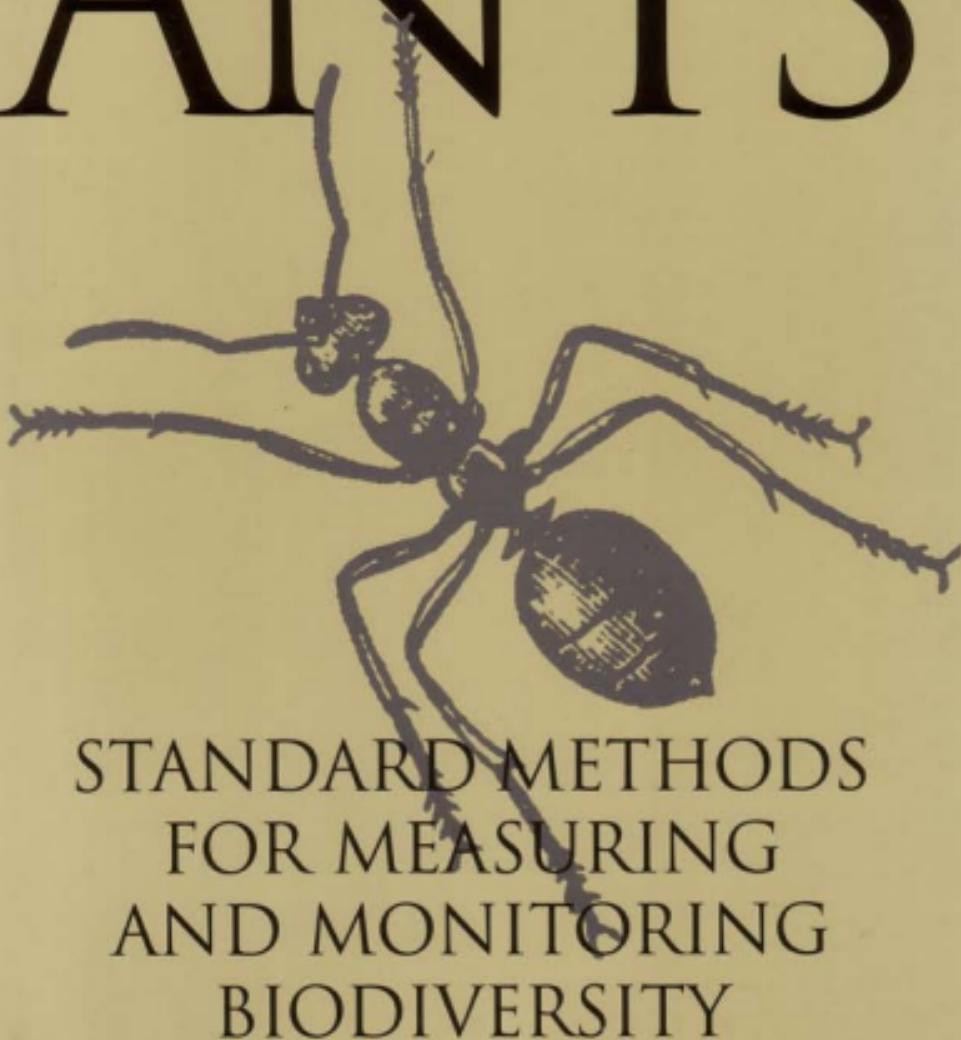


ANTS



STANDARD METHODS
FOR MEASURING
AND MONITORING
BIODIVERSITY

EDITED BY DONAT AGOSTI, JONATHAN D. MAJER,
LEEEANNE E. ALONSO, AND TED R. SCHULTZ

FOREWORD BY EDWARD O. WILSON



ANTS

STANDARD METHODS
FOR MEASURING
AND MONITORING
BIODIVERSITY



Biological Diversity Handbook Series

Series Editor: Don E. Wilson

This series of manuals details standard field methods for qualitative and quantitative sampling of biological diversity. Volumes focus on different groups of organisms, both plants and animals. The goal of the series is to identify or, where necessary, develop these methods and promote their adoption worldwide, so that biodiversity information will be comparable across study sites, geographic areas, and organisms, and at the same site, through time.

ANTS

STANDARD METHODS
FOR MEASURING
AND MONITORING
BIODIVERSITY

EDITED BY DONAT AGOSTI, JONATHAN D. MAJER,
LEEEANNE E. ALONSO, AND TED R. SCHULTZ

SMITHSONIAN INSTITUTION PRESS
WASHINGTON AND LONDON

© 2000 by the Smithsonian Institution
All rights reserved

Copy editor and typesetter:
Princeton Editorial Associates, Inc.
Production editor: Duke Johns
Designer: Amber Frid-Jimenez

Library of Congress Cataloging-in-Publication Data

Ants : standard methods for measuring and monitoring
biodiversity / edited by Donat Agosti . . . [et al.].
p. cm.—(Biological diversity handbook
series)
Includes bibliographical references (p.).
ISBN 1-56098-858-4 (cloth : alk. paper)—
ISBN 1-56098-885-1 (pbk. : alk. paper)
1. Ants—Speciation—Research. 2. Biological
diversity—Measurement. I. Agosti, Donat.
II. Series.
QL568.F7 A575 2000
595.79'6—dc21 00-021953

British Library Cataloguing-in-Publication Data available

Manufactured in the United States of America
07 06 05 04 03 02 01 00 5 4 3 2 1

♾ The paper used in this publication meets the
minimum requirements of the American National
Standard for Information Sciences—Permanence
of Paper for Printed Library Materials
ANSI Z39.48-1984.

For permission to reproduce illustrations appearing in
this book, please correspond directly with the owners
of the works, as listed in the individual captions. The
Smithsonian Institution Press does not retain repro-
duction rights for these illustrations individually, or
maintain a file of addresses for illustration sources.

This book is dedicated to the memory of William L. Brown Jr.,
with affection, respect, and gratitude. For the inspiration you provided,
for the firm foundation you built for ant systematics, and especially
for your generous soul and irreverent good humor, we will never forget you, Bill.

Contents



List of Figures ix

List of Tables xiii

Foreword xv

Edward O. Wilson

Preface xvii

Chapter 1

**Biodiversity Studies, Monitoring, and
Ants: An Overview** 1

Leeanne E. Alonso and Donat Agosti

Chapter 2

A Primer on Ant Ecology 9

Michael Kaspari

Chapter 3

**A Global Ecology of Rainforest Ants:
Functional Groups in Relation to
Environmental Stress and Disturbance**
25

Alan N. Andersen

Chapter 4

**The Interactions of Ants with Other
Organisms** 35

Ted R. Schultz and Terrence P. McGlynn

Chapter 5

Diversity of Ants 45

William L. Brown Jr.

Chapter 6

Ants as Indicators of Diversity 80

Leeanne E. Alonso

Chapter 7

Using Ants to Monitor Environmental Change 89

Michael Kaspari and Jonathan D. Majer

Chapter 8

Broad-Scale Patterns of Diversity in Leaf Litter Ant Communities 99

Philip S. Ward

Chapter 9

Field Techniques for the Study of Ground-Dwelling Ants: An Overview, Description, and Evaluation 122

Brandon T. Bestelmeyer, Donat Agosti, Leeanne E. Alonso, C. Roberto F. Brandão, William L. Brown Jr., Jacques H. C. Delabie, and Rogerio Silvestre

Chapter 10

Sampling Effort and Choice of Methods 145

Jacques H. C. Delabie, Brian L. Fisher, Jonathan D. Majer, and Ian W. Wright

Chapter 11

Specimen Processing: Building and Curating an Ant Collection 155

John E. Lattke

Chapter 12

Major Regional and Type Collections of Ants (Formicidae) of the World and Sources for the Identification of Ant Species 172

C. Roberto F. Brandão

Chapter 13

What to Do with the Data 186

John T. Longino

Chapter 14

The ALL Protocol: A Standard Protocol for the Collection of Ground-Dwelling Ants 204

Donat Agosti and Leeanne E. Alonso

Chapter 15

Applying the ALL Protocol: Selected Case Studies 207

Brian L. Fisher, Annette K. F. Malsch, Raghavendra Gadagkar, Jacques H. C. Delabie, Heraldo L. Vasconcelos, and Jonathan D. Majer

Appendix 1

List and Sources of Materials for Ant Sampling Methods 215

Appendix 2

Ant Survey Data Sheet 219

Appendix 3

List of Materials for Ant Specimen Processing 221

Glossary 223

Ted R. Schultz and Leeanne E. Alonso

Literature Cited 231

Contributors 271

Index 275

Figures



Figure 1.1. Composition of total animal biomass and species composition of insect fauna near Manaus, Brazil 4

Figure 3.1. Classification of communities in relation to stress and disturbance 27

Figure 3.2. Functional group model of ant community organization in relation to environmental stress and disturbance 29

Figure 3.3. Behavior of ants at tuna baits at desert, woodland, and forest sites in south-eastern Arizona, illustrating high, moderate, and low levels of behavioral dominance, respectively 30

Figure 3.4. Effects of vegetation on functional group composition in the monsoonal tropics

of northern Australia and in cool-temperate southern Australia 32

Figure 3.5. Effects of disturbance on functional group composition of rainforest ants in the humid tropics of Queensland 33

