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Controlling Mosquito Populations and Reducing the Risk of Mosquito-Borne Diseases in a Beach Resort of Punta Cana Using Eco-Friendly Technologies

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Abstract:*A new technology to deliver eco-friendly pesticides was developed in order to control mosquitoes, reduce the threat posed by mosquito-borne diseases, and to greatly reduce the amount of pesticides delivered into the environment surrounding hotel environments and in densely populated areas. The ProVector®Mosquito Control Systemis designed to use color as an attractant while delivering an attractant Entobac™ attractant pesticide to target pests. This technologydramatically reduces the amount of pesticides in the environment and protects non-target species. Anefficacy trial was conducted at the Iberostar Hotel, Punta Cana, Dominican Republic to test whether the ProVector System would reduce mosquito populations in the hotel area. The total mosquito population as well as individual medically important genera were reduced significantly within 30 days. The area at highest risk from mosquitoes was reduced by 217% within 70 days. Delayed lethality of Entobac on adult mosquitoes allows the adults to transport the biopesticide to larval breeding sites before the adults die, whereby the larvae are also killed by the biopesticide.This study shows for the first time, that an attractant applicator system can be used to reduce mosquito populations in a hotel resort area threatened by mosquito-borne diseases in a way that does not reduce, but in fact enhances, the tourist experience at theresort.*

I. Introduction

Mosquito-borne diseases are a major threat to local residents as well as tourists visiting tropical and semi-tropical countries. For example, the Olympic and Para Olympic Games being held in Rio de Janeiro are threatened by international outcries and worry because of the perceived lack of control of Zika virus and the *Aedes* species transmitting the virus. Because of this threat, the World Health Organization (WHO) has developed a “to do list” for athletes and visitors to follow in Rio de Janeiro (WHO, 2016). The threat of mosquito-borne pathogens to tourists to tropical and semi-tropical is common and in addition to Zika virus includes, malaria, West Nile virus, dengue, and chikungunya viruses, etc. Zika virus is a new emerging mosquito-borne disease and it is spreading globally (IAMAT, 2016). The Dominican Republic is a major tourist destination, and Zika virus as well as malaria, dengue and chikungunya viruses are present in several parts of the country (Schilthuis and Overbosch, 2000; WHO, 2016).

Controlling mosquito populations is an effective public health intervention for reducingthe prevalence of mosquito-borne diseases (Tomerini et al, 2011). Because of the effectiveness of mosquito control, national ministries of health, local politicians and hotel management often implement integrated vector management programs (IVM). Spraying of pesticides is an integral management tool in IVM, however spraying large areas can be expensive, non-target species are often negatively impacted,and the spraying can be negatively perceived by tourists visiting resorts. Tourists are concerned with what type and how much pesticides are applied into the environmentbecause of health and safety concerns for themselves and their families,and the damage to the environment that often occurs when pesticides are improperly applied.

Because of the publichealth threat posedby mosquitoes to both tourists and staff, many hotels in the Dominican Republic conduct mosquito control operations. The Iberostar Hotel, located in the beach resort city of Punta Cana, conducted weekly spraying/fogging of pyrethroid pesticides. However, even with an active pesticide application program the mosquitoes continued to be a pest problem and exposed tourists and staff to the possible health riskand annoyance over large areas of the hotel property. Our team was contacted to determine whether the ProVector System could be implemented as part of the integrated mosquito management plan.

II. Methods and Materials

Eight CDC light traps, with octenol bait, were placed on Day 0, Day 30 and Day 70 and trapped for 3 nights each period. Mosquitoes were collected and identified to genus and data was analyzed using statistical software (Statsoft, Dell Inc.) and geospatial analysis software (ArcView, ESRI Inc.). The ProVector System includes the ProVector® Flower ™, ProVector Tube ™ and ProVector Super Netty™ applicators from MEVLABS, Inc. These applicators are designed with colors and apertures to attract mosquitoes, gnats and flies. A pesticide bait pad or semi-solid bait using Mosquito Attractant Bait (MAB™) formulated with a pesticide is placed within the applicator and the vector species feed through the apertures on the pesticide bait.The applicator with bait pad is hung from a ceiling, door post, tree or other structure where mosquitoes frequent. Various pesticide baits have been developed to economically and safely deliver virtually non-toxic pesticides to mosquitoes, including Entobac™(with *Bacillus thuringiensis israelensis*,Bti) and Ecobait™ (with Eugenol). Depending on the ProVector System used, baits can last for as long as 3 months and cost as little as $0.01 per day to operate.In the present study, 75 ProVector Flower applicators with one Entobac bait pad each, wereplaced on the outside balconies of alternating rooms, on the first and second floors of two buildings at the Iberostar Hotel, Punta Cana, Dominican Republic, Figure 1.

