JOURNAL OF THE NACAA

ISSN 2158-9429

VOLUME 17, ISSUE 2 – DECEMBER, 2024

Editor: Linda Chalker-Scott

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Effectiveness of Treatments to Reduce Mosquito Larvae in Rain Barrels

Abstract

Rain barrels are a practice to help homeowners conserve water but may provide mosquito breeding habitats. Extension programs that provide barrels suggest treatments that reduce mosquito breeding opportunities, like screening barrel openings or using soap, oil, or Mosquito Dunks®. This project evaluated these various Extension-recommended treatments in simulated rain barrels. Each treatment reduced mosquito larvae by more than 99% compared to untreated buckets with open water. Issues arose during the study, such as oil going rancid, Mosquito Dunks® breaking apart, difficulty maintaining a soap or oil layer, and screens filtering debris, that homeowners should be aware of to make appropriate decisions when maintaining their rain barrels.

Keywords: BTI larvicide, larval control, mosquitoes, New Jersey, rain barrels

Introduction

Future predictions of water availability in New Jersey show an increase in water consumption by the state's growing population (New Jersey Department of Environmental Protection [NJDEP], 2017). The climate in the northeast is predicted to change dramatically in the next 100 years, also, as the northeast is warming faster than other regions of the country (NJDEP, 2020). This increased consumption, as well as the likelihood of decreased rainfall and more frequent droughts due to climate change, makes water scarcity a real possibility for New Jersey residents (NJDEP, 2017). Due to these issues, there is great interest from the public in this region in conserving water through a rainwater harvesting system, with rain barrels being a popular choice. In New Jersey alone, over 3,000 barrels were distributed by one Cooperative Extension program from 2009 through 2014 (Rutgers Water Resources Program, 2014). Rain barrels provide the opportunity for homeowners to become active in water conservation while opening the opportunity to be involved in other forms of stormwater management (Bakacs et al., 2013). As a practice in New Jersey, rain barrels installed in residential areas are used for irrigation of lawns and landscape plants, and other non-potable uses (NJDEP, 2021).

Stormwater management practices that involve the collection of rainwater, such as rain barrels, have the potential to provide habitats for mosquito breeding (Brown et al., 2022; Kwan et al., 2008; Metzger et al., 2008; Taguchi et al., 2020). Increasing populations of mosquitoes can be a nuisance that affects quality of life for residents in New Jersey, affecting their ability to utilize and enjoy outdoor spaces, such as their yards (Halasa et al., 2014). Mosquitoes are also known vectors of several infectious diseases, such as malaria, West Nile Virus, and dengue (Bonizzoni et al., 2013; Farajollahi et al., 2011). Strategies to reduce the availability of rain barrels as mosquito breeding habitats will protect both quality of life and public health.

To deter mosquito breeding in rain barrels, several recommendations are made available through Rutgers Cooperative Extension publications (Rector et al., 2014). These recommendations include screening all openings, use of Mosquito Dunks®

(Summit Company, U.S.A.; hereafter referred to as Mosquito Dunks®), a *Bacillus thuringiensis israelensis* (BTI) larvicide, and creating a surface barrier of oil or soap. However, the relative success of these Extension-recommended practices for rain barrels at the homeowner scale is currently unknown. This study was developed to close this knowledge gap. Since many homeowners may be reluctant to use rain barrels because of the potential for increasing mosquito populations, having science-based information on how to effectively reduce mosquito breeding habitats would allow for wider adoption of rain barrels as a practice and more water being conserved for the future.

Methods

Study Area

Located in southeastern New Jersey, Toms River is a coastal town in Ocean County that serves as the county seat of government (Figure 1). The town has a total population of 98,326 (2022 census data) and covers an area of 136.98 square kilometers (km^2), giving it a population density of 717.8 people per km^2. Land use in Toms River is primarily residential, with many single-family dwellings and senior communities, as well as developed areas in support of these areas (commercial and transportation centers) (2020 GIS data). As it borders Barnegat Bay, the eastern portion of town has some small estuarine marshes dotting its shoreline.

Samples were collected from the Rutgers Cooperative Extension’s Agriculture Building on Whitesville Road. This building is surrounded by land uses typical of Toms River, NJ (primarily single-family houses and age-restricted developments).

