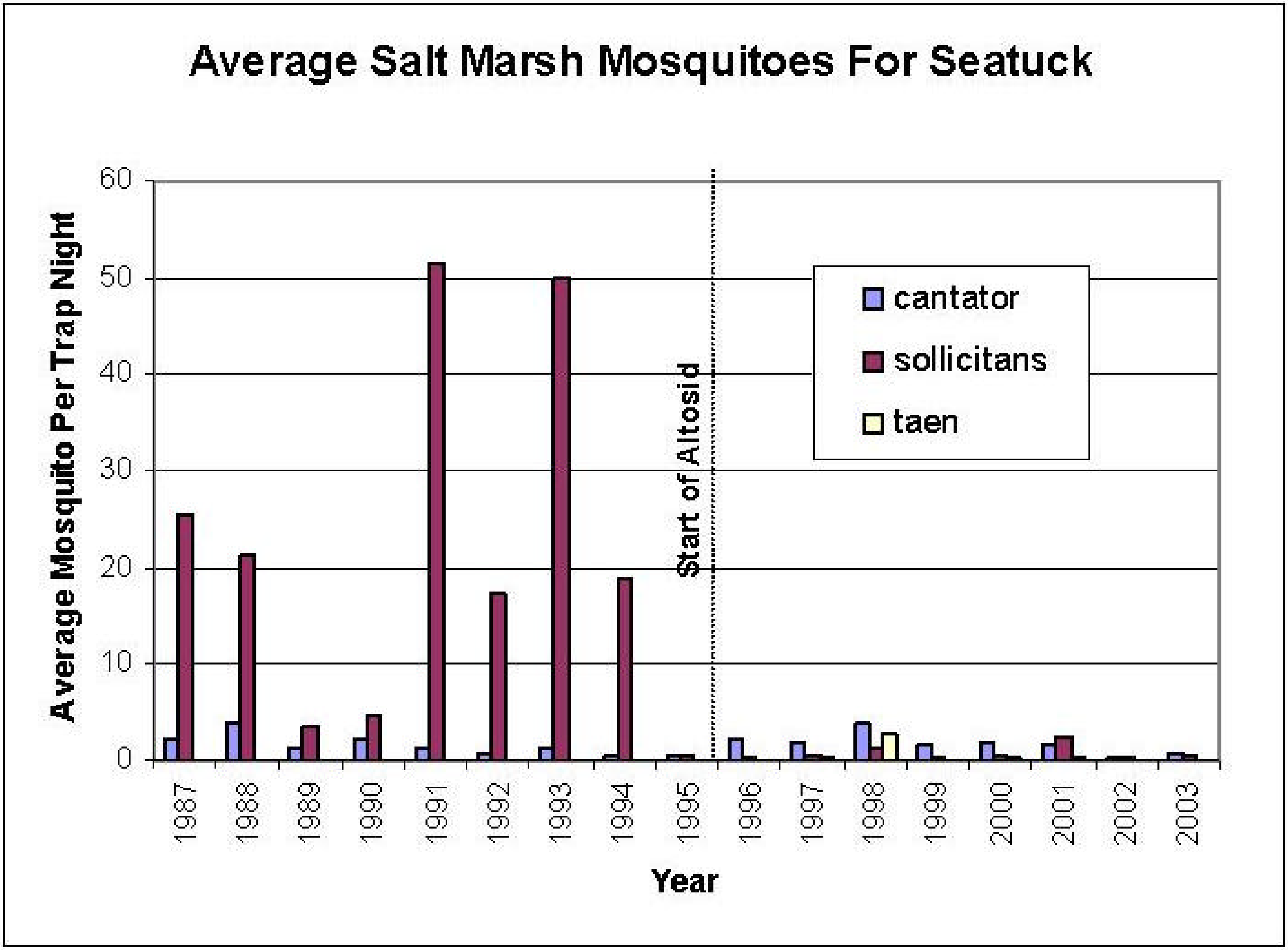
Malathion is a nonsystemic broad-spectrum organophosphate chemical that is used in agriculture and horticulture applications. Malathion has been widely used since the 1950s on raw agricultural products including edible grains, fruits, nuts, forage crops, cotton, and tobacco. Malathion has also been used to control parasites of livestock and domestic animals, through aerial applications in and around livestock barns, dairies, poultry houses, and food processing plants. Malathion has widespread use as a ground and aerial spray to control Mediterranean fruit fly and mosquito populations. Malathion is used as a pediculicide in shampoos to treat head lice on children and adults (Cashin Associates and Integral Consulting, 2004).

