



# **Environmental Niche Modeling of Order Mantodea Using Biodiversity Informatics and Geographical Information System**

**A Thesis**

**Submitted for the degree of Master of Science As a Partial  
fulfillment for requirements of the master of Science  
"Entomology Department"**

**By**

**Mohamed Okely Bayoumi**

**B.Sc. (First class honor) in Entomology, Faculty  
of Science, Ain Shams University  
2015**

**Under Supervision of**

**Prof. Dr. Rabia Abdel Wahab Enan**

**Professor of Entomology, Entomology Department, Faculty of  
Science, Ain Shams University**

**Prof. Dr. Sohair Mohammad Mahmoud GadAllah**

**Professor of Entomology, Entomology Department, Faculty of  
Science, Ain Shams University**

**Dr. Mohamed Gamal El-Den Nasser**

**Lecturer of Entomology, Entomology Department, Faculty of  
Science, Ain Shams University**

**(2018)**

# **Biography**

**Name:** Mohamed Okely Bayoumi

**Qualification:** B.Sc. First class honor Science (Entomology),

2015

Entomology Department

Faculty of Science

Ain Shams University

**Present Occupation:** Demonstrator, Entomology Department,  
Faculty of Science, Ain Shams University.

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿ قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا

إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ ﴾

صدق الله العظيم

الآية (32) سورة البقرة

## **ACKNOWLEDGEMENTS**

*“I wish to express my deep thanks to **ALLAH** who fulfilled my hopes, offered every possible aid for any one in need to it”.*

*I wish to express my deep gratitude to **Prof. Dr. Rabia Abdel Wahab Enan**, Professor of Entomology, Faculty of Science, Ain Shams University for her kind supervision, assistance sincere, help criticism, kind encouragement and precious advice during the progress of this study.*

*I am particularly grateful to **Prof. Dr. Sohair Mohammad Mahmoud GadAllah**, Professor of Entomology, Faculty of Science, Ain Shams University for giving me the chance to be one of her students, her faithful encouragement, her generous advice and valuable discussions during the progress of this study until the preparation and writing of this manuscript.*

*I am deeply indebted to **Dr. Mohamed Gamal El-Den Nasser**, Lecturer of Entomology, Entomology Department, Faculty of Science, Ain Shams University, for his kind supervision, his faithful encouragement, valuable advice and guidance during the progress of this study until the*

*Preparation and writing of this manuscript*

*Thanks are also to **Prof. Dr. Ragaa Elmohammady** the head of Entomology Department, Faculty of Science, Ain Shams University.*

*My grateful thanks are passed to **Dr. Abdallah Samy** Lecturer of Entomology, Entomology Department, Faculty of Science, Ain Shams University, for his assistance with data analysis of chapter IV.*

*My thanks are also passed to **Prof. Dr. Kareem Mohammad Mahni** the head of Plant Protection Department, Faculty of Agriculture, South Valley University, thanks also go to **Dr. Awad Hassan** and **Dr. Refat Olway** for their help and advice they give to me during the field work in Qena governorate in Upper Egypt.*

*Appreciating also passed to **Reinhard Ehrmann** of the Staatliches Museum für Naturkunde Karlsruhe, and **Roberto Battiston** of the Musei Civici di Valstagna, for all of their support, and also for by providing us with very important literature.*

*My thanks are also passed to the staff members and colleagues of Entomology Department for the various help they offered me throughout this study.*

*Sincere thanks are also due to my family who suffered a lot during the preparation of this work. Finally, I am indebted forever to my mother for her help, support and continuous encouragement.*

## Contents

Chapter I. Introduction and Literature review .....	1
I.1. Introduction .....	1
I.2. Statement of research problem.....	5
I.3. Aim of the study.....	7
I.4. Literature review.....	8
I.4.1. Occurrence of Mantodea in Egypt.....	8
I.4.2. Eremiaphila in the Middle East and North Africa....	16
I.4.3. Analysis and inference .....	23
I.4.4. Data science and Eco-technology .....	28
Chapter II: Biogeographical analysis of order Mantodea in Egypt.....	36
II.1. Introduction.....	36
II.2. Materials and Methods.....	37
II.2.1. Study area.....	37
II.2.2. Species data collection .....	37
II.2.3. Species-level distribution in the ecological zones .....	38
II.2.4. Environmental layers .....	38
II.2.5. Model procedures, performance, and evaluation.....	39
II.3. Results .....	42
II.3.1. Species-level distribution in the ecological zones ...	42
II.3.2. Environmental niche modeling of Mantodea species .....	46
II.3.3. Environmental niche modeling for <i>Iris oratoria</i> and <i>Oxyothespis dumonti</i> .....	50
II.4. Discussion .....	59
Chapter III. Spatio-Temporal analysis of the Egyptian flower mantis <i>Blepharopsis mendica</i> in Egypt, with notes of its future status under climate change .....	62
III.1. Introduction.....	62
III.2. Materials and Methods .....	63
III.2.1. Study area and species data collection .....	63