III. Results and Discussion

There was not a significant difference between the mean number of mosquitoes per trap in the test and control sites before the ProVector Flowers with Entobac were placed on balconies; $F(1, 6)=.87565$, $p \geq 0.05$. Within 30 days there was a significant difference between the test sites and control sites $F(1, 24)=13.129$, $p \leq 0.05$(Figure 2). General linear modeling revealed the ProVector Flowers with Entobac significantly reduced the mosquito population over time and space $F(1, 43)= 15.13$, $p \leq 0.05$ (Figure 3). There was a significant reduction in the mean number of *Aedes*, *Anopheles* and *Culex* per trap in the ProVector/Entobac site but not in the control site; there was a significant increase in *Uranotaenia* in the control site (Table 1).

In addition to the statistical comparison, geostatisticalanalysis using kriging revealed a significant reduction of the mosquito population throughoutthe hotelproperty beyond where the ProVector Flowers were placed.Although the Iberostar Hotel had an active IVM program only a small area of the resort was relatively mosquito free before placement of the ProVector Flowers. Using the ProVector System, the area at risk by mosquitoes was reduced by 217% (Chi-square=2.7×10^7, $p \leq 0.05$) (Figure 4). The mechanism by which area control is attained using Entobac biopesticide is by delayed lethality, from 3 to 7 days, (Ponlawat et al. 2016). The delayed lethalityallows the Bti to reproduce in the adult mosquitoes, whereby the adults transport the Bti to larval breeding sites before they die, killing the larvae as well(Kollars et al. 2016). On the Iberostar Hotel grounds, the ProVector Flowers were contained in an area approximately 14,500 square meters yet the effective coverage as indicated by geospatial analysis was 105,000 square meters, over 7 times the expected coverage. This delayed lethality provides mosquito control within a larger area than would be expected and may be particularly useful for *Ae. aegypti* and *Ae. albopictus* and other container breeders as breeding sites can be problematic to reach with traditional mosquito control technologies.

Attractive sugar baits can serve as an effective, inexpensive, and environmentally friendly tool for integrated mosquito management programs (Qualls et al., 2012). When the pesticide is optimized for delayed lethality in adult mosquitoes, additional reduction of mosquito populations can occur. One Entobac bait pad is sufficient to provide control for a minimum of50,000 mosquitoes and when used as part of the ProVector System large areas of property can be protected. The amount of pesticide needed to cover an area is reduced by approximately 10,000 times due to target specificity and dissemination of the pesticide to breeding sites by target species and control to areas outside of the immediate vicinity of the ProVector System is attained.

Both hotel staff and hotel guests found the ProVector devices attractive and liked the fact Bti biopesticide is considered virtually non-toxic. Additional studies of the ProVector Systems in several countries have been conducted, e.g. orphanages, housing compounds and villages. For example, the U.S. Army tested the ProVector Flower with Entobac in the malaria hot-zone surrounding Lake Victoria in Kenya and found the ProVector System reduced the mosquito population by 69% within one month. The U.S. Army study in Kenya also demonstrated the ProVector System was effective on the major vector groups, reducing*Anopheles*, *Aedes*, *Culex*, *Coquillettidia*, and *Mansonia* species (Yalwalla et al. 2016). In the U.S., the ProVector System has been modified using insect growth regulators (IGR) to provide additional control of biting midges, tabanid flies and filth flies. Additional studies to further quantify the effective radius of the ProVector System should be conducted.

In addition to the threat posed by mosquitoes to local residents, guests to countries with high rates of mosquito-borne diseases may be so negatively impacted that they will not return and news outlets may negatively tourism by negative reporting. For example, in the Ko Somui beach resort in Thailand, when foreigners who were still suffering from dengue fever returned home ill, a negative impression to that country was maintained (Thavara et al. 2000). It is essential the managers of hotels and those personnel tasked with controlling mosquito populations in tourist areas incorporate a variety of integrated mosquito control measures in order to reduce the threat of disease and to enhance the experience of tourists visiting their facilities. The ProVector System has been proven to be an effective new technology in the control of mosquito populations and reducing the risk of infection by mosquito-borne diseases. This study shows for the first time, that an attractant applicator system can be used to reduce mosquito populations in a hotel resort area threatened by mosquito-borne diseases in a way that does not reduce, but in fact enhances, the tourist experience at the resort.