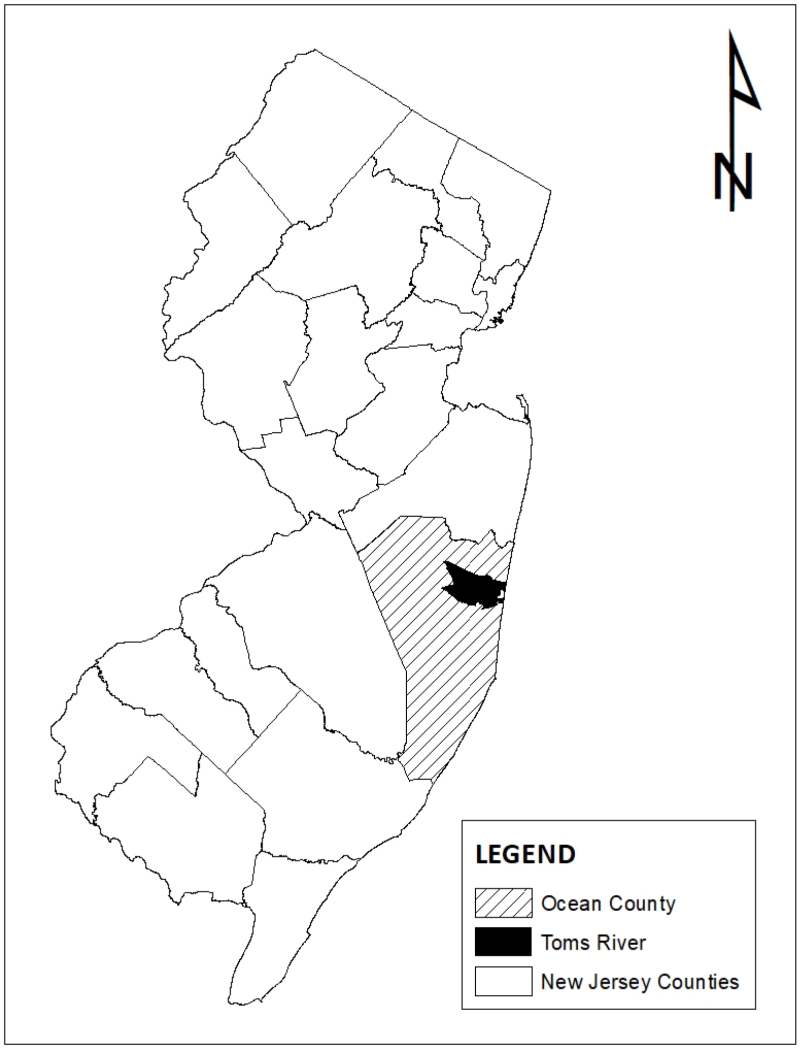

Figure 1: Location of Toms River (Ocean County), New Jersey. (This map was developed using NJDEP Geographic Information System digital data, but this secondary product has not been verified by NJDEP and is not state-authorized.)

Sampling

Sampling was conducted using 19.1 liter (L) buckets as simulated rain barrels filled with 3.8L of water. The water used to fill each bucket was obtained from a rain barrel installed on the Rutgers Cooperative Extension's Agriculture Building which harvests rainwater from its roof. Water was obtained from the rain barrel and screened through a 150 micrometer (μm) sieve to remove any debris and any existing mosquito larvae and/or eggs prior to being added to the buckets. All measuring containers and sieves were rinsed between filling each bucket to prevent cross-contamination of samples.

Four (4) mosquito reduction treatment options were examined to determine their effectiveness in preventing mosquito breeding populations in rainwater harvesting systems (i.e., rain barrels): 1) screening; 2) Mosquito Dunks®; 3) a surface barrier of oil; and 4) a surface barrier of soap. A 45 centimeter (cm) by 45 cm square of window screen was attached to bucket 1, one half of a Mosquito Dunk® was placed in bucket 2, 250 milliliters (mL) of vegetable oil was added to bucket 3, and 250mL of liquid hand soap was added to bucket 4. For the oil and soap, 250mL approximates a 0.32 cm thick layer as recommended by Rutgers Cooperative Extension (Rector et al., 2014). A fifth bucket was filled with water and received no treatment to be used as a control. Each treatment was repeated three (3) times during each round of sampling for a total of fifteen (15) samples per trial. All buckets were labelled with each treatment to prevent cross-contamination between rounds of sampling (Figure 2). Note that the treatment options evaluated are those recommended by Rutgers Cooperative Extension (Rector et al., 2014) and not the American Mosquito Control Association (AMCA). The AMCA recommends the use of screening and larvicides, such as Mosquito Dunks®, only (AMCA, 2021).

