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ORIGINAL ARTICLE

Effectiveness of mosquito magnets for reducing mosquito (Diptera) populations in coastal areas of Samut Songkhram province, Thailand

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ABSTRACT

Objective: The aim of this research is to study the effectiveness of mosquito magnet (MM) for reducing mosquitoes (Diptera) populations in coastal areas.
Materials and methods: The study sites are in the coastal area of Samut Songkhram province, Thailand, which is divided into two locations; one that is 2 km and another that is 4 km in distance from the sea. We used the Mosquito Magnet® Independence (MMI) trap for effective field testing in Samut Songkhram Province, Thailand. Traps were placed 100 m away from the house (one trap per location) and mosquitoes were collected at night from 6 PM to 6 AM during September and October 2017 (30 days).
Results: A total of 2,561 adult mosquitoes, including *Anopheles epiroticus* Linton & Harbach, *Culex quinquefasciatus* Say, *Cx. sitiens* Wiedmann, and *Cx. gelidus* Theobald were collected by MMI. At a 2-km distance from the sea were captured more mosquitoes per night more than at a 4-km distance (63.63 ± 42.30 *vs.* 21.70 ± 12.42). The comparison of effectiveness of MMI in two locations of the coastal area was shown to have a statistically significant difference ($p < 0.05$) and analysis of the correlation between the number of mosquitoes caught in coastal areas, including at a 2- and 4-km distance from the sea, accounting for weather factors, we found that the effectiveness of MMI was not correlated with weather ($p > 0.05$).
Conclusion: Overall, this study demonstrated that MM can be used to control mosquitoes in coastal areas with high efficiency, especially 2 km away from the sea.

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KEYWORDS

Effectiveness; mosquito magnets; mosquito-borne diseases; species diversity

Introduction

Mosquitoes are insect vectors involved in the transmission of many diseases to humans and distributed all over the world except in cold areas [1]. Most mosquito-borne diseases are caused by nocturnal mosquitoes, such as certain species of *Anopheles*, a malaria vector; *Culex*, a Japanese encephalitis vector; and *Mansonia*, a lymphatic filariasis vector [2,3]. Globally, there are over 2.5 million cases of these diseases and 1 million people die each year from them [4]. Especially, in tropical and subtropical areas [5], including Thailand. According to data on malaria patients from the Bureau of Epidemiology, Thailand, from 2015 to 2017, it was reported there were 5,933, 5,273, and 2,969 cases, respectively [6]. Still, the outbreak of other mosquito-borne diseases by nocturnal mosquitoes is widespread throughout the country.

Samut Songkhram is one of the central provinces of Thailand. It is also the smallest province and located on the Gulf of Thailand. The environment of this province is one of a coastal area, which makes it different from other areas, including with respect to species diversity of mosquito vectors [7]. From 2013 to 2017, this area also reported malaria in patients numbering at 10 cases [6]. However, there have been no reports of finding primary malaria vectors, including *Anopheles dirus* (Peyton & Harrison), *An. minimus* Theobald, and *An. maculatus* Theobald in this area because the environment is not conducive to their habitat, yet there is *An. epiroticus* (Linton & Harbach) present as a secondary vector.

Mosquito traps are a tool for mosquito vector control [8]. At present, there are many types of mosquito traps, of which each has a different efficiency depending on the species of

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mosquito in each area. Each type of trap has a different price, quality, features, methods of operation, and working mechanisms which must be selected to suit the area for a maximally efficient mosquito control program [9]. In our previous study, we developed a mosquito trap box which was not highly effective for doing the research in coastal areas of Samut Songkhram Province [10]. In addition, we studied the efficiency of the mushroom extracts used to attract mosquitos in the studied areas [7,11]. Compared with the standard octenol mosquito attractant, the mushroom extracts were found not to be effective enough to attract mosquitos [11,12,13,14,15]. As a result, we sought another way and found a more effective mosquito trap called Mosquito magnet (MM).

MM is one of the mosquito trap based on attracting female mosquitoes [16]. The working mechanism underlying MM begins with changing propane gas or LPG into carbon dioxide combined with the release of synthetic odor that is similar to the odor of humans or animals [17]. Previous research has reported that MM is highly effective in controlling mosquitoes in many areas. For example, it has been applied in rural areas of Brazil and found to have a profound ability to trap mosquitoes [18]. In coastal areas of Thailand, MM has not been studied for vector control, and although it is known to be highly effective, it is expensive. In addition, the effectiveness of MM depends on the climate in the area because climate affects the organism. Mosquito vectors can adapt to changing the weather by reducing activities, including aviation and feeding behavior [19].