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Figures and Tables

Figure 1. ProVector Flower containing Entobac placed in upper corner of outside balcony of hotel room of the Iberostar Hotel.

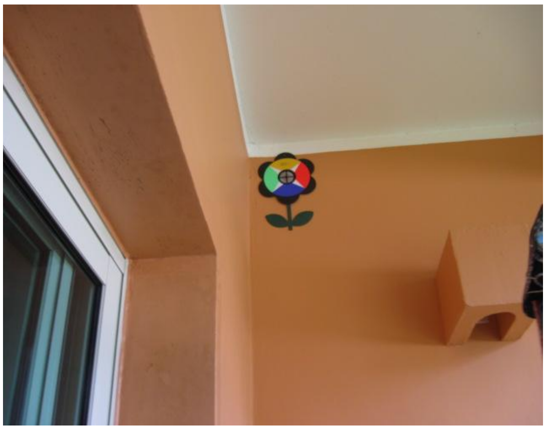

Table 1. Four genera were identified during this study, with significant differences in each population over time.

Species	Day 0 Control	Day 0 Test	Day 30 Control	Day 30 Test	Day 70 Control	Day 70 Test
Aedes	1.3	1.8	0.3	0.1**	2.0	0**
Anopheles	0	1.3	1.8	0.1**	2.3	0.2**
Culex	8.5	8.3	8.3	1.7	13.3	12.3
*Uranotaenia**	0	0	0.2	0	2.3*	0

*significant increase from day 0, $p \leq 0.05$

**significant decrease from day 0, $p \leq 0.05$

Figure 2. Monthly mean number of mosquitoes captured per trap in ProVector/Entobac Test site and Control sites.

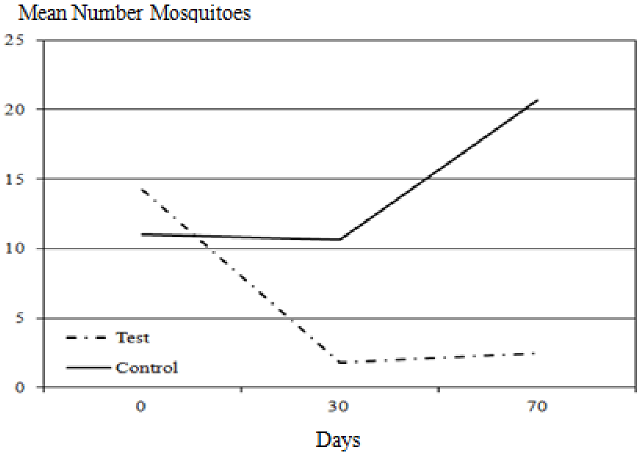

Figure 3. There was a significant difference between the overall number of mosquitoes collected from ProVector/Entobac Sites and Control Sites during the 70 day trial in Punta Cana using General Linear Modeling,vertical bars denotes +/- standard.

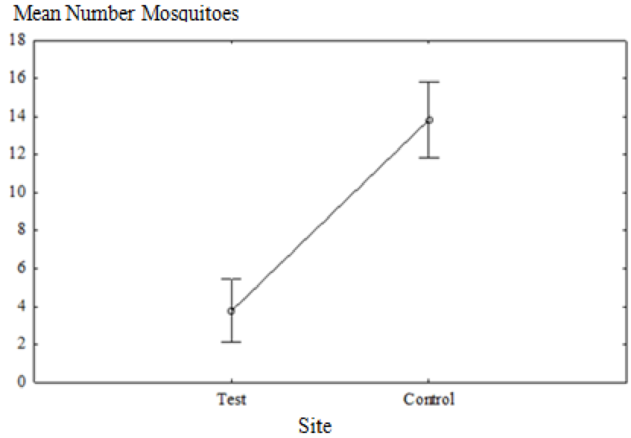

Figure 4. The estimated density of adult mosquitoes using geospatial krigging analysis before (top) and 70 days after placement of ProVector Flowers with Entobac biopesticide on the outside of hotel balconies along blue lines (bottom).