Malathion contains approximately 5 percent impurities consisting largely of reaction byproducts and degradation products. As many as 14 impurities have been identified in technical-grade malathion (Cashin Associates and Integral Consulting, 2004).

Organophosphates exert toxicity through the inhibition of acetylcholinesterase (AChE) at cholinergic junctions of the nervous system of organisms. These junctions include postganglionic parasympathetic neuroeffector junctions (sites of muscarinic activity), autonomic ganglia and the neuromuscular junctions (sites of nicotinic activity) and certain synapses in the central nervous system. Acetylcholine (ACh) is the neurohumoral mediator at these junctions. Since AChE is the enzyme that degrades ACh following stimulation of a nerve, its inhibition allows ACh to accumulate and result in initial excessive stimulation followed by depression. In insects, this inhibition interferes with the nerve-muscle communication at neuromuscular junctions, and that ultimately causes paralysis of the insect (Cashin Associates and Integral Consulting, 2004).

Malathion is degraded in the environment through three main pathways, activation, degradation, and isomerization. Activation of the compound involves oxidative desulfuration, yielding malaoxon. Activation may be achieved by photo-oxidation, chemical oxidation, or biological activation, the latter of which occurs enzymatically through the activity of mixed function oxidases. Degradation of malathion occurs through both chemical and biological means, with hydrolysis being the most important pathway for each. Malathion can be broken down via microbial and photodegradation under various settings. Its half-lives can range from five hours to 25 days, depending on the medium (i.e. water, soil, air). Limited data exists with respect to the environmental fate of malaoxon and isomalathion (Cashin Associates and Integral Consulting, 2004).

3.2 General Efficacy Studies


Average Salt Marsh Mosquitoes For Seatuck
Average Mosquito Per Trap Night
60
50
40
30
20
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Start of Altosid
cantator
sollicitans
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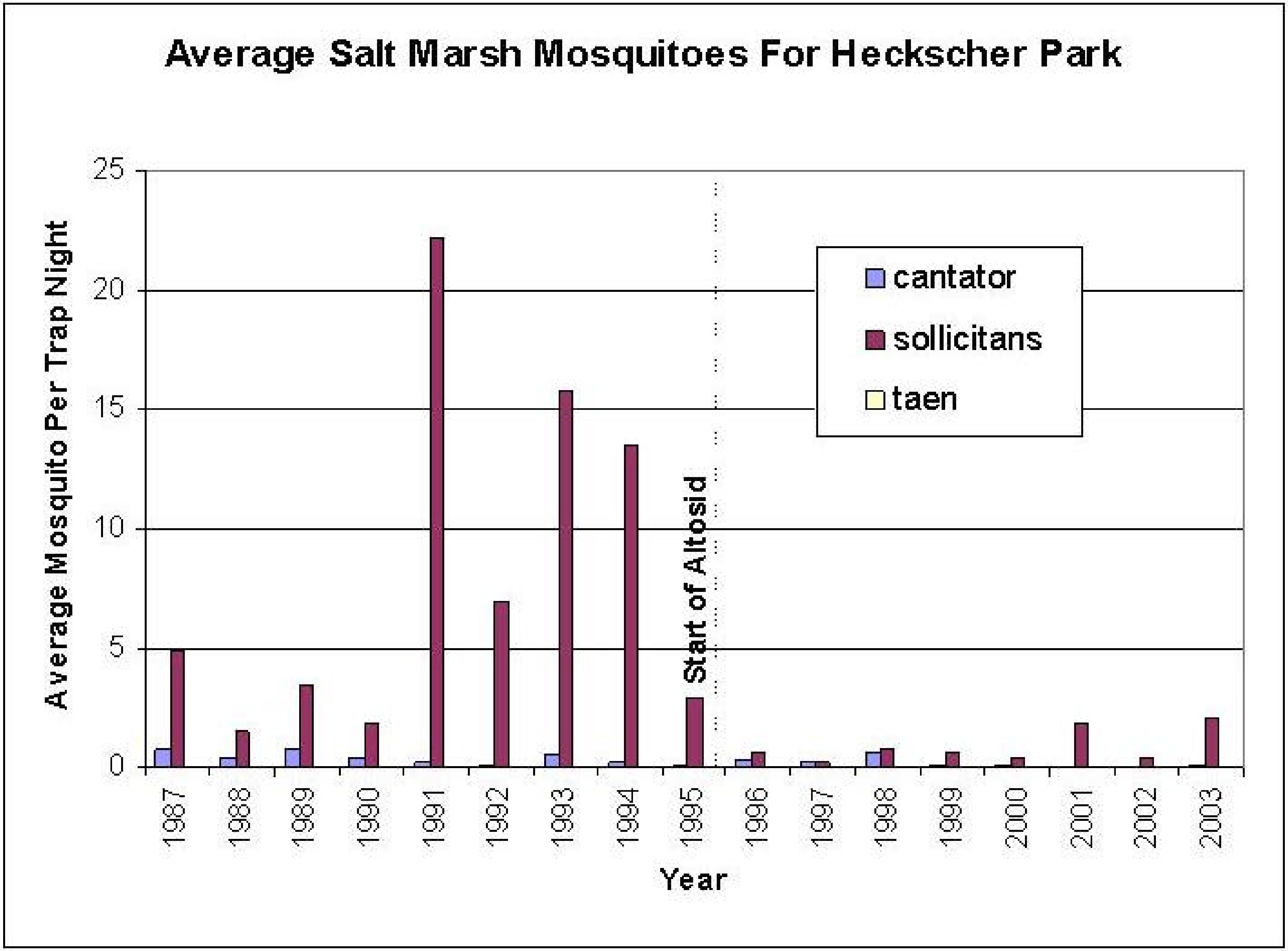