From all available literature on vector control in the coastal area of Thailand, MM is a potentially intriguing tool to implement in Samut Songkhram province, Thailand. Therefore, we conducted a study on the effects of MM in trapping mosquitoes there. We divided the study area into two locations; one at a 2-km and another at a 4-km distance from the sea. The results of this study are very important in medicine and public health for controlling mosquito vectors in the coastal area of Thailand in order to reduce the number of mosquito vectors with the goal of reducing the risk of mosquito-borne diseases further.

Materials and Methods

This study is based on research field trials. The study sites are in the coastal area of Samut Songkhram province, Thailand, which is divided into two locations, including one at 2-km (13°25′11.7″N and 100°02′21.0″E) and another at a 4-km (13°24′33.6″N and 100°00′53.0″E) distance from the sea (Fig. 1). The reason for the division of the coastal area according to the distance from the sea is based on varied environments of both locations. The area 2-km distance from the sea is that with a low-density population, where there are mangrove forests and salt ponds distributed throughout. Meanwhile, the area at a 4-km distance from the sea is a coastal community where there is high-density population. In addition, there are saltwater wastewater resources scattered within it.

Study on the effectiveness of MMs in the coastal area

We used the Mosquito Magnet® Independence (MMI) trap (Wood stream Corporation, Lititz, USA) for effectiveness field testing at two locations in the coastal areas of Samut Songkhram province, Thailand. Traps were placed 100 m away from the house (one trap per location) and

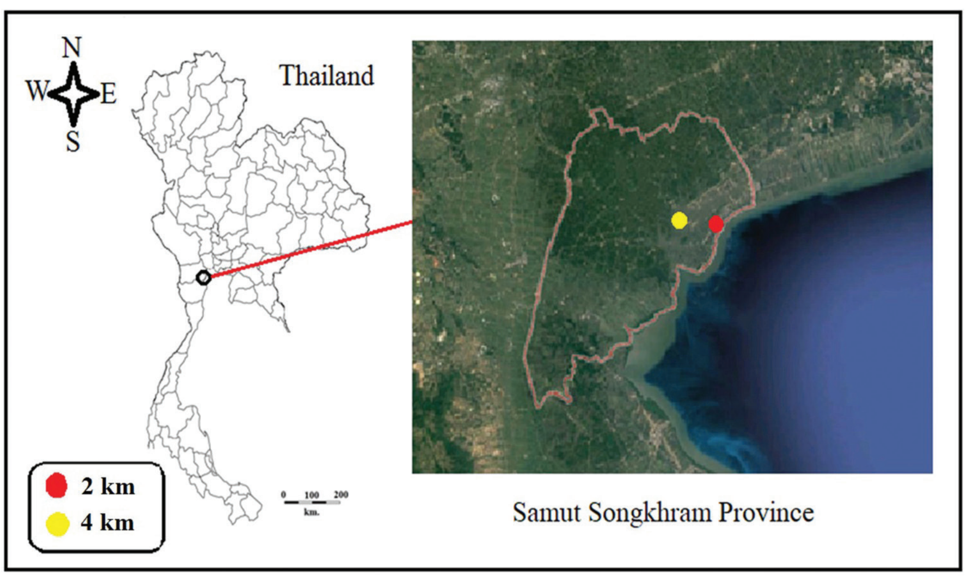

Figure 1. Study areas.

mosquitoes were collected at night from 6 PM to 6 AM during September and October 2017 (a total of 30 days). Every morning, we counted, recorded, and sent samples to the laboratory at the College of Allied Health Sciences, Suan Sunandha Rajabhat University, Samut Songkhram Education Center. Afterward, nocturnal mosquitoes were identified with a Nikon AZ 100 M stereomicroscope (Nikon Corp., Tokyo, Japan) according to the Illustrated Keys to the Mosquitoes of Thailand [20].

Study on the correlation between numbers of mosquitoes caught and weather factors

In this research, we studied the relationship between the effectiveness of MMI and weather factors, which was supported by data on weather factors supplied by the Samut Songkhram Provincial Meteorological Department, including rainfall data, temperature, wind speed, and relative humidity. Thereafter, these data were analyzed to determine the correlation between the numbers of mosquitoes caught and weather factors.

Data analysis

The effectiveness of the MMI trap in the coastal areas of Samut Songkhram province was represented by mean with standard deviation. Comparison of the effectiveness of the MMI trap in two locations of the coastal area (2 *vs.* 4 km) was carried out with a student's *t*-test. As well, the analysis of the relationship between the numbers of mosquitoes caught in each area and weather factors was performed with Pearson's correlation.