Figure 5.1. Body parts of an ant 70

Figure 7.1. Abundance of 11 species of ant guard on *Calathea ovandensis* in a Neotropical rainforest 91

Figure 7.2. Abundance of two harvester ants, *Pogonomyrmex occidentalis* and *P. salinus*, over 15 and 9 years, respectively, in North America 92

Figure 7.3. Changes in two Chihuahuan desert ant assemblages 93

- Figure 7.4. Model illustrating the response of an ecosystem to perturbation 93
- Figure 7.5. Relationship between the number of ant species in 3-year-old rehabilitated mines and annual rainfall for a range of sites throughout Australia 94
- Figure 7.6. Pattern of recolonization of ants in rehabilitated sand-mined areas on North Stradbroke Island, Queensland 95
- Figure 8.1. Locations of 110 leaf litter collection sites 106
- Figure 8.2. Species richness of ant leaf litter samples as a function of latitude 110
- Figure 8.3. Species richness of ant leaf litter samples as a function of altitude 110
- Figure 8.4. Proportion of ant species in a sample belonging to the subfamily Ponerinae as a function of latitude 120
- Figure 9.1. An aspirator 125
- Figure 9.2. A tuna bait monopolized by *Solenopsis xyloni* in a desert grassland in New Mexico 127
- Figure 9.3. A pitfall trap placed in desert soil, a polypropylene sample container used as a pitfall trap, and a pitfall-trap scoop 129
- Figure 9.4. Construction of the litter sifter, external dimensions of the “mini-Winkler” sack, and construction of the “mini-Winkler” sack 134
- Figure 9.5. Leaf litter extraction using the Winkler extractor 135
- Figure 9.6. The pattern used to create a Berlese funnel and the appearance of the assembled funnel 137
- Figure 10.1. Assessment of each of 17 leaf litter ant sampling methods in Brazil 150
- Figure 10.2. Assessment of Winkler sampling methods in Brazil 152
- Figure 11.1. An ant mounted on a point and pinned with labels 159
- Figure 11.2. Sample labels for mounted and alcohol specimens 161
- Figure 11.3. Mounted ants arranged in unit trays in a collection drawer 169
- Figure 13.1. Raw versus smoothed species-accumulation curves from 16 Berlese samples of litter-soil cores 190
- Figure 13.2. Cost in samples of adding an additional species to an inventory 191
- Figure 13.3. Within-habitat versus combined species-accumulation curves for the Berlese data 191
- Figure 13.4. Comparing methods that differ in cost 192
- Figure 13.5. Rank abundance plot from Berlese data 193
- Figure 13.6. Hypothetical communities with contrasting species-accumulation curves 195
- Figure 13.7. Lognormal distribution of species abundance 196
- Figure 13.8. Contrasting relative abundance distributions for the Berlese data 197
- Figure 13.9. Michaelis-Menten estimates of species richness based on the Berlese data 199
- Figure 13.10. Chao2 estimates of species richness based on the Berlese data 200
- Figure 15.1. Assessment of leaf litter ant sampling technique for the most species-rich

site, that at 825 m on the Masoala Peninsula, Madagascar 209

Figure 15.2. Frequency of capture for species in nine 9-m², 16-m², and 25-m² plots in Malaysia 210

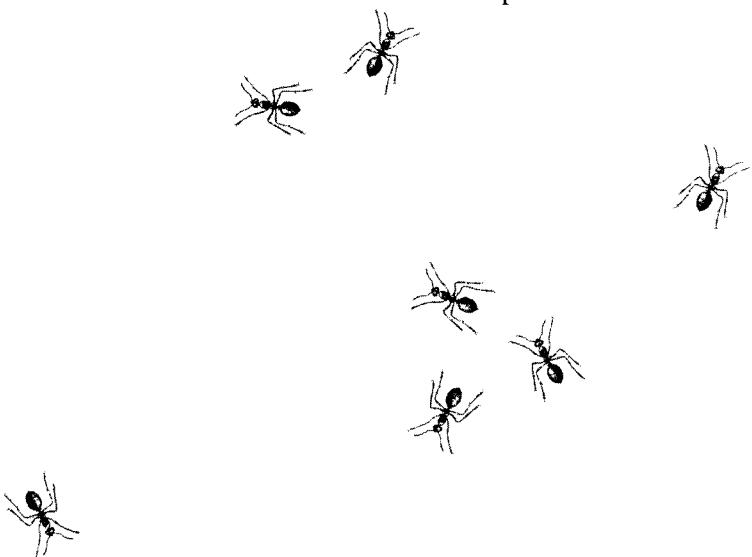
Figure 15.3. Species-accumulation curves for the three plot sizes of 9 m², 16 m², and 25 m² in Malaysia 210

Figure 15.4. Dendrograms comparing different sampling methods by ant species trapped in India 211

Figure 15.5. Mean number of ant species sampled by pitfall traps, Winkler sacks, and both methods combined along ten transects extending from the field into the rainforest in Bahia, Brazil 212

Broad-Scale Patterns of Diversity in Leaf Litter Ant Communities

Philip S. Ward



Ants are an important biological component of the leaf litter stratum in temperate and especially tropical forests. A number of regional studies have documented the predominance and diversity of soil and leaf litter ants (Kempf 1961a; Levings 1983; Andersen and Majer 1991; Olson 1991, 1994; Agosti et al. 1994; Belshaw and Bolton 1994a; Longino 1994; Delabie and Fowler 1995; Fisher 1996a, 1997, 1998; Kaspari 1996a; Majer et al. 1997; see also Chapter 15), but there have been few attempts at interregional comparisons. Emery (1920), Brown (1973), Hölldobler and Wilson (1990), Bolton (1995a), and Fisher (1997) provide valuable summaries of the global distributions of ant genera, but without focusing on particular habitats. Wilson (1976) presented data on the most prevalent arboreal and ground-dwelling ant genera at a

series of tropical sites, but he did not specifically analyze the leaf litter fauna.

This chapter characterizes, in rather general terms, diversity patterns among assemblages of leaf litter ant species inhabiting forest and woodland habitats in different biogeographic regions. It is based primarily on a set of leaf litter ant collections made by the author over a 12-year period. The survey is somewhat uneven in its geographic coverage, but it does reveal some robust patterns: the number of ant species at a given site (alpha diversity) is strongly negatively correlated with latitude and altitude; there is a slight secondary decline in species richness at the lowest elevations in tropical (but not temperate) forests; and, at higher taxonomic levels (genus, subfamily), there is substantial faunal turnover (beta diversity) among biogeographic regions.

The study also highlights certain glaring knowledge gaps: without much greater effort devoted to alpha taxonomy (i.e., the description and discrimination of ant species), we will be unable to obtain complete measures of beta diversity at the species level. We are also ignorant of the ecological habits of most leaf litter ants and their effects on other cohabiting organisms. Thus, although we can point to biogeographic patterns—such as the predominance of *Stenamma* in Nearctic and montane Central American forests or the profusion of *Tetramorium* species in the Old World tropics—we have little idea about the ecological significance of these observations.

Data Sources and Methods

The primary database for this analysis is a set of 110 Winkler litter samples collected by the author from various tropical and temperate localities (Table 8.1; Fig. 8.1). The sites ranged in latitude from 47°43'N to 35°34'S and in elevation from 10 to 2700 m. Defining biogeographic realms broadly, the provenance of these samples is as follows: Nearctic (23 samples), Neotropical (49), Malagasy (19), and Indo-Australian (19). The last includes a collection each from Singapore and peninsular Malaysia that have been grouped with the Australian and New Guinea samples for the purposes of comparing taxonomic diversity across broadly defined regions. When analyzing the distribution of leaf litter ant genera I have included data from additional sources and used a finer division of biogeographic regions, as discussed later in the chapter.

Most of the Winkler samples were taken from closed canopy forest (see under "Habitat" in Table 8.1), and all were taken under conditions in which the leaf litter was moist from precipitation. None of the collections was made during or immediately after heavy rain, however, because experience suggests that Winkler ex-

tractions from water-saturated litter underestimate the diversity of the ant fauna. At each site handfuls of moist leaf litter and rotten wood were gathered haphazardly over an area of about 1 ha or less and sifted through a sieve (8 cm diameter) until a total of 6 liters of sifted litter had been acquired. An attempt was made to sample each area broadly, avoiding undue concentration on a few localized accumulations of litter. The 6 liters of litter were placed in three mesh bags, which were hung in a cloth Winkler sack ("Gesiebeautomat") for passive arthropod extraction (for further description of this method, see Besuchet et al. 1987; Ward 1987; Fisher 1998; Chapter 9). Extraction was usually carried out near the field site, under ambient temperatures, typically in a sheltered field camp or in a local hotel. The total extraction time varied depending upon the circumstances (10–72 hours; mean 32.3 hours). Extraction time was treated as an independent variable in multiple regression analyses of several measures of taxonomic diversity (species richness, genus richness, number of subfamilies represented), but it was found not to have a significant effect on these measurements. This is probably because representatives of most of the ant species in a sample fall out of the mesh bags within a few hours.