III.2.2. Climate data .....	63
III.2.3. Model procedures, performance, and evaluation .....	64
III.2.4. Environmental niche modeling.....	64
III.2.5. Field validation .....	65
III.3. Results.....	65
III.3.1. Environmental niche modeling .....	65
III.3.2. Temporal analysis.....	71
III.3.3. Field validation.....	72
III.3.4. Future distribution.....	75
III.4. Discussion .....	76
Chapter IV. Environmental niche modeling of genus <i>Eremiaphila</i> (desert mantis) in the Middle East and North Africa.....	80
IV.1. Introduction .....	80
IV.2. Materials and Methods .....	82
IV.2.1. Study area and occurrence data .....	82
IV.2.2. Climate data.....	83
IV.2.3. Model procedures, performance, and evaluation .....	84
IV.2.4. Niche overlapping among four species of genus <i>Eremiaphila</i> .....	85
IV.3. Results .....	85
IV.3.1. Environmental niche modeling for genus <i>Eremiaphila</i> .....	85
IV.3.2. Environmental niche modelling of the four target <i>Eremiaphila</i> species.....	86
IV.3.3. Niche overlapping of the four targeted <i>Eremiaphila</i> species .....	106
IV.4. Discussion .....	108
Conclusion and Recommendations .....	111
English Summary.....	114
References.....	118



## List of Tables

<b>Table Number</b>	<b>Caption</b>	<b>Page Number</b>
<b>Table 2.1</b>	<b>Environmental and topographic variables used in Maxent to predict the current habitat suitability distribution of Mantodea species</b>	<b>41</b>
<b>Table 2.2</b>	<b>Mantodea species richness in the different ecological zones</b>	<b>44</b>
<b>Table 2.3</b>	<b>The similarity of Mantis fauna in the Egyptian ecological zones</b>	<b>45</b>
<b>Table 2.4</b>	<b>The contribution percentages of 18 ecological and topographic layers in predicting the spatial distribution of Mantodea species in Egypt</b>	<b>49</b>
<b>Table 2.5</b>	<b>The contribution percentages of the bioclimatic and topographic variables in the Maxent Models for <i>Iris oratoria</i> and <i>Oxyothespis dumonti</i></b>	<b>52</b>
<b>Table 3.1</b>	<b>The contribution percentages of 11 ecological layers and altitude in predicting the spatial distribution of <i>B. mendica</i> in Egypt</b>	<b>69</b>
<b>Table 3.2</b>	<b>Maximum suitable habitat range for each bioclimatic factor that affects the distribution of <i>B. mendica</i></b>	<b>70</b>
<b>Table 3.3</b>	<b>Field validation for the habitat suitability of <i>B. mendica</i> in ten selected sites</b>	<b>74</b>
<b>Table 4.1</b>	<b>Percent contributions of the bioclimatic and topographic variables in the Maxent Models for all <i>Eremiaphila</i> species</b>	<b>93</b>
<b>Table 4.2</b>	<b>Overlapping among the four targeted species of genus <i>Eremiaphila</i> in Jordan</b>	<b>95</b>
<b>Table 4.3</b>	<b>Overlapping among the four targeted species of genus <i>Eremiaphila</i> in Palestine</b>	<b>96</b>
<b>Table 4.4</b>	<b>Overlapping among the four targeted species of genus <i>Eremiaphila</i> in Egypt.</b>	<b>97</b>
<b>Table 4.5</b>	<b>The contribution percentages of the bioclimatic and topographic variables in the Maxent Models for the four targeted species</b>	<b>105</b>

