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**Trapping of Small
Organisms Moving
Randomly**
Principles and
Applications to Pest
Monitoring and
Management



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Trapping of Small Organisms Moving Randomly

Principles and Applications to Pest
Monitoring and Management

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James R. Miller
Department of Entomology
Michigan State University
East Lansing
Michigan
USA

Paul A. Weston
School of Agricultural and Wine Sciences
Charles Sturt University
Wagga Wagga
New South Wales
Australia

Christopher G. Adams
Department of Entomology
Michigan State University
East Lansing
Michigan
USA

Jeffrey H. Schenker
Department of Mathematics
Michigan State University
East Lansing
Michigan
USA

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*The senior author dedicates this book to the three wonderful scientific educators/mentors most responsible for his scientific development and career success: **Dr. William Yurkiewicz** (Department of Biology, Millersville University; undergraduate advisor and person who, despite my dubious grade point average, extended the invitation to join him in real research leading to peer-reviewed publications); **Dr. Ralph Mumma** (Department of Entomology, Penn State University; Ph.D. Major Professor); and **Dr. Wendell Roelofs** (Department of Entomology, Cornell University; Post-doc mentor). This book is a product of the superb example you set for creativity and innovation, critical thinking, rigorous experimentation, and the seamless integration of fundamental and applied research. Your passion for research and demonstration that science can be great fun has been a lifelong gift, nearly as important as your unwavering belief in me and my potential.*

—J. R. Miller

Preface

This SpringerBrief focuses on how the numbers of randomly moving organisms caught in monitoring traps can be translated into reliable estimates of their absolute rather than just relative density. Quick and inexpensive methods for establishing absolute density are sorely needed to enable pest managers to sharpen their decisions about when pesticides are or are not justified, thereby boosting profits as well as human and environmental safety.

This book grew out of seemingly disparate experiences by Dr. James Miller during a research and teaching career as a quantitative insect behaviorist and chemical ecologist working at Michigan State University, a Land-Grant University where fundamental and applied science are expected to blend seamlessly to produce knowledge that makes a difference in the world. Our applied research on how insect control might be effectively achieved using sex attractant pheromones to disrupt mate-finding led to fundamental research on the mechanisms whereby sex pheromones impact insect behavior and physiology. One highly productive approach explored parallels between mating disruption of moth pests of apple and enzyme kinetics. The goal was to determine whether mating disruption was or was not mediated principally by competition between artificial and natural point sources of pheromone (“substrates”) for the attention of responsive males (“enzyme”). However, the “test tubes” for these quantitative experiments interrelating capture numbers in traps with manipulated numbers of female and male insects as well as dispensers of artificial pheromone were 20 field cages, each covering 12 full-sized apple trees. Nevertheless, striking and useful parallels were found between these inanimate and molecular vs. macroscopic and whole-organism systems. Highly reproducible patterns in the capture data convinced us that insects and molecules were behaving similarly at their given spatial scales, e.g., both diffusing randomly throughout their test tubes before complexing for measurable times with any agents for which they had affinity. Moreover, we discovered that the known absolute density of insects deployed in the cages could accurately be derived from graphical plots of the number of attractive pheromone dispensers deployed per cage against the inverse of catch per monitoring trap. That insight piqued our curiosity about whether such an approach might also be successful in the open-field situation.

Further insights into random elements in animal behavior came from teaching a graduate-level course in insect behavior. One of the laboratory exercises required students to record and analyze the tracks of dispersing insects. The picture emerging across years of data was that most insects not influenced by cues from resources, move randomly and display normal distributions of headings for new steps whose width is characteristic of the species, but varies across species. Additionally, striking matches were found between the tracks produced by real vs. the randomly-based computer-simulated movers we developed for teaching the mechanisms of insect orientation and their consequences when foraging.

Yet another line of research on egg depositional behaviors of onion flies interacting with artificial host plants of varying quality gave evidence for the existence of some sort of “random number generator” that injected randomness into the investment decisions of insect herbivores, essentially allowing them to diversify investments across the full range of resource qualities while investing most heavily in the best resources. The patterns of investment by real insects were faithfully reproduced by simple computer simulations where the strength of the positive factors promoting egg deposition was divided by the strength of any negative factors to yield a quotient then increased or decreased by a random input. A bout of oviposition was envisioned to turn on when the overall outcome fell above some threshold value.

This convergence of data from various systems points toward a central and highly valuable role for random elements within the mechanics underpinning the biology of simple organisms like insects. We elected to tackle the important puzzle of understanding the mechanics of trapping with the confidence that random elements and random outcomes would feature prominently in the problem, and that computer simulations permitting the manipulation of random elements would be an essential tool in that exploration. We also recognized that this effort would best be accomplished by a team bringing expertise from biology/behavior (J.R.M., C.G.A., P.A.W.), computer science (P.A.W.), and mathematical physics (J.H.S.). Thus, the product you are about to read represents an interdisciplinary synthesis.