The ants from each sample were sorted to subfamily, genus, and morphospecies, with higher classification following Bolton (1995b). The approach taken toward species identification was as follows. All specimens in a sample were first rough-sorted in alcohol. Several workers of each putative morphospecies were then point-mounted for examination (as were all uniques in a sample). For difficult genera, such as *Pheidole* and *Solenopsis*, this approach often revealed additional species masquerading as a single form when first examined in alcohol.

The alcohol residue was then reexamined more carefully and additional specimens point-mounted and checked. This process was

Table 8.1 List of Winkler Leaf Litter Collection Sites

Accession No.	Region	Country ^a	Locality ^b	Habitat	Latitude	Longitude	Altitude (m)	Date	Time (hours)	Extraction	Number of Workers	Number of Species	Number of Genera
9522	NEA	CAN	NS: 6 km N Greenfield	Deciduous forest	44°19'N	64°51'W	80	17-Sep-88	36	32	3	3	3
9520	NEA	CAN	NS: 8 km N Greenfield	Pine-hemlock-northern hardwood	44°21'N	64°51'W	80	17-Sep-88	24	64	8	8	8
9534	NEA	CAN	NS: Hemlock Ravine	Mixed coniferous forest	44°41'N	63°40'W	20	20-Sep-88	48	2	1	1	1
7050	NEA	CAN	NS: Aldershot	Mixed coniferous forest	45°06'N	64°31'W	15	09-Sep-84	72	47	8	1	1
6371	NEA	CAN	ONT: Lake Opinicon	Deciduous forest	44°33'N	76°22'W	150	22-Oct-83	24	4	3	3	3
7080	NEA	UNI	VA: 25 km NNW Madison	Deciduous forest	38°36'N	78°22'W	1030	15-Sep-84	72	15	1	1	1
5936	NEA	UNI	WA: Seattle	<i>Pseudotsuga-Tsuga-Acer</i> forest	47°43'N	122°22'W	10	02-May-83	72	2	2	2	2
7531	NEA	UNI	OR: 10 km ESE Oakridge	<i>Pseudotsuga-Tsuga-Acer</i> forest	42°43'N	122°20'W	500	20-May-85	72	17	4	3	3
7523	NEA	UNI	OR: 10 km NW LaPine	<i>Pinus ponderosa</i> forest	43°43'N	121°36'W	1400	20-May-85	36	4	3	3	3
7533	NEA	UNI	OR: W. L. Finley NWR	Riparian woodland	44°25'N	123°19'W	75	01-Jan-85	72	0	0	0	0
6984	NEA	UNI	NV: 14 km WSW Carson City	Pine-fir forest	39°08'N	119°55'W	2080	19-Jul-84	72	9	2	2	2
8463	NEA	UNI	NV: 3 km SSE Mt. Rose	Pine-hemlock forest	39°19'N	119°54'W	2640	20-Jul-86	72	1	1	1	1
6986	NEA	UNI	NV: 9 km SSE Incline Village	Mixed coniferous forest	39°10'N	119°55'W	1950	19-Jul-84	72	5	1	1	1
11621	NEA	UNI	CA: 8 km NW Quincy	Mixed coniferous forest	40°00'N	120°59'W	1030	26-Jun-92	24	5	2	2	2
6733	NEA	UNI	CA: Lang Crossing	Oak woodland	39°19'N	120°39'W	1425	12-May-84	72	36	4	4	4
10663	NEA	UNI	CA: 4 km NNW Guinda	Riparian woodland	38°52'N	122°12'W	120	07-Apr-90	72	49	6	5	5
8222	NEA	UNI	CA: 4 km E Yolo	Oak woodland	38°44'N	121°46'W	15	01-Feb-86	72	99	4	4	4
8254	NEA	UNI	CA: Cold Canyon	Oak woodland	38°30'N	122°06'W	120	29-Mar-86	72	46	7	5	5
9377	NEA	UNI	CA: Gold Creek Road	Oak woodland	34°19'N	118°20'W	550	07-Mar-88	72	25	4	3	3
12033	NEA	UNI	CA: Centinela, Santa Cruz Island	Coastal pine forest	34°01'N	119°48'W	435	26-Jun-93	72	28	6	4	4
9372	NEA	UNI	CA: Banner	Mixed coniferous forest	33°04'N	116°33'W	820	29-Feb-88	72	14	3	2	2
7213	NEA	UNI	TX: 8 km E George West	Riparian woodland	28°20'N	98°02'W	40	16-Dec-84	72	91	14	9	9
7149	NEA	UNI	TX: Santa Ana NWR	Subtropical dry forest	26°05'N	98°08'W	30	13-Dec-84	42	245	8	7	7

Continued on next page

Table 8.1 continued

Accession No.	Region	Country ^a	Locality ^b	Habitat	Latitude	Longitude	Altitude (m)	Date	Extraction Time (hours)	Number of Workers	Number of Species	Number of Genera
12826	NEO	ARG	Tuc.: 11 km N Tafí Viejo	Tropical dry forest	26°38'S	65°14'W	820	01-Feb-95	60	882	21	8
9085	NEO	BOL	Beni: 42 km E San Borja	Tropical dry forest	14°48'S	66°23'W	210	05-Sep-87	12	193	20	12
12314	NEO	BOL	SC: 10 km NW Terevinto	Tropical moist forest	17°40'S	63°27'W	380	09-Dec-93	24	1289	52	19
12199	NEO	BOL	SC: 35 km SSE Flor de Oro	Rainforest	13°50'S	60°52'W	450	29-Nov-93	24	965	65	22
12174	NEO	BOL	SC: Aserradero Moira	Rainforest	14°34'S	61°12'W	180	27-Nov-93	12	463	45	20
12438	NEO	BOL	SC: Buena Vista	Second-growth rainforest	17°27'S	63°40'W	350	18-Dec-93	20	1116	73	26
12266	NEO	BOL	SC: Las Gamas	Rainforest	14°48'S	60°23'W	700	03-Dec-93	30	259	39	17
12285	NEO	BOL	SC: Las Gamas	Rainforest	14°48'S	60°23'W	700	04-Dec-93	12	219	42	19
9159	NEO	BRA	AM: 80 km NNE Manaus	Rainforest	2°25'S	59°46'W	80	15-Sep-87	24	361	37	16
7912	NEO	COL	Magd.: 4 km N San Pedro	Rainforest	10°57'N	74°03'W	550	14-Aug-85	24	350	32	18
7858	NEO	COL	Magd.: Cañaveral	Tropical dry forest	11°19'N	73°56'W	300	11-Aug-85	48	383	31	16
7891	NEO	COL	Magd.: El Campano	Montane rainforest	11°07'N	74°06'W	1300	13-Aug-85	24	233	23	14
6468	NEO	COS	Gstc.: Parque Nacional Santa Rosa	Tropical dry forest	10°48'N	85°41'W	10	16-Dec-83	12	34	6	4
6423	NEO	COS	Gstc.: Parque Nacional Santa Rosa	Tropical dry forest	10°51'N	85°37'W	290	14-Dec-83	24	276	15	9
6530	NEO	COS	Limón: 3 km SSE Cahuita	Rainforest	9°43'N	82°50'W	70	24-Dec-83	24	734	39	18
7771	NEO	COS	Pts.: 3 km N Ciudad Neily	Second-growth rainforest	8°41'N	82°57'W	210	31-Jul-85	36	342	29	17
7692	NEO	COS	Pts.: Parque Nacional Manuel Antonio	Second-growth rainforest	9°23'N	84°09'W	10	27-Jul-85	36	202	28	14
7650	NEO	COS	Pts.: Reserva Biológica Carara	Rainforest	9°47'N	84°36'W	500	25-Jul-85	72	257	36	18
7832	NEO	COS	San José: 1 km N La Ese	Montane rainforest	9°27'N	83°43'W	1400	05-Aug-85	12	157	27	13
7811	NEO	COS	San José: near San Gerardo	Montane rainforest	9°28'N	83°35'W	1600	04-Aug-85	12	109	18	13
11726	NEO	DOM	16 km ENE Pedernales	Montane rainforest	18°07'N	71°37'W	800	09-Sep-92	24	593	23	14
11751	NEO	DOM	16 km ENE Pedernales	Tropical-temperate mesic forest	18°07'N	71°37'W	800	10-Sep-92	16	198	16	11
11770	NEO	DOM	4 km NNW Villa Altgracia	Rainforest	18°42'N	70°11'W	200	12-Sep-92	12	724	17	11
11418	NFO	FCTI	10 km FNF II a Mana	Second-growth rainforest	0°55'27"	70°01'W	1100	10-Anio-91	24	514	23	10