Sampling rounds were conducted during the summers of 2021 (July-September), 2022 (June-September), and 2023 (July-September). The buckets were placed in a lightly wooded area adjacent to a building and/or other structure, such as a shed (Figure 2). Each set of buckets was left out for approximately 20 days to ensure that sufficient time was allowed for egg deposition, development, and hatching. During each round of sampling, the containers were visually inspected daily for larvae development.

Figure 2: View of the experimental setup showing one set of the buckets after sample initiation.

After the sample period, each sample was screened through a 150μm sieve. Each bucket was rinsed three (3) times with tap water to ensure that sample collection was thorough. Large organic debris (twigs, leaves, and the like) were rinsed off with tap water into the sieve and removed from the sample. Samples were then transferred from the sieve to a 500mL or 1L container, with tap water, for transport to the Ocean County Mosquito Commission laboratory in Barnegat, NJ. Identification and counts of larvae were conducted by staff of the Ocean County Mosquito Commission with the help of keys by Carpenter and LaCasse (1955) and Stojanovich (1961). Species nomenclature follows Farajollahi and Crans (2012) unless otherwise noted.

Monitoring weather data is necessary to ensure that the mosquito's life cycle, particularly during the larval stages, was not influenced by variations that could impact our study. Weather data was downloaded from the Toms River station of the Rutgers NJ Weather Network (https://www.njweather.org/). Daily weather data (maximum and minimum temperatures, in degrees Fahrenheit, and precipitation, in inches) were downloaded for each corresponding sampling period. This weather station is approximately 7.0 kilometers (km) from the sampling location and was determined to be adequate for analytical purposes.

Data Analysis

Percent reduction in mosquito larvae (%Red) for each treatment practice was calculated as the number of larvae in each treatment practice (NP) divided by the total larvae from the control (no treatment) bucket (NTOT) subtracted from 1, then multiplied by 100, to represent a percentage (Eq. 1).

$$\%Red = \left(1 - \frac{NP}{NTOT}\right) X\ 100 \qquad \text{(Eq. 1)}$$

A one-way analysis of variance (ANOVA) was used to determine if there were significant differences between the number of mosquito larvae in the control (no treatment) and each type of treatment method (screen, Mosquito Dunks®, soap, or oil) with a significance level of $p < 0.01$ established for all statistical tests. Post hoc comparisons using the Tukey HSD (honestly significant difference) test were also performed to compare the treatments to the control.

Results

A total of fourteen (14) rounds of sampling were conducted between 2021 and 2023; four (4) rounds in 2021, six (6) in 2022, and four (4) in 2023 (Table 1). This resulted in 173 samples being collected over those three (3) years. A total of 1,927 mosquito larvae were collected over the course of this study: 379 larvae in 2021, 961 in 2022, and 587 in 2023 (Table 1). Most of the larvae (99.6% or 1,920 individuals) were collected from the control (i.e., untreated) buckets (Table 1). These larvae came from six (6) mostly container-breeding species: *Aedes albopictus*, *Aedes japonicus*, *Anopheles punctipennis*, *Anopheles quadrimaculatus*, *Culex pipiens*, and *Toxorhynchites rutilus*. Due to the degraded nature of one of the samples in 2021, three (3) individuals were categorized as ‘unknown species.’

Table 1: Summary of results from 2021 – 2023 sampling period.