## List of Figures

<b>Fig Number</b>	<b>Caption</b>	<b>Page Number</b>
<b>Fig 1.1</b>	New mantis species that were described from Egypt through 50-year intervals between 1750-2017	<b>26</b>
<b>Fig 1.2</b>	Number of new mantis species that were discovered in the different ecological zones in Egypt.	<b>26</b>
<b>Fig 1.3</b>	Number of new species of genus <i>Eremiaphila</i> from 13 countries of the Middle East and North Africa.	<b>27</b>
<b>Fig 1.4</b>	Actual number of species in genus <i>Eremiaphila</i> from each country of the Middle East and North Africa.	<b>27</b>
<b>Fig 2.1</b>	Dendrogram of species composition similarity in the ecological zones	<b>44</b>
<b>Fig 2.2</b>	Map of Egypt showing the habitat suitability of Mantodea species according to the occurrence records	<b>47</b>
<b>Fig 2.3</b>	Relative importance of environmental variables based on jackknife in Maxent model for Mantodea species	<b>48</b>
<b>Fig 2.4</b>	Map of Egypt showed the Predicted current (suitable and unsuitable) habitat for <i>Iris oratoria</i>	<b>51</b>
<b>Fig 2.5</b>	Relative importance of bioclimatic variables based on the Jackknife in Maxent model for <i>Iris oratoria</i>	<b>53</b>
<b>Fig 2.6</b>	Response curve showing the relationship between the probability of the presence of <i>Iris oratoria</i> and altitude	<b>53</b>
<b>Fig 2.7</b>	Map of Egypt showed the Predicted future (suitable and unsuitable) habitat for <i>Iris oratoria</i>	<b>54</b>
<b>Fig 2.8</b>	Map of Egypt showed the Predicted current (suitable and unsuitable) habitat for <i>Oxyothespis dumonti</i>	<b>56</b>
<b>Fig 2.9</b>	Relative importance bioclimatic variables based on the Jackknife in Maxent model for <i>Oxyothespis dumonti</i>	<b>57</b>
<b>Fig 2.10</b>	Response curve showing the relationship between the probability of the presence of <i>Oxyothespis dumonti</i> and altitude	<b>57</b>

<b>Fig 2.11</b>	Map of Egypt showed the Predicted future (suitable and unsuitable) habitat for <i>Oxyothespis dumonti</i>	<b>58</b>
<b>Fig 3.1 a&amp;b</b>	(a) Habitat suitability of <i>B. mendica</i> according to occurrence records (b) Relative importance of environmental variables based on jackknife in Maxent model for <i>B.mendica</i>	<b>67</b>
<b>Fig 3.2</b>	Response curve showing the relationship between the probability of the presence of <i>B. mendica</i> and altitude	<b>68</b>
<b>Fig 3.3</b>	Response curve showing the relationship between the probability of the presence of <i>B. mendica</i> and Temperature Annual Range	<b>68</b>
<b>Fig 3.4</b>	Map of Egypt showing the habitat suitability of <i>B. mendica</i> in two historical periods: a 1900-1960, b 1961-2017	<b>71</b>
<b>Fig 3.5</b>	Habitat suitability of <i>B. mendica</i> in South Sinai protected areas in the period 1961-2017	<b>72</b>
<b>Fig 3.6</b>	Field validation for the habitat suitability of <i>B. mendica</i> in ten selected sites	<b>73</b>
<b>Fig 3.7</b>	Map of Egypt showed the Predicted future distribution of habitat suitability for <i>B. mendica</i> under RCP 8.5 emission scenario for 2070	<b>75</b>
<b>Fig 3.8</b>	Satellite image for Cairo and its surrounding areas at earlier period	<b>77</b>
<b>Fig 3.9</b>	Satellite image for Cairo and its surrounding areas at later period	<b>78</b>
<b>Fig 4.1</b>	<i>Eremiaphila</i> samples and its habitat: a. female <i>Eremiaphila</i> spp. nymph; b. the habitat of <i>Eremiaphila</i> spp. in Wadi Qena, Upper Egypt (the place where the female <i>Eremiaphila</i> spp. nymph photographed); c. female <i>Eremiaphila cerisyi</i> in Gebel Elba National park, Egypt; d. <i>Eremiaphila arabica</i> in Sarawat Mountains Saudi Arabia	<b>81</b>
<b>Fig 4.2</b>	The Map of the Middle East and North Africa showing predicted current distribution of genus <i>Eremiaphila</i>	<b>91</b>
<b>Fig 4.3</b>	Response curve showing the relationship between the probability of presence of <i>Eremiaphila</i> species and altitude	<b>92</b>
<b>Fig 4.4</b>	The map of Middle East and North Africa showing predicted current distribution of <i>E. ammonita</i> .	<b>94</b>
<b>Fig 4.5</b>	Relative importance of environmental variables based on jackknife in Maxent model for <i>E. ammonita</i> .	<b>98</b>

<b>Fig 4.6</b>	Response curve showing the relationship between the probability of presence of <i>E. ammonita</i> and one top bioclimatic predictor	<b>98</b>
<b>Fig 4.7</b>	The map of Middle East and North Africa showing predicted current distribution of <i>E. arabica</i> .	<b>99</b>
<b>Fig 4.8</b>	Relative importance of environmental variables based on jackknife in Maxent model for <i>E. arabica</i> .	<b>100</b>
<b>Fig 4.9</b>	Response curve showing the relationship between the probability of presence of <i>E. arabica</i> and one top bioclimatic predictor.	<b>100</b>
<b>Fig 4.10</b>	The map of Middle East and North Africa showing predicted current distribution of <i>E. braueri</i>	<b>101</b>
<b>Fig 4.11</b>	Relative importance of environmental variables based on jackknife in Maxent model for <i>E. braueri</i>	<b>102</b>
<b>Fig 4.12</b>	Response curve showing the relationship between the probability of presence of <i>E. braueri</i> and one top bioclimatic predictor	<b>102</b>
<b>Fig 4.13</b>	The map of Middle East and North Africa showing predicted current distribution of <i>E. genei</i>	<b>103</b>
<b>Fig 4.14</b>	Relative importance of environmental variables based on jackknife in Maxent model for <i>E. genei</i>	<b>104</b>
<b>Fig 4.15</b>	Response curve showing the relationship between the probability of presence of <i>E. genei</i> and one top bioclimatic predictor	<b>104</b>
<b>Fig 4.16</b>	The map of Middle East and North Africa showing niche overlapping among the four targeted species	<b>107</b>