11364	NEO	ECU	Jatun Sacha	Rainforest	1°04'S	77°37'W	400	05-Aug-91	24	653	75	27
11503	NEO	ECU	Maquipucuna	Second-growth rainforest	0°07'N	78°38'W	1500	17-Aug-91	24	358	20	15
11581	NEO	MEX	Chis.: 5 km E Rayon	Second-growth rainforest	17°13'N	92°58'W	1700	23-Dec-91	12	235	11	8
11570	NEO	MEX	Chis.: Lago Pojoj	Tropical-temperate mesic forest	16°06'N	91°40'W	1500	21-Dec-91	24	23	7	6
9283	NEO	MEX	Col.: 19 km NNE Comala	Tropical-temperate mesic forest	19°29'N	103°41'W	1650	25-Dec-87	12	9	4	4
9273	NEO	MEX	Jal.: 10 km S Autlan	Tropical-temperate mesic forest	19°41'N	104°23'W	1600	20-Dec-87	24	55	3	2
9326	NEO	MEX	Jal.: 14 km SSW Puerto Vallarta	Rainforest	20°30'N	105°18'W	130	31-Dec-87	24	290	13	10
9280	NEO	MEX	Jal.: 16 km SW Ciudad Guzman	Mixed coniferous forest	19°35'N	103°34'W	2700	24-Dec-87	24	0	0	0
9327	NEO	MEX	Jal.: 6 km NE El Tuito	Tropical-temperate mesic forest	20°22'N	105°19'W	730	31-Dec-87	24	149	11	10
9255	NEO	MEX	Jal.: Estación Biológica Chamela	Tropical dry forest	19°30'N	105°02'W	100	18-Dec-87	36	285	13	9
7369	NEO	MEX	Ver.: Los Tuxtlas	Rainforest	18°35'N	95°05'W	500	21-Mar-85	60	626	42	19
7333	NEO	MEX	Ver.: Los Tuxtlas	Rainforest	18°35'N	95°05'W	200	20-Mar-85	72	1632	53	24
7314	NEO	MEX	Ver.: 10 km S Orizaba	Cloud forest	18°45'N	97°05'W	1500	19-Mar-85	72	73	12	9
7414	NEO	MEX	Ver.: 11 km N San Andres	Cloud forest	18°33'N	95°12'W	1400	23-Mar-85	12	80	18	12
7415	NEO	MEX	Ver.: 11 km N San Andres	Cloud forest	18°33'N	95°12'W	1600	23-Mar-85	12	44	11	7
6391	NEO	PAN	CZ: 3 km NW Gamboa	Rainforest	9°08'N	79°43'W	40	10-Dec-83	24	566	38	18
8701	NEO	PER	15 km WSW Yurimaguas	Rainforest	5°59'S	76°13'W	200	22-Aug-86	24	269	38	21
8684	NEO	PER	30 km NNE Tarapoto	Rainforest	6°15'S	76°15'W	220	21-Aug-86	24	222	25	15
9011	NEO	VEN	17 km SSW Ciudad Bolivia	Second-growth rainforest	8°02'N	70°46'W	240	28-Aug-87	36	1071	32	19
8511	NEO	VEN	49 km ENE Tumeremo	Second-growth rainforest	7°28'N	61°06'W	200	09-Aug-86	17	146	22	9
8927	NEO	VEN	5 km SW Guarico	Rainforest	9°36'N	69°50'W	1350	23-Aug-87	24	206	16	9
8537	NEO	VEN	66 km ESE El Dorado	Rainforest	6°09'N	61°30'W	250	11-Aug-86	24	652	42	20
8920	NEO	VEN	9 km SE Barbaos	Montane rainforest	9°46'N	70°00'W	2000	27-Aug-87	12	12	4	4
8572	NEO	VEN	Campamento Rio Grande	Rainforest	8°07'N	61°42'W	250	14-Aug-86	24	290	23	14
8548	NEO	VEN	km 114 El Dorado-Santa Elena	Rainforest	6°01'N	61°24'W	1000	12-Aug-86	18	93	23	11

Continued on next page

Table 8.1 continued

Accession No.	Region	Country ^a	Locality ^b	Habitat	Latitude	Longitude	Altitude (m)	Date	Extraction Time (hours)	Number of Workers	Number of Species	Number of Genera
11862	MAL	MAD	Berenty Reserve	Tropical dry forest	25°01'S	46°18'E	25	09-Feb-93	18	192	13	9
11831	MAL	MAD	3 km E Mahamavo	Montane rainforest	24°45'S	46°45'E	1050	05-Feb-93	12	137	17	6
11820	MAL	MAD	6 km SSW Eminiminny	Rainforest	24°44'S	46°48'E	330	04-Feb-93	12	230	30	13
11935	MAL	MAD	15 km E Sakaraha	Tropical dry forest	22°54'S	44°41'E	760	15-Feb-93	24	87	16	8
10413	MAL	MAD	3 km W Ranomafana	Rainforest	21°15'S	47°25'E	950	27-Apr-89	24	699	32	13
10435	MAL	MAD	28 km SSW Ambositra	Montane rainforest	20°46'S	47°11'E	1660	29-Apr-89	12	178	11	4
11971	MAL	MAD	Manjakatompo	Montane rainforest	19°21'S	47°19'E	1600	20-Feb-93	18	168	10	6
10966	MAL	MAD	16 km S Moramanga	Rainforest	19°05'S	48°14'E	950	18-Nov-90	24	210	22	9
10956	MAL	MAD	6 km ESE Perinet	Rainforest	18°57'S	48°28'E	900	17-Nov-90	14	287	30	10
11146	MAL	MAD	1 km SSW Andasibe	Rainforest	18°56'S	48°25'E	920	12-Dec-90	12	109	14	9
11086	MAL	MAD	25 km NNE Ankazobe	Rainforest	18°06'S	47°11'E	1500	05-Dec-90	24	508	18	8
10358	MAL	MAD	Nosy Mangabe	Rainforest	15°30'S	49°46'E	150	21-Apr-89	24	409	22	9
10320	MAL	MAD	Nosy Mangabe	Rainforest	15°30'S	49°46'E	300	18-Apr-89	24	393	27	12
10340	MAL	MAD	Nosy Mangabe	Rainforest	15°30'S	49°46'E	20	20-Apr-89	24	151	21	9
10379	MAL	MAD	19 km ESE Maroantsetra	Rainforest	15°29'S	49°54'E	350	22-Apr-89	20	1162	40	11
10471	MAL	MAD	4 km ESE Hellville	Rainforest	13°25'S	48°18'E	200	02-May-89	24	375	23	8
11010	MAL	MAD	Reserve Ankaranana	Rainforest	12°54'S	49°07'E	150	28-Nov-90	48	180	16	10
10264	MAL	MAU	Le Pouce	Low closed forest	20°12'S	57°31'E	700	09-Apr-89	24	30	6	6
10503	MAL	MAU	Bassin Blanc	Disturbed rainforest	20°27'S	57°28'E	500	06-May-89	24	303	8	8
8140	AUS	AUS	WAust.. 4 km E Walpole	Open tall eucalypt forest	34°59'S	116°47'E	150	08-Dec-85	36	65	5	4
9685	AUS	AUS	NSW Kioloa State Forest	Closed eucalypt forest	35°34'S	150°18'E	35	17-Dec-88	24	314	21	13
8214	AUS	AUS	NSW Royal National Park	Rainforest	34°09'S	151°01'E	50	15-Dec-85	24	332	21	15
8217	AUS	AUS	NSW Royal National Park	Closed eucalypt forest	34°09'S	151°01'E	50	15-Dec-85	24	254	15	13
9770	AUS	AUS	NSW Mt. Kaputar National Park	Closed eucalypt forest	30°17'S	150°08'E	1180	26-Dec-88	10	186	11	10
9833	AUS	AUS	QLD 6 km SSW North Tamborine	Rainforest	27°56'S	153°11'E	500	31-Dec-88	12	106	18	12
6246	AUS	AUS	QLD 10 km SE Kenilworth	Closed eucalypt forest	26°40'S	152°47'E	340	25-Aug-83	12	82	14	12
2770	AT&T	AT&T	OF THE LONE STAR STATE OF TEXAS	Distribution	22°00'N 100°00'W	22°40'N 100°40'W	127	27 AUGUST 1983	12	174	21	12

6202	AUS	AUS	QLD 1 km SW Eungella	Rainforest	21°0' S	148°29'E	840	23-Aug-83	12	67	5	5
6013	AUS	AUS	QLD 27 km NNE Coen	Rainforest	13°44' S	143°20'E	530	06-Aug-83	24	190	17	10
6028	AUS	AUS	QLD 27 km NNE Coen	Rainforest	13°44' S	143°20'E	530	06-Aug-83	19	93	19	11
6073	AUS	AUS	QLD 12 km WNW	Rainforest	12°44' S	143°14'E	30	09-Aug-83	24	243	22	11
			Lockhart River									
10050	AUS	PNG	Vatirata National Park	Rainforest	9°27' S	147°21'E	800	26-Jan-89	12	250	30	17
10121	AUS	PNG	24 km N Madang	Rainforest	5°01' S	145°46'E	80	02-Feb-89	24	285	41	19
10127	AUS	PNG	38 km N Madang	Rainforest	4°53' S	145°45'E	40	03-Feb-89	72	588	49	21
10142	AUS	PNG	5 km SW Mt. Uluman	Rainforest	4°41' S	145°57'E	800	05-Feb-89	24	478	34	23
10186	AUS	PNG	Ambunti	Rainforest	4°13' S	142°49'E	150	12-Feb-89	20	418	56	25
9576	ORI	SIN	Bukit Timah Nature Reserve	Rainforest	1°21' N	103°47'E	100	20-Nov-88	48	116	22	16
9586	ORI	MAL	Kota Tinggi Falls	Rainforest	1°50' N	103°50'E	100	22-Nov-88	24	161	24	13

^aAbbreviations: ARG, Argentina; AUS, Australia; BOL, Bolivia; BRA, Brazil; CAN, Canada; COL, Colombia; COS, Costa Rica; DOM, Dominican Republic; ECU, Ecuador; MAD, Madagascar; MAL, Malaysia; MAU, Mauritius; MEX, Mexico; PAN, Panama; PER, Peru; PNG, Papua New Guinea; SIN, Singapore; UNI, United States; VEN, Venezuela.