Results and Discussion

Effectiveness of MM in coastal area

A total of 2,561 adult mosquitoes within four species belonging to two genera, including *Anopheles epiroticus* Linton & Harbach, *Culex quinquefasciatus* Say, *Cx. sitiens* Wiedmann, and *Cx. gelidus* Theobald were caught (Fig. 2). At a 2-km distance from the sea, more mosquitoes were captured per night than at 4 km (63.63 ± 42.30 *vs.* 21.70 ± 12.42). *Cx. sitiens* was the most collected species at a 2-km distance from the sea, which is different from a 4-km distance from the sea where most *Cx. quinquefasciatus* were found (Table 1). The comparison of the effectiveness of the MMI trap at two locations of the coastal area was shown to have a statistically significant difference ($p \leq 0.05$) (Table 1).

Correlation between numbers of mosquitoes caught and weather factors

The analysis of the correlation between the number of mosquitoes caught in coastal areas, including at a 4-km distance from the sea, and weather factors elicited the finding that the effectiveness of the MMI trap was not correlated with any weather factors (Table 2).

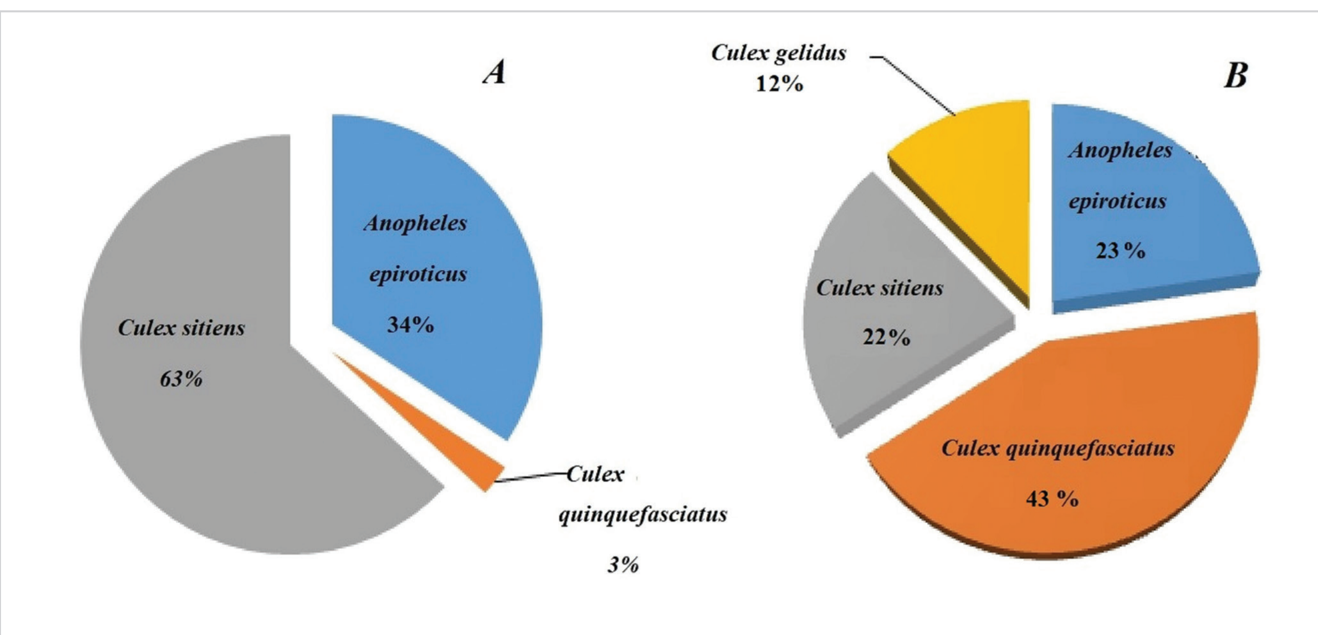

Figure 2. Percentage of mosquitoes caught in coastal areas of Samut Songkhram province. (A) 2-km distance from the sea and (B) 4-km distance from the sea.

Table 1. Effectiveness of MM in coastal area of Samut Songkhram province.

Locations	Species of mosquito	*n* (30 days)	Mean ± SD (numbers/night)
2-km distance from the sea	*An. epiroticus*	656	22.20 ± 35.02
	Cx. quinquefasciatus	47	1.56 ± 1.80
	Cx. sitiens	1,206	40.20 ± 22.26
	Total	1,909	63.63 ± 42.30[a]
4-km distance from the sea	*An. epiroticus*	148	4.93 ± 5.95
	Cx. quinquefasciatus	281	9.36 ± 7.31
	Cx. sitiens	144	4.80 ± 5.53
	Cx. gelidus	79	2.63 ± 3.06
	Total	652	21.70 ± 12.42[b]

*Comparison of the effectiveness of MMI (2 *vs.* 4 km): Different letters indicate that the difference is statistically significant ($p < 0.05$).