September 24, 2014

J. R. Miller

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Contents

1	Why Care About Trapping Small Organisms Moving Randomly?	1
1.1	Most Animals Are Small and Forage Using Simple Behavioral Rules.....	1
1.2	The Most Serious Animal Pests Are Small.....	1
1.3	Responsible Pest Management Decisions Require Knowledge of Pest Numbers	2
1.4	Current Methods of Estimating Absolute Densities of Pests Are Prohibitively Costly.....	2
1.5	Can Traps and Trapping Fill This Need?.....	4
1.6	Aims and Approach of This Book.....	5
2	Trap Function and Overview of the Trapping Process.....	7
2.1	Definition and Functions of Traps	7
2.2	Overview of the Trapping Process.....	8
3	Random Displacement in the Absence of Cues	15
3.1	The Classical Random Walk	15
3.2	The Correlated Random Walk.....	16
3.3	Outward Dispersion as Influenced by c.s.d.	17
3.4	Outward Dispersion as Influenced by Time.....	19
3.5	Does a Population of Random Walkers Spread Indefinitely Away from the Point of Origin and, If So, Why?	20
3.6	Maximum Net Outward Dispersion as Influenced by Mover Sample Size	20
3.7	Patterns in Random-Walker Ending Positions After a Short Period of Dispersion as Influenced by c.s.d.....	21
3.8	Experimental Analyses of Tracks and Measures of Meander for Individuals	22
4	Intersections of Movers with Traps.....	25
4.1	Ballistic Movers—The Simplest Case.....	25
4.2	Random Walkers	26

4.3 Gain as Influenced by c.s.d. and Run Time 29

4.4 Optimal c.s.d. as Influenced by Trap or Resource Size 30

4.5 What Aspect of Plume Geometry Correlates Best
with Capture Probability? 32

4.6 Contrasts of Ellipsoid Plumes with Discoid Plumes..... 33

4.7 Setting the Stage for Estimating Plume Reach
from Field Experiments Measuring spT_{fer} 36

5 Interpreting Catch in a Single Trap 39

5.1 A Simple Trapping Equation..... 39

5.2 Converting spT_{fer} into T_{fer} 39

5.3 From Where Does most of the Catch
Accumulating in a Trap Originate?..... 41

5.4 Preparing to Put Eq. (5.1) to Work..... 45

5.5 Measures of Variation around Estimates of Absolute
Animal Density Derived from Trapping..... 47

5.6 Examples of Eq. 5.1 at Work 48

5.7 Patterns in T_{fer} Values and Plume Reaches
for Organisms Displacing Randomly..... 63

5.8 This Single Trap Approach is Ready for Testing
and Implementation Where Proven Reliable 63

5.9 A Caveat..... 65

6 Competing Traps..... 67

6.1 Definition of Trap Competition 67

6.2 Complete Competition 67

6.3 Test for Whether or Not Competition is Complete 68

6.4 Incomplete Competition..... 70

6.5 Trapping Radius Does Not Equate to Competition Threshold 73

6.6 Equation for Incompletely Competing Traps..... 73

6.7 Estimating Mover Numbers and Trapping Area
Simultaneously by Competitive Trapping 79

6.8 Computer Simulations Demonstrating How Absolute
Density of Biological Random Walkers Can Be Estimated
by Competitive Trapping under Variable Run Times..... 82

6.9 Suggested Plan for Employing Competitive
Trapping Under Field Conditions 84

6.10 Summary 84

**7 Experimental Method for Indirect Estimation of c.s.d.
for Random Walkers via a Trapping Grid 85**

7.1 The Idea..... 85

7.2 Translation of the Idea to Field Tests with Real Organisms 86

- 8 Trapping to Achieve Pest Control Directly** 89
 - 8.1 The Idea..... 89
 - 8.2 Time-Dependency and Dynamics of Mass Trapping..... 89
 - 8.3 Damage Suppression as Influenced by Trap Number
and Spacing: Simulations..... 90
 - 8.4 Examples of Successful Pest Control by Mass Trapping..... 97
 - 8.5 New Approaches to Mass Trapping 100

- 9 Automated Systems for Recording, Reporting,
and Analyzing Trapping Data** 103
 - 9.1 Need for Such Systems 103
 - 9.2 History of Insect Trap Automation 103
 - 9.3 Recent Developments and Future Prospects..... 107
 - 9.4 Wrap-Up..... 109

- References**..... 111