^bAbbreviations: AM, Amazonas; CA, California; CHS, Chiapas; COL, Colima; CZ, Canal Zone; GTE, Guanacaste; JAL, Jalisco; MAGD, Magdalena; NS, Nova Scotia; NSW, New South Wales; NV, Nevada; ONT, Ontario; OR, Oregon; PIS, Puntarenas; QLQ, Queensland; SC, Santa Cruz; TUC, Tucumán; TX, Texas; VA, Virginia; VER, Veracruz; WA, Washington; WAAUST, Western Australia.

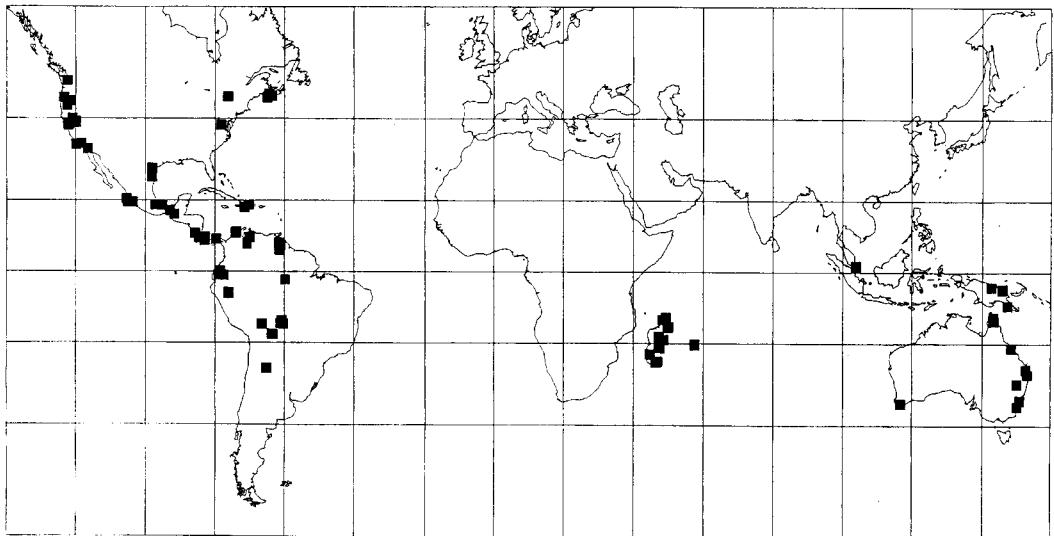


Figure 8.1. Locations of the 110 leaf litter collection sites. Grid lines are shown for every 20° of latitude (between 60°N and 60°S) and for every 20° of longitude.

continued until no further distinctions could be made. All point-mounted specimens were retained as vouchers. I drew upon my experience as an ant taxonomist to make judgments about the kinds of morphological discontinuities that would indicate the presence of two biological species. The morphospecies so designated can be thought of as working hypotheses about species identities, which can be independently assessed in the future by examination of the voucher specimens. Specific names were assigned where feasible (i.e., for taxonomically well-understood genera), but in many instances it was necessary to develop a system of code names for the species in a given geographical area (e.g., *Pheidole* BOL-32 for one of about 40 *Pheidole* species from eastern Bolivia). Such code numbers have local applicability only, and the task of reconciling the specific identities of code-named taxa from different geographic regions has not yet been completed.

Indeed, although sorting species from samples taken within the same geographical area is challenging and time consuming, such difficul-

ties pale in comparison to those that attend any attempt to resolve species identities over large geographical scales. As a result, this study is primarily about patterns of alpha diversity (i.e., geographical variation in *within-site* species richness) and about regional variation in faunal composition at higher taxonomic levels (genera, subfamilies). Large-scale measurements of species beta diversity (species turnover) remain constrained by insufficient taxonomic knowledge.

All the results reported here are based on workers only, although the presence of other castes was noted. For each sample the number of individual workers of each morphospecies was recorded. Variables of interest for each sample include the total number of workers and the numbers of species, genera, and subfamilies represented. Among the independent variables recorded for each sample were biogeographic region, habitat, latitude, longitude, and altitude (see Table 8.1). Latitude was converted to absolute decimal latitude for all statistical analyses.

Voucher specimens were deposited in the Museum of Comparative Zoology, Harvard University (MCZC) and in the P. S. Ward collection at the University of California at Davis (PSWC). In addition, duplicate specimens from Australia, Papua New Guinea, Madagascar, Mauritius, Argentina, Bolivia, Brazil, Colombia, Ecuador, and Venezuela were returned to the following host institutions, respectively: Australian National Insect Collection, Canberra (ANIC); Entomology Collection, University of Papua New Guinea (UPNG); Parc Botanique et Zoologique de Tsimbazaza, Antananarivo (PBZT); Mauritius Sugar Industry Research Institute (MSIR); Instituto Miguel Lillo, Tucumán (IMLA); Museo de Historia Natural "Noel Kempff Mercado," Santa Cruz (UASC); Instituto Nacional de Pesquisas da Amazônia, Manaus (INPA); Museo de Historia Natural, Universidad Nacional de Colombia, Bogotá (UNCB); Museo Ecuatoriano de Ciencias Naturales, Quito (MECN); and Instituto de Zoología Agrícola, Universidad Central de Venezuela, Maracay (IZAV).

The primary database was supplemented by information on Winkler leaf litter collections from Malaysia (data kindly provided by Annette Malsch) and West Africa (Belshaw and Bolton 1994a). The 11 Malaysian samples are all from Pasoh Forest Reserve, and each consists of 9 m²

of rainforest leaf litter sifted to yield about 6 liters of concentrated litter. The West African samples are from 34 sites (20 localities) in Ghana; at each site ten 1-m² quadrats were randomly placed in an area of approximately 1000 m², and all the leaf litter in these quadrats was collected, sifted, and extracted. Because the sampling methods used in the Malaysian and Ghanaian studies differ from those described here, I have not used these data for the analysis of diversity patterns. They have been employed mainly to broaden the geographic base for a genus-level comparison of faunal composition (Tables 8.11 and 8.12).

Content of the Winkler Leaf Litter Samples

The 110 Winkler samples yielded a total of 29,942 worker ants from 6 subfamilies, 103 genera, and approximately 911 species (Table 8.2). Because of taxonomic uncertainties the cumulative tally of the number of species should be considered provisional. I estimate that it could be higher or lower by as much as 10%. Site richness (alpha diversity) per sample ranged from 0 to 75 species (mean 20.3 ± 15.9 s.d.), from 0 to 27 genera (mean 10.6 ± 6.4 s.d.), and from 0 to 5 subfamilies (mean 2.8 ± 1.0 s.d.). The number of worker ants per Winkler

Table 8.2 Summary of Winkler Leaf Litter Samples: Taxonomic Content

Subfamily	Number of Genera	Number of Species (% of Total)	Number of Workers (% of Total)
Cerapachyinae	2 (1.9)	4 (0.4)	45 (0.2)
Dolichoderinae	6 (5.8)	10 (1.1)	137 (0.5)
Ectoninae	2 (1.9)	3 (0.3)	107 (0.4)
Formicinae	14 (13.6)	ca. 97 (10.6)	3,873 (12.9)
Myrmicinae	57 (55.3)	ca. 594 (65.2)	22,067 (73.7)
Ponerinae	22 (21.4)	ca. 203 (22.2)	3,713 (12.4)
Total	103	ca. 911	29,942