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Average Mosquito Per Trap Night
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Start of Altosid
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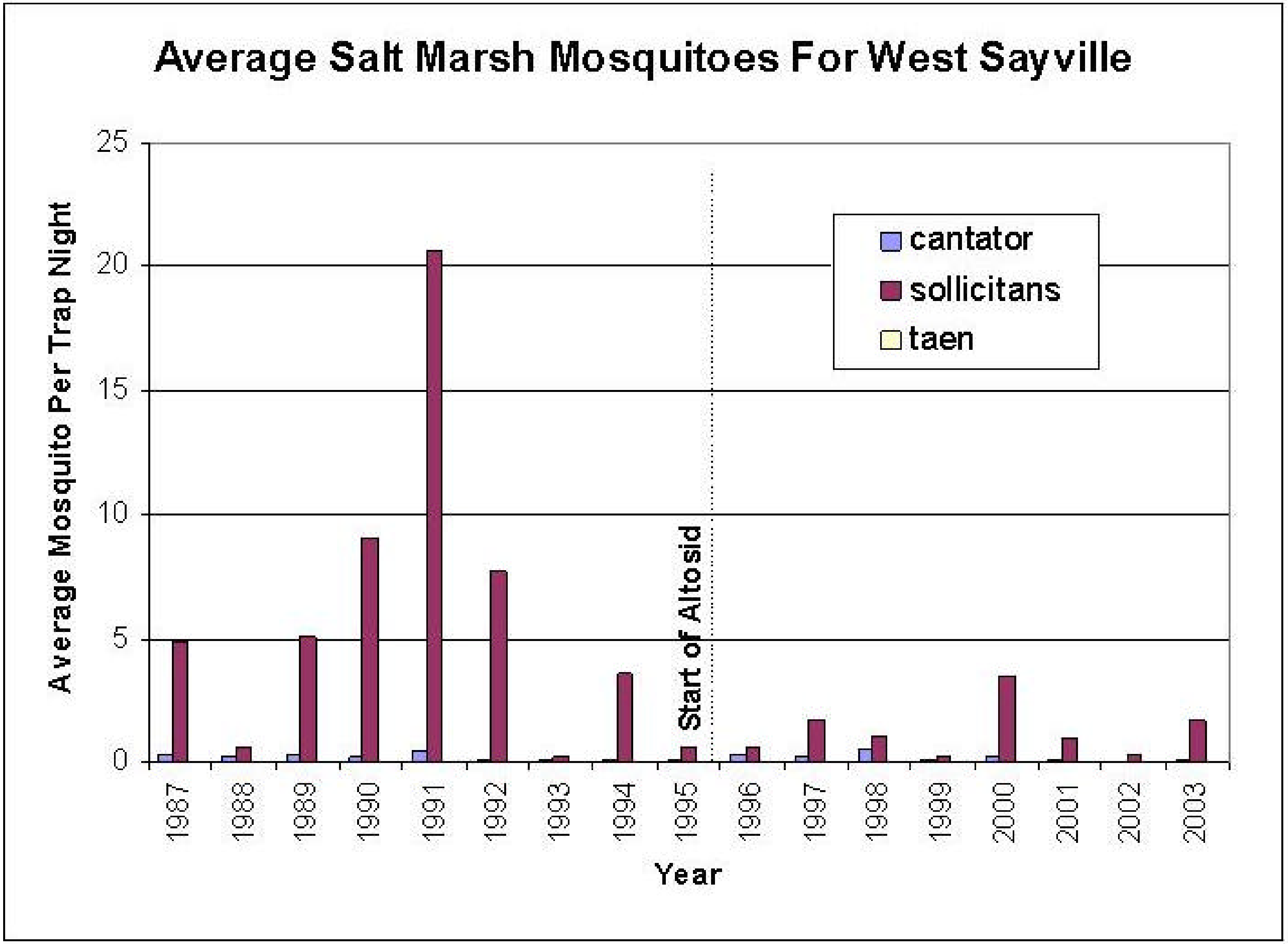
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Average Mosquito Per Trap Night
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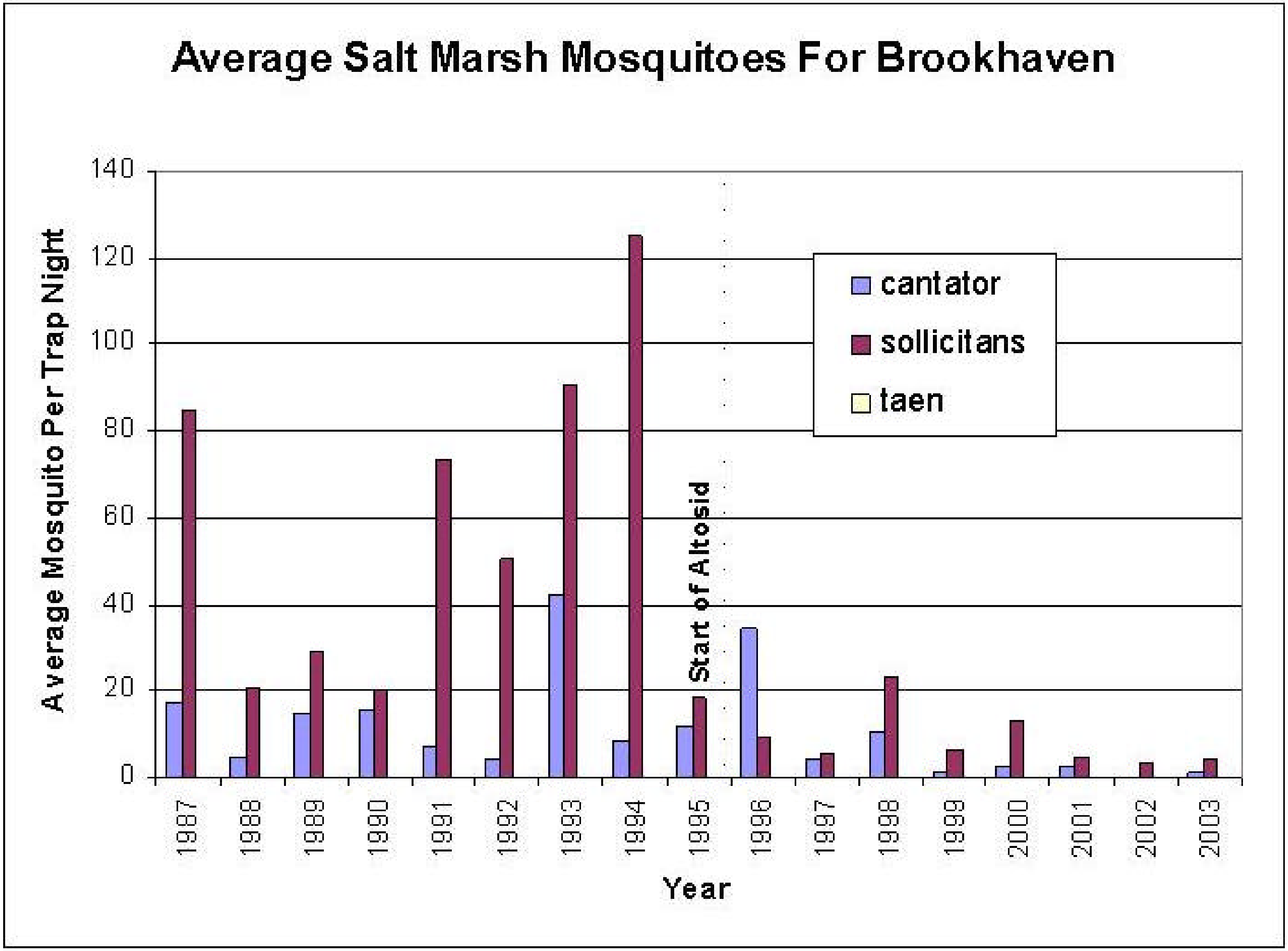
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cantator
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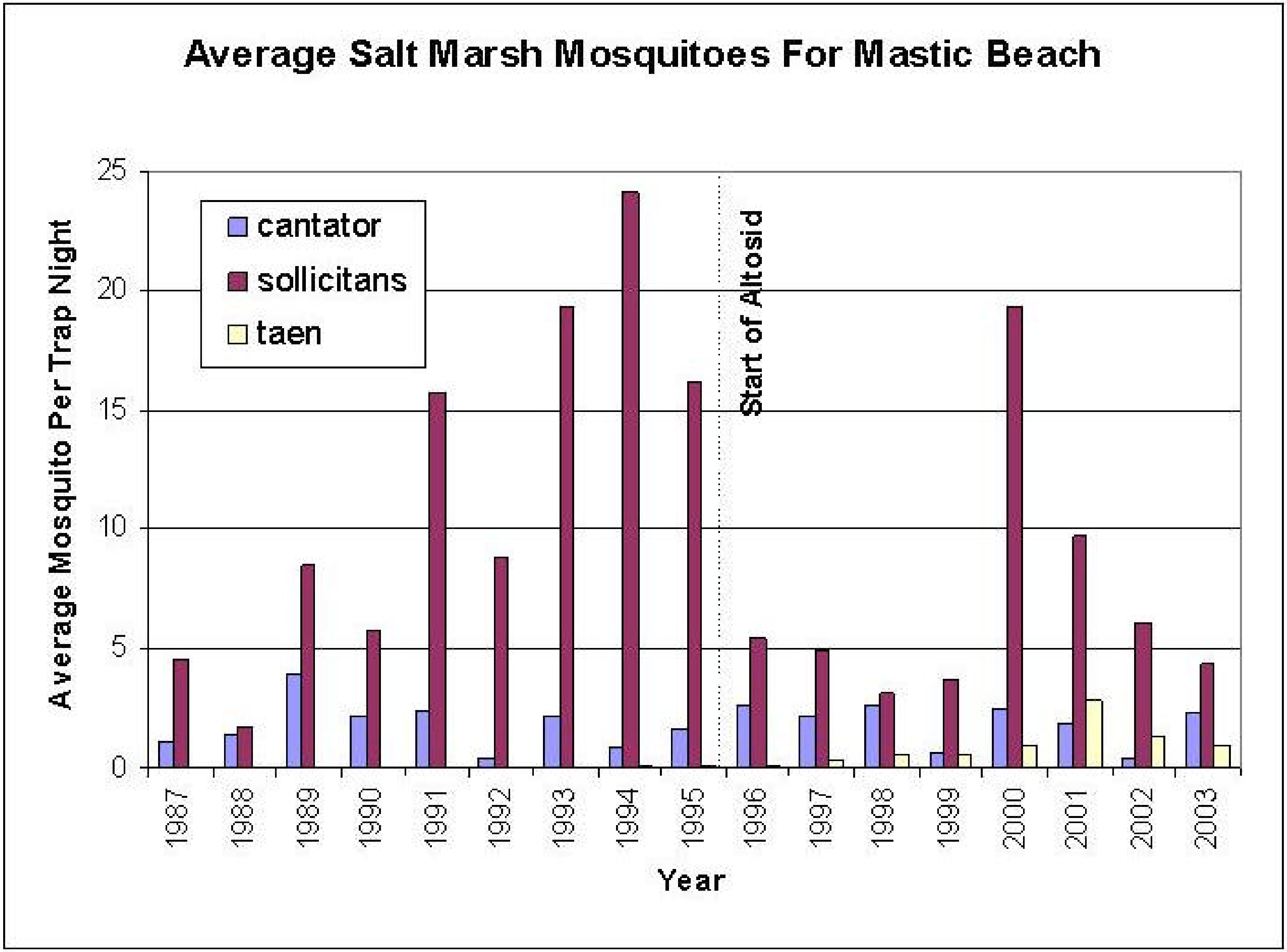
Average Salt Marsh Mosquitoes For Mastic Beach
Average Mosquito Per Trap Night
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sollicitans
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