Year	No. of Sampling Rounds	No. of Samples	No. of Larvae Collected - By Treatment Type				
			Control	Dunk	Oil	Screen	Soap
2021	4	23	374	2	0	1	2
2022	6	90	959	0	0	0	2
2023	4	60	587	0	0	0	0
Total	14	173	1,920	2	0	1	4

Of the remaining treatments, seven (7) larvae were collected between 2021 and 2023, with four (4) in the buckets treated with soap, two (2) from those treated with the Mosquito Dunks®, and the remaining one (1) from the screened buckets (Table 1). Only the buckets treated with oil had no larvae present throughout the study (Table 1). Each of the treatment methods had a greater than 99% reduction in mosquito larvae for the entirety of the study (Table 2). A one-way ANOVA found that there were significant differences between the different treatments and the control (no treatment) during this study ($F(4, 69) = 11.76$, p = <0.001), but no statistical difference between each of the treatments. Post-hoc comparisons using the Tukey HSD test indicate that the mean number of larvae in buckets treated with Mosquito Dunks® (M = 0.14, SD = 0.53), oil (M = 0.00, SD = 0.00), screening (M =0.07, SD = 0.27), and soap (M = 0.19, SD = 0.55) was significantly different than the control bucket with no treatment (M = 50.17; SD = 54.6). Assumptions of homogeneity of variance were met on the sample dataset.

Table 2: Percent (%) reduction in larvae (in relation to the control) for each treatment method.

Sample	Total Number of Larvae	% Reduction in Larvae
Control	1,920	- -
Dunk	2	99.9%
Oil	0	100.0%
Screen	1	99.9%
Soap	4	99.8%

Discussion and Conclusion

Use of rain barrels for rainwater harvesting is an excellent way for homeowners to conserve water. One rain barrel is estimated to save hundreds of gallons of water each year per household (Logan, 2014; Steffen et al., 2013). A concern that many homeowners have is the possibility of rain barrels to increase mosquito breeding habitats. To balance environmental protection and human health, this project assessed the effectiveness of various Extension-recommended practices to reduce the potential of mosquito breeding in rain barrels that are described and encouraged to those who obtain rain barrels. The results indicate any of the methods examined (Mosquito Dunks®, screening, or a barrier of soap or oil) are effective at reducing the likelihood of mosquito larvae growing in rain barrels that use them by at least 99% (Table 2).

While the reduction in mosquito larvae was quantified for each practice, there are some practical outcomes that need to be noted that would affect a homeowner's choice of practice for their rain barrel. For example, the buckets with the oil added to them began to smell due to the summer heat causing the oil to go rancid, the Mosquito Dunks® broke apart leaving debris in the buckets from the filler/media used to contain the BTI bacteria, the screened buckets not only kept mosquito breeding to a minimum but also prevented debris such as leaves and twigs from entering the simulated barrels, and having to maintain a constant 0.32 cm layer of oil or soap in a closed and opaque rain barrel may be difficult for homeowners to achieve effectively. These issues may impact a homeowner's decision as to the type of practice to use to reduce mosquito larvae in their rain barrel. When recommending these options, the noted outcomes should be mentioned to homeowners.

It is important to disclose that the Mosquito Dunk® dose used in this study was higher than recommended for a 208L rain barrel (Rector et al., 2014). The recommended dosage for a water surface area between 1 to 5 square feet (ft^2) (0.09 to 0.46 square meters [m^2]) is one quarter of a Mosquito Dunk® to provide protection from mosquitoes for at least 30 days (Summit Responsible Solutions, 2024). This study used one half of a Mosquito Dunk® in buckets having an average surface area of 0.06 m^2, quadrupling the product's recommended dosage. This larger dose of BTI bacteria may have led to the high reduction in mosquito larvae. The Extension recommendation to prevent mosquitoes in rain barrels is "to add *Bacillus thuringiensis israelensis* (BTI) often sold as a Mosquito Dunk®" (Rector et al. 2014). This may result in the use of a whole Mosquito Dunk® by a homeowner by mistake. Future Extension programming and publications on rainwater harvesting should explicitly state the importance of following product guidelines for proper use of Mosquito Dunks® in rain barrels.

Rain barrels provide an opportunity for homeowners to become active in saving water while also providing a method of maintaining their landscape. Because of the environmental mindedness of individuals who wish to utilize rain barrels, having options to reduce mosquitoes in rain barrels that are proven will help homeowners make better-informed decisions.

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