Table 8.3 Forty Ant Genera Most Frequently Encountered in the Survey

Genus	Number (%) of Winkler Samples Occupied	Mean Number of Species per Sample Belonging to Genus	Mean Proportion of Species per Sample Belonging to Genus
<i>Hypoponera</i>	83 (75.5)	2.27	0.099
<i>Pheidole</i>	83 (75.5)	3.82	0.148
<i>Strumigenys</i>	75 (68.2)	1.55	0.061
<i>Solenopsis</i>	64 (58.2)	1.63	0.069
<i>Paratrechina</i>	59 (53.6)	0.84	0.034
<i>Pachycondyla</i>	48 (43.6)	0.70	0.028
<i>Oligomyrmex</i>	42 (38.2)	0.57	0.020
<i>Cyphomyrmex</i>	33 (30.0)	0.46	0.018
<i>Rogeria</i>	30 (27.3)	0.45	0.019
<i>Anochetus</i>	28 (25.5)	0.31	0.012
<i>Brachymyrmex</i>	28 (25.5)	0.40	0.017
<i>Monomorium</i>	28 (25.5)	0.54	0.025
<i>Tetramorium</i>	28 (25.5)	0.71	0.034
<i>Stenamma</i>	27 (24.5)	0.46	0.086
<i>Wasmannia</i>	27 (24.5)	0.25	0.009
<i>Gnamptogenys</i>	25 (22.7)	0.35	0.012
<i>Crematogaster</i>	23 (20.9)	0.31	0.011
<i>Prionopelta</i>	23 (20.9)	0.28	0.008
<i>Octostruma</i>	22 (20.0)	0.27	0.010
<i>Smithistruma</i>	20 (18.2)	0.21	0.009
<i>Acropyga</i>	17 (15.5)	0.21	0.007
<i>Neostruma</i>	17 (15.5)	0.16	0.006
<i>Odontomachus</i>	17 (15.5)	0.16	0.005
<i>Discothyrea</i>	15 (13.7)	0.15	0.008
<i>Adelomyrmex</i>	14 (12.7)	0.22	0.009
<i>Leptothorax</i>	14 (12.7)	0.14	0.036
<i>Ponera</i>	13 (11.8)	0.16	0.009
<i>Aphaenogaster</i>	12 (10.9)	0.11	0.018
<i>Cryptopone</i>	12 (10.9)	0.15	0.007
<i>Apterostigma</i>	11 (10.0)	0.12	0.003
<i>Myrmecina</i>	11 (10.0)	0.11	0.007
<i>Lasius</i>	10 (9.1)	0.10	0.042
<i>Myrmicocrypta</i>	10 (9.1)	0.10	0.002
<i>Hylomyrma</i>	9 (8.2)	0.09	0.002
<i>Rhytidoponera</i>	9 (8.2)	0.11	0.005
<i>Eurhopalothrix</i>	8 (7.3)	0.08	0.002
<i>Heteroponera</i>	7 (6.4)	0.06	0.005
<i>Proceratium</i>	7 (6.4)	0.06	0.004
<i>Camponotus</i>	6 (5.5)	0.05	0.002
<i>Leptogenys</i>	6 (5.5)	0.05	0.002

sample varied from 0 to 1632 (mean 272.2 ± 301.4 s.d.).

Over the entire collection of Winkler samples, the predominant subfamily is the Myrmicinae (57 genera, about 594 species), followed by the Ponerinae (22 genera, about 203 species), Formicinae (14 genera, about 97 species), Dolichoderinae (6 genera, 10 species), Cerapachyinae (2 genera, 4 species), and Ecitoninae (2 genera, 3 species). The predominance of the Myrmicinae is greater, and that of the Ponerinae is less, when numbers of individual workers rather than numbers of species are considered (Table 8.2). The most frequent and species-rich genera are listed in Table 8.3. The six most frequent genera are *Pheidole* (represented in 83 out of 110 samples), *Hypoponera* (83/110), *Strumigenys* (75/110), *Solenopsis* (64/110), *Paratrechina* (59/110), and *Pachycondyla* (48/110). The six most species-rich genera are an overlapping but not identical set: *Pheidole* (mean number of species per sample: 3.82), *Hypoponera* (2.27), *Solenopsis* (1.63), *Strumigenys* (1.55), *Paratrechina* (0.84), and *Tetramorium* (0.71). Based on the proportion of species in any sample that belong to a particular genus, the most species-predominant genera are *Pheidole* (mean proportion: 0.15), *Hypoponera* (0.10), *Stenamma* (0.09), *Solenopsis* (0.07), and *Strumigenys* (0.06). The mean proportion for *Stenamma* is accompanied by a high variance and does not indicate large numbers of species because this genus is largely confined to species-poor samples taken from temperate Nearctic localities.

Latitudinal and Altitudinal Patterns of Leaf Litter Ant Diversity

Results of a multiple regression analysis of species richness (number of species in a sample) on latitude, altitude, and extraction time are

Table 8.4 Multiple Regression Analysis of Sample Species Richness^a

Variable	Coefficient	Standard Error	P
Constant	40.412	2.642	0.000
Latitude	-0.803	0.103	0.000
Altitude	-0.008	0.002	0.000
Extraction time	0.033	0.061	0.593

^aIndependent variables are latitude (absolute), altitude (m), and extraction time (hours). Multiple $R^2 = 0.471$, $n = 110$.

shown in Table 8.4. Latitude and altitude alone account for about 47% of the variance in species richness, and extraction time has no significant effect ($P = 0.593$). Plots of species richness as a function of latitude and altitude are shown in Figs. 8.2 and 8.3. The latitudinal species gradient is steeper for low-altitude than for high-altitude sites, and the decline in ant species richness with altitude is less pronounced at high latitudes. There is also an indication that species richness shows a slight decline below 500 m in tropical regions (Figure 8.3a). In fact, for tropical and subtropical sites (latitude $< 30^\circ$) at elevations below 500 m there is a significant positive correlation between species richness and altitude ($r = 0.453$, $n = 42$, $P = 0.003$), whereas for sites at or above 500 m the relationship is negative ($r = -0.561$, $n = 42$, $P = 0.000$). No such midelevation peak in species richness was detected among the high-latitude ($> 30^\circ$) sites, although the sample size is admittedly small ($n = 26$).

A latitudinal gradient in the species richness of leaf litter ants is hardly surprising and accords with the pattern seen generally in ants (Kusnezov 1957; Jeanne 1979) and in numerous other taxa (Stevens 1989). A sharp attenuation of the ant fauna at higher elevations in tropical forests has also been well documented (e.g., Weber 1943a; Brown 1973; Janzen et al. 1976; Olson 1994; Fisher 1996a, 1998). Darlington

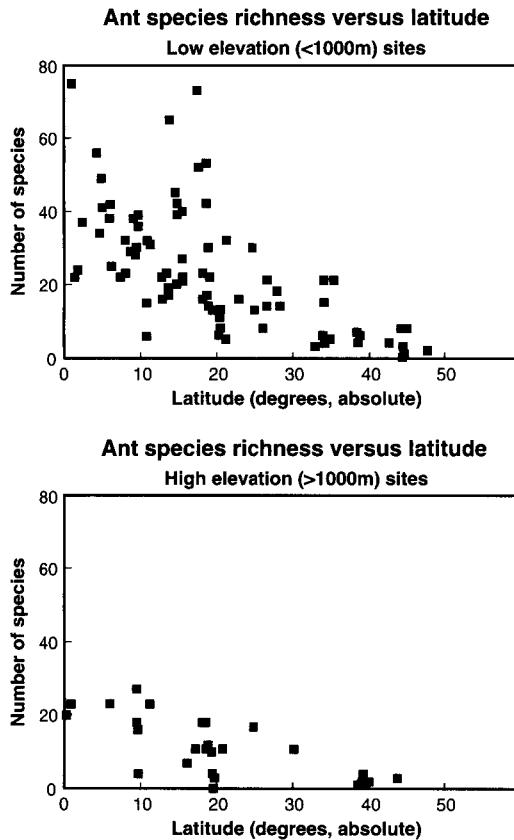


Figure 8.2. Species richness of ant leaf litter samples as a function of latitude. Values are plotted separately for low-elevation and high-elevation sites. Total number of sites: 110.

(1971) and Olson (1994) have discussed the possible consequences of this decline in ant diversity for other ground-dwelling arthropods. In Olson's (1994) study of leaf litter invertebrates in Panama, carabid beetles and weevils showed peaks of abundance and diversity at the highest elevations, where ants were relatively scarce, suggesting ecological release or replacement.

A midelevation peak in species richness of leaf litter ants was documented by Olson (1994) for Panama and by Fisher (1998) for Madagascar. Sampson et al. (1997) described a similar pattern for ground-dwelling and arboreal ants in the Philippines. The present results

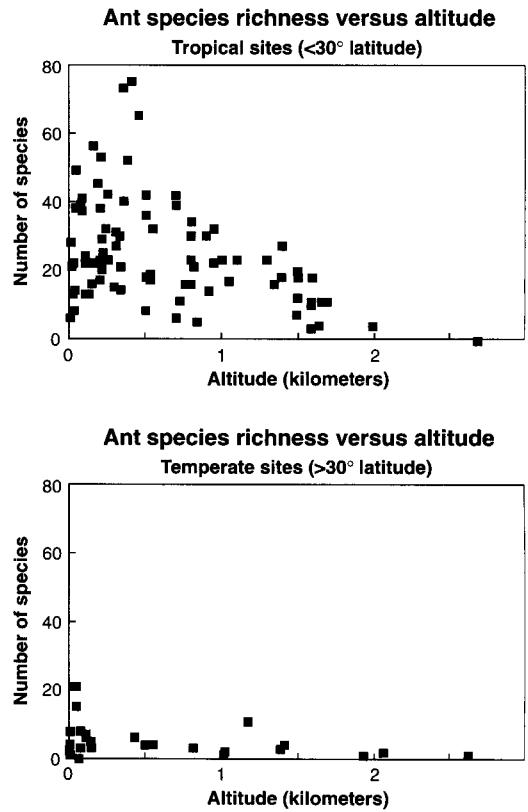


Figure 8.3. Species richness of ant leaf litter samples as a function of altitude. Values are plotted separately for tropical ($<30^\circ$ latitude) and temperate sites.

extend the generality of these findings. Midelevation diversity peaks have also been reported for other taxa and on larger spatial scales (e.g., McCoy 1990; Colwell and Hurtt 1994; Rahbek 1995, 1997; cf. Stevens 1992). Various nonexclusive hypotheses have been put forward to explain this phenomenon, including the coincidence of midelevation sites with regions of either intermediate (Rosenzweig 1995) or maximum (Janzen et al. 1976) productivity, coupled with the respective assumptions that species richness bears a unimodal or monotonic relationship to productivity. It has also been argued that topographical constraints such as bounded ranges (Colwell and Hurtt 1994) and narrower

midelevation zone widths (Rahbek 1997) produce greater overlap of faunas at midelevation (see also Fisher 1998). The apparent absence of a midelevation ant diversity peak in temperate regions (Fig. 8.3b; see also Cole 1940:11; Gregg 1963:201) argues against a unifying explanation for elevational gradients in ant diversity or suggests that patterns of covariation between elevation and other environmental variables differ between temperate and tropical areas.