### **List of Abbreviations**

<b>Abbreviations</b>	<b>Complete Name</b>
<b>ASUC</b>	Ain Shams University collection
<b>Arc-GIS</b>	Aeronautical Reconnaissance Coverage Geographic Information System
<b>AUC</b>	Al-Azhar University Collection
<b>AUC value</b>	Area Under Curve
<b>BIN 21</b>	Biodiversity Information Network 21
<b>CONABIO</b>	Mexican Commission for the Knowledge and use of Biodiversity
<b>CUC</b>	Cairo University Collection
<b>EESC</b>	Egyptian Society of Entomology collection
<b>ENM</b>	Environmental niche Modeling
<b>ERIN</b>	Environmental Resources Information Network
<b>GBIF</b>	Global Biodiversity Information Facility
<b>GCM</b>	Global Climate Model
<b>GIS</b>	Geographical Information System
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>IUCN</b>	International Union for Conservation of Nature
<b>MAC</b>	Ministry of Agriculture Collection
<b>Maxent</b>	Maximum Entropy Algorithm
<b>MRI-CGCM3</b>	Global Climate Model of the Meteorological Research Institute
<b>NABIN</b>	North American Biodiversity Information Network
<b>RCP</b>	Representative Concentration Pathway
<b>SDM</b>	species distribution modeling
<b>SMNK</b>	State Museum of Natural History Karlsruhe
<b>TSA</b>	The Species Analyst
<b>WWF</b>	World Wildlife Fund for Nature

## ABSTRACT

The present study was carried out to predict the environmental niche modeling of order Mantodea in Egypt and genus *Eremiaphila* in the Middle East and North Africa. Studying the affinities among ecological zones in Egypt demonstrated that there was a high faunal similarity between Western desert and Eastern desert, Coastal strip and Lower Nile valley. Gebel Elba had lower similarities to any of the other zones. Temporal analysis for *B. mendica* between the two periods (1900-1961) and (1961-2017) showed a current reduction of this species distribution through Greater Cairo and South Delta governorates due to Urbanization and increase in newly protected areas of South Sinai. Under the future climate change scenario, the Maxent model predicted the habitat loss for *B.mendica* in RCP 8.5 for 2070. The results for species of genus *Eremiaphila* indicated that the fundamental niche for these species anticipated in Protected Areas, National Parks and Special Conservation areas. Niche overlapping among *Eremiaphila ammonita*, *E. arabica*, *E. braueri* and *E. genei* indicated that Jordan, Palestine, Syria and Lebanon may be considered as the origin of the desert mantis in this area. Altitude was considered as the most important predictor that effect on the Mantodea distribution.

**Keywords:** Niche modeling, Mantodea, *Blepharopsis mendica*, *Eremiaphila*, Maxent, climate change, altitude

# **Chapter I**

## **Introduction and Literature review**

### **I.1. Introduction**

Biodiversity inventory represents the main step in understanding any biological community (**Sodhi and Ehrlich 2010**). In recent years, the world has experienced unprecedented biodiversity loss due to human activities and the use of technologies, which damage the environment and increase climate change rate (**Diaz et al. 2006**).

Climate change is among the main current environmental changes, threatening biodiversity and ecosystem functioning worldwide (**Walther 2010; Antiqueira et al. 2018**). Extreme temperature and cumulative Carbon dioxide emissions could have many negative impacts on the future of the ecosystem and biodiversity (**Gruner et al. 2017**). Many studies have reported that organisms, especially predators are more sensitive to environmental and climate changes (**Estes et al. 2011**).

This world's biodiversity crisis is one of the greatest current threats to the planet (**Jones and Solomon 2013**). World Wildlife Fund for Nature (WWF) noted in 2013 that current biodiversity extinction rates are estimated to be between 1.000 and 10.000 times higher than the background natural extinction rate (**WWF 2013**).

Insect biodiversity is very important as more than 80% of the world's known species are insects (**Scheffers et al. 2012**). The extinction number of insects is more than any other group of