Table 2. The relationship between the numbers of mosquitoes caught in coastal areas and weather factors.

Locations		Rain	Temperature	Wind speed	Relative humidity
2-km distance from the sea	*r*	0.248	0.165	−0.196	−0.248
	p	0.185	−0.382	0.299	0.185
4-km distance from the sea	*r*	−0.076	−0.107	−119	0.076
	p	0.690	0.573	0.531	0.690

Correlation is significant at $p > 0.05$.

This research has shown that the effectiveness of MMI traps is such that it can capture 63.63 ± 42.30 mosquitoes per night, and in our work, three species of mosquito, including *An. epiroticus, Cx. Quinquefasciatus*, and *Cx. sitiens* at 2 km from the sea were caught. At 4-km from the sea, MMI traps caught 21.70 ± 12.42 mosquitoes per night, and this included four species of mosquito, including *An. epiroticus, Cx. quinquefasciatus, Cx. Sitien*s, and *Cx. gelidus*. The greater numbers of mosquitoes caught by MMI traps in the two different areas may be based on the density of the mosquito population at each location. This is consistent with the results of the survey of mosquito abundance in this area, which reported the density of *An. epiroticus* and *Cx. sitien*s populations at 2 km being more than 4 km from the sea [19]. This study also revealed the major effectiveness of MMI traps in capturing mosquitoes in coastal areas. This is consistent with the research of Chaves *et al.* [21] on the effectiveness of MM in coastal Atlantic rainforests, where they found it has great potential for use in mosquito control in coastal areas. In addition, not only in coastal areas, but there are reports that have shown that MM can be used in other areas and has major potential for reducing the number of mosquitoes in rural areas of Brazil [18].

In the work presented herein, we predominantly found that two species of mosquitoes, including *Cx. sitiens* as a vector of filariasis and *An. epiroticus* as a vector of malaria, are usually located in coastal areas. Currently, there is relatively little literature on how to control these species [7]. This research determined that MM can aid in reducing the number of *An. epiroticus* as secondary malaria vectors in Thailand. This is in agreement with Lühken *et al.* [22]—MM was the most effective in catching *Anopheles* spp. compared to various traps, including Biogents Sentinel trap (BG trap), Heavy Duty Encephalitis Vector Survey trap (EVS trap), and Centers for Disease Control miniature light trap (CDC trap) in northern and southern Germany. In addition, MMI can also capture *Cx. quinquefasciatus*, as a Japanese encephalitis and filariasis vector, quite effectively at a 4-km distance from the sea.

Recently, we have studied the efficiency of a standard mosquito trap, CDC Light Trap, in coastal areas of Samut Songkhram Province [10]. It was found that the trap was able to attract a lot of *Culex* mosquitos in the areas but it was not efficient enough to control *Anopheles* mosquitos, the primary vector for malaria. The results of this study showed that the MM trap offers high efficiency in controlling the malaria vector mosquito. However, when compared with the CDC Light Trap, the MM trap was less efficient in catching *Culex* mosquitoes. The results suggested that it is essential to choose a suitable trap for each mosquito species for effective control of mosquitoes in the coastal areas.

To control mosquito-borne diseases or the number of *Anopheles* mosquitos in the coastal areas, we suggested using the MM trap which is also recommended in case that there is an outbreak of malaria. Meanwhile, when there is an outbreak of encephalitis or the high number of *Culex* mosquitos in the areas, we highly suggested using CDC Light Trap.

The results of the analysis of the relationship between the effectiveness of MMI and weather factors yielded no correlation. These findings may be because the study period had similar weather conditions throughout. Therefore, the future research should increase the study duration to account for this possibility.

Conclusion

Overall, this study demonstrated that MM can be used to control mosquitoes in coastal areas with high efficiency, especially 2 km away from the sea. In coastal areas, there are two major mosquito vectors, including *Cx. sitiens* and *An. epiroticus.* MMI traps can be employed to reduce the numbers of both mosquito species. Although in general, MM is expensive compared to other traps, it is highly effective in controlling mosquito populations. Therefore, MM is an alternative mosquito trap that could lead to success in diminishing the number of mosquitoes.

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Conflict of Interest

The authors declare that there is no conflict of interests.

Authors' Contribution

Tanawat Chaiphongpachara and Chaekki Kunphichayadecha designed the study. Tanawat Chaiphongpachara supervised, provided suggestions throughout the experiment. Sedthapong Laojun assists help in the collection of mosquitoes by mosquito magnetMM traps. All the authors contributed to writing and reviewing the manuscript and approved the final manuscript.

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