Regional Differences in Taxonomic Diversity of Leaf Litter Ants

The mean numbers of ant species, genera, subfamilies, and individual workers, per Winkler sample, are given in Table 8.5 for the different biogeographic regions. All of these variables show significant regional heterogeneity (ANOVA, $P = 0.000$, for all four comparisons). This is due largely to the relatively low ant diversity and abundance in the Nearctic region,

however, and an analysis of covariance of sample species richness, with region as the grouping variable and latitude and altitude as covariates, reveals no significant effect of biogeographic region ($P = 0.448$; Table 8.6). Thus in this study no intrinsic differences between regions in species-level alpha diversity were detected, other than those that could be attributed to differences in latitude and altitude. By contrast, a comparable analysis of covariance of genus richness shows significant regional variation ($P = 0.007$; Table 8.7), independent of latitude and altitude. Relatively low genus-level alpha diversity occurs not only in the Nearctic region, where it is expected on the basis of high latitudes, but also in samples from the Malagasy region.

The finding that sites in the Malagasy region are depauperate in ant genera but have levels of species richness comparable to other regions of the same latitude and altitude suggests the existence of a climatically influenced asymptote to local species richness, which can be achieved even in an island fauna with a limited

Table 8.5 Data on Winkler Samples from Different Biogeographic Regions^a

Region	Species	Genera	Subfamilies	Workers
Nearctic (n = 23)	4.1 ± 3.3 (0–14)	3.5 ± 2.4 (0–9)	1.87 ± 1.01 (0–4)	36.5 ± 53.5 (0–245)
Neotropical (n = 49)	26.8 ± 17.3 (0–75)	13.5 ± 6.1 (0–27)	2.90 ± 0.85 (0–4)	385.6 ± 360.8 (0–1632)
Malagasy (n = 19)	19.8 ± 9.0 (6–40)	8.8 ± 2.4 (4–13)	3.05 ± 0.52 (2–4)	305.7 ± 263.1 (30–1162)
Indo-Australian (n = 19)	23.4 ± 13.5 (5–56)	13.8 ± 5.5 (4–25)	3.32 ± 0.75 (2–5)	231.7 ± 145.5 (65–588)
ANOVA (n = 110)	F = 15.062 <i>P</i> = 0.000	F = 25.050 <i>P</i> = 0.000	F = 13.032 <i>P</i> = 0.000	F = 8.721 <i>P</i> = 0.000
ANOVA, excluding Nearctic (n = 87)	F = 1.538 <i>P</i> = 0.221	F = 5.720 <i>P</i> = 0.005	F = 2.044 <i>P</i> = 0.136	F = 1.836 <i>P</i> = 0.166

^aMeans, standard deviations, and ranges of the numbers of species, genera, subfamilies, and individual workers are given.

Table 8.6 Analysis of Covariance of Sample Species Richness^a

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-ratio	P
Region	368.169	3	122.723	0.892	0.448
Latitude	1,910.767	1	1,910.767	13.890	0.000
Altitude	2,676.789	1	2,676.789	19.458	0.000
Error	14,306.663	104	137.564		

^aGrouping variable is biogeographic region; covariates are latitude and altitude. Multiple $R^2 = 0.48$, $n = 110$.

source pool, given sufficient time for autochthonous speciation.

Subfamilies

There are significant differences among biogeographic realms in the prevalence of different ant subfamilies (Tables 8.8–8.10). The relative scarcity of the Cerapachyinae in the New World is reflected in their absence from the Nearctic and Neotropical litter samples. They are present in 10% and 16% of Malagasy and Indo-Australian litter collections, respectively. Conversely, army ants of the subfamily Ecitoninae, absent from the Old World, are found in 4% of Nearctic samples and 10% of Neotropical samples. Old World army ants (Aenictinae and Dorylinae) were not

recovered from the leaf litter samples that were taken during this survey, although they were observed at some of the Indo-Australian localities.

Ponerinae are most frequent in the Indo-Australian region (making up about one-third of the species in Winkler samples and present in 100% of samples), poorly represented in the Nearctic samples (3.9% of species, on average, per sample; present in 22% of samples), and of intermediate occurrence in the Neotropical and Malagasy regions (Tables 8.8 and 8.10). The subfamily Formicinae, although present in a higher percentage of tropical than temperate (Nearctic) samples (Table 8.8), shows a greater proportional representation of species in the Nearctic sites (Table 8.10).

Table 8.7 Analysis of Covariance of Sample Genus Richness^a

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-ratio	P
Region	211.199	3	70.40	4.236	0.007
Latitude	295.267	1	295.267	17.766	0.000
Altitude	470.126	1	470.126	28.287	0.000
Error	1728.465	104	16.620		

^aGrouping variable is biogeographic region; covariates are latitude and altitude. Multiple $R^2 = 0.61$, $n = 110$.

Table 8.8 Percentage of Winkler Samples in Which One or More Species of a Given Subfamily Were Present

Subfamily	Nearctic	Neo-tropical	Malagasy	Indo-Australian
Cerapachyinae	0.0	0.0	10.5	15.8
Dolichoderinae	8.7	12.2	5.3	26.3
Ectoninae	4.4	10.2	0.0	0.0
Formicinae	65.2	75.5	89.5	89.5
Myrmicinae	87.0	98.0	100.0	100.0
Ponerinae	21.7	93.9	100.0	100.0

Table 8.9 Mean Number of Species per Subfamily per Winkler Sample

Subfamily	Nearctic	Neo-tropical	Malagasy	Indo-Australian
Cerapachyinae	0.00	0.00	0.11	0.16
Dolichoderinae	0.09	0.12	0.05	0.32
Ectoninae	0.04	0.12	0.00	0.00
Formicinae	0.91	2.06	1.84	2.21
Myrmicinae	2.83	18.22	12.63	13.11
Ponerinae	0.26	6.27	5.16	7.63
All sub-families	4.13	26.80	19.79	23.47

The mean proportions of species, per sample, belonging to a given subfamily vary significantly among regions for the Cerapachyinae, Formicinae, Myrmicinae, and Ponerinae (Kruskal-Wallis tests, $P = 0.017, 0.011, 0.000$, and 0.000 , respectively; Table 8.10). These differences are sustained even if one excludes the Nearctic region. Thus even on the coarse scale of ant subfamilies there is significant regional heterogeneity in taxonomic composition. This finding cautions against the use of “indicator taxa” (i.e., the use of a small subset of tribes or subfami-

lies) when making interregional comparisons of leaf litter ant communities.

Genera

For the analysis of genus-level differences in faunal composition among leaf litter ant assemblages I have used a finer subdivision of biogeographic regions. The 2 “standard” Winkler samples from Singapore and Malaysia have been combined with the 11 additional leaf litter samples from Pasoh Forest, Malaysia (collected by A. Malsch), to provide an assessment of the

Table 8.10 Mean Proportion of Species per Subfamily per Winkler Sample^a

Subfamily	Nearctic	Neotropical	Malagasy	Indo-Australian	P^b
Cerapachyinae	0.000	0.000	0.003	0.007	0.017
Dolichoderinae	0.012	0.006	0.003	0.018	ns
Ectoninae	0.003	0.005	0.000	0.000	ns
Formicinae	0.278	0.066	0.102	0.112	0.011
Myrmicinae	0.667	0.695	0.624	0.520	0.000
Ponerinae	0.039	0.228	0.268	0.343	0.000

^aTwo samples (one Nearctic and one Neotropical) that yielded no ants are excluded.

^bKruskal-Wallis test. ns, Not significant.

Table 8.11 Most Frequent Genera in Each Biogeographic Region^a

Neotropical (n = 49)		Nearctic (n = 23)		Australian (n = 17)		Oriental (n = 13)		Malagasy (n = 19)	
<i>Solenopsis</i>	91.8	<i>Stenamma</i>	69.6	<i>Hypoponera</i>	100.0	<i>Strumigenys</i>	100.0	<i>Hypoponera</i>	100.0
<i>Pheidole</i>	89.8	<i>Leptothorax</i>	56.5	<i>Pheidole</i>	94.1	<i>Tetramorium</i>	100.0	<i>Pheidole</i>	100.0
<i>Hypoponera</i>	83.7	<i>Lasius</i>	43.5	<i>Strumigenys</i>	94.1	<i>Monomorium</i>	92.3	<i>Strumigenys</i>	89.5
<i>Strumigenys</i>	79.6	<i>Aphaenogaster</i>	30.4	<i>Solenopsis</i>	76.5	<i>Oligomyrmex</i>	92.3	<i>Tetramorium</i>	89.5
<i>Cyphomyrmex</i>	67.3			<i>Oligomyrmex</i>	70.6	<i>Odontoponera</i>	84.6	<i>Monomorium</i>	84.2
<i>Paratrechina</i>	61.2			<i>Paratrechina</i>	70.6	<i>Pheidole</i>	84.6	<i>Paratrechina</i>	78.9
<i>Pachycondyla</i>	57.1			<i>Ponera</i>	58.8	<i>Myrmecina</i>	76.9	<i>Oligomyrmex</i>	57.9
<i>Wasmannia</i>	55.1			<i>Monomorium</i>	52.9	<i>Odontomachus</i>	69.2	<i>Pachycondyla</i>	57.9
<i>Rogeria</i>	53.1			<i>Rhytidoponera</i>	52.9	<i>Hypoponera</i>	61.5	<i>Anochetus</i>	36.8
<i>Gnamptogenys</i>	51.0			<i>Tetramorium</i>	47.1	<i>Lophomyrmex</i>	53.8	<i>Prionopelta</i>	31.6
<i>Brachymyrmex</i>	49.0			<i>Heteroponera</i>	41.2	<i>Vollenhovia</i>	46.2		
<i>Octostruma</i>	44.9			<i>Pachycondyla</i>	41.2	<i>Cerapachys</i>	38.5		
<i>Anochetus</i>	40.8			<i>Myrmecina</i>	35.3	<i>Crematogaster</i>	38.5		
<i>Oligomyrmex</i>	36.7			<i>Acropyga</i>	29.4	<i>Pachycondyla</i>	38.5		
<i>Neostruma</i>	34.7			<i>Cryptopone</i>	29.4	<i>Pristomyrmex</i>	38.5		
<i>Crematogaster</i>	32.7			<i>Lordomyrma</i>	29.4	<i>Pseudolasius</i>	38.5		
<i>Odontomachus</i>	30.6			<i>Prionopelta</i>	29.4	<i>Anochetus</i>	30.8		
<i>Smithistruma</i>	30.6			<i>Pristomyrmex</i>	29.4	<i>Cryptopone</i>	30.8		
<i>Adelomyrmex</i>	26.5			<i>Prolasius</i>	29.4	<i>Myrmoterias</i>	30.8		
						<i>Pheidolegeton</i>	30.8		
						<i>Rostromyrmex</i>	30.8		
						<i>Smithistruma</i>	30.8		
						<i>Solenopsis</i>	30.8		

^aGenera are those present in 25% or more of Winkler samples in each biogeographic region. Figures refer to the percentage of Winkler samples in which a given genus was represented. n, Number of samples.

Oriental region. The 17 remaining Indo-Australian samples, from Australia and Papua New Guinea, can be considered representative of the Australian biogeographic region.

Table 8.11 summarizes the distribution and prevalence of the most common leaf litter ant genera in the five biogeographic regions considered here; the full data set is given in Table 8.12. A few genera, including *Hypoponera*, *Pachycondyla*, *Pheidole*, and *Strumigenys*, are predominant in all four tropical realms. For most other genera, however, there are striking regional differences in the frequency of occurrence. Here I focus on the most frequently encountered ant genera. Rare ant taxa, including those endemic to a region or otherwise of biogeographic inter-

est (e.g., *Kyidris*, *Mystrium*, *Perissomyrmex*), are largely ignored since they appear to contribute in only a minor way to the composition of the leaf litter community.

The Nearctic region stands out as distinctly different from the others and low in genus-level diversity. The most frequent genera in the leaf litter samples are, in decreasing order of importance, *Stenamma*, *Leptothorax*, *Lasius*, *Aphaenogaster*, *Hypoponera*, *Solenopsis*, *Prenolepis*, *Formica*, and *Myrmecina*. *Stenamma* has a primarily Holarctic distribution, being absent from the Old World tropics and of sharply diminished importance at Neotropical sites with increasing distance from the Nearctic region. The same is true of most other Nearctic

leaf litter ants; *Hypoponera* and *Solenopsis* are obvious exceptions.

The Neotropical samples reveal a generic diversity comparable to that of the Oriental and Australian regions. Common leaf litter genera that are largely or entirely confined to the Neotropics include *Adelomyrmex*, *Brachymyrmex*, *Neostruma*, *Octostruma*, *Rogeria*, *Wasmannia*, and all the attine genera (of which *Cyphomyrmex* appears most frequently in Winkler samples). *Solenopsis*, represented mostly by small to minute species, reaches its zenith in the New World tropics. Despite its morphological homogeneity, Neotropical *Solenopsis* is species rich (mean number of species per Winkler sample: 3.14; range: 0–9; mean proportion of species per sample: 0.12) and undoubtedly of considerable ecological importance. In mean species richness per sample it is exceeded in the Neotropics only by *Pheidole* (mean: 5.45 species; range: 0–16; mean proportion of species per sample: 0.19). Another distinctive hallmark of the New World leaf litter fauna is the virtual absence of species of *Monomorium* and *Tetramorium*.

The wet forests of the Australian region are characterized by high frequencies of *Cryptopone*, *Discothyrea*, *Heteroponera*, *Ponera*, and *Rhytidoponera*, ponerine genera that tend to be uncommon or absent elsewhere. Other distinctive and common elements include the myrmicine genera *Lordomyrma*, *Myrmecina*, *Pristomyrmex*, and *Tetramorium*, and the endemic formicine genus *Prolasius*. The solenopsidine genera *Monomorium*, *Oligomyrmex*, and *Solenopsis* are also prevalent leaf litter ants in this region.

The Oriental samples are from a geographically restricted area in peninsular Malaysia and Singapore. Insofar as they are representative of the Oriental region as a whole, they indicate a leaf litter ant fauna with a distinctive complexion. Some genera are prominent both here and in the Australian region (*Cryptopone*, *Monomorium*, *Myrmecina*, *Oligomyrmex*, *Pristomyrmex*, *Tetramorium*), but others are more com-

mon in, and in some instances unique to, the Oriental region: *Acanthomyrmex*, *Lophomyrmex*, *Myrmoteras*, *Odontoponera*, *Pheidologeton*, *Pseudolasius*, *Rostromyrmex*, and *Vollenhovia*. The genus *Cerapachys* also appears in a high percentage of the Oriental leaf litter samples; more extensive geographic sampling is needed to confirm the generality of this result.

Barry Bolton (pers. comm.) has recently analyzed a larger set of leaf litter ant samples from Pasoh Forest, Malaysia, with results that are consistent with the foregoing generalizations, although *Cerapachys* shows lesser prominence.

The Malagasy region is depauperate in genera, as befits an island fauna, but species-rich in certain groups, such as *Hypoponera*, *Monomorium*, *Pheidole*, and *Tetramorium*. The genus *Solenopsis*, a very significant component of litter and soil faunas in the Australian and Neotropical regions, is completely lacking in Madagascar, its presence in the Malagasy samples being due to a single Mauritian species. In Madagascar the ecological counterparts of the small species of *Solenopsis* appear to be drawn from the genus *Monomorium*. Another significant absence from Madagascar and adjacent islands is that of Old World army ants (Aenictinae, Dorylinae), with the possible consequence that there is a relatively rich cerapachyne ant fauna (Fisher 1997).

Winkler leaf litter samples, collected using the same methods as previously described, are unavailable from the Ethiopian region (mainland Africa), but Belshaw and Bolton's (1994a) detailed census of the leaf litter ant fauna in Ghana provides useful and approximately comparable information. In that study the most widespread and species-rich genera included *Tetramorium* (27 species), *Monomorium* (16 species), *Oligomyrmex* (12 species), *Smithistruma* (12 species), *Pheidole* (11 species), *Pachycondyla* (8 species), *Strumigenys* (7 species), *Anochetus* (6 species), *Hypoponera* (6 species), and *Technomyrmex* (5 species).

Table 8.12 Distribution and Prevalence of Leaf Litter Ant Genera in Different Biogeographic Regions

Genus	Nearctic			Neotropical			Madagascar			Australian			Oriental		
	Percentage	No. spp.	Percentage	No. spp.	Percentage	No. spp.	Percentage	No. spp.	Percentage	No. spp.	Percentage	No. spp.	Percentage	No. spp.	Percentage
<i>Acanthognathus</i>	—	—	2.04	0.02	—	—	—	—	—	—	—	—	—	—	—
<i>Acanthomyrmex</i>	—	—	—	—	2.04	0.02	—	—	—	—	—	—	23.08	0.23	—
<i>Acromyrmex</i>	—	—	—	—	20.41	0.24	5.26	0.05	—	—	—	—	—	—	—
<i>Acropyga</i>	—	—	—	—	26.53	0.47	—	—	29.41	0.41	7.69	0.23	—	—	—
<i>Adelomyrmex</i>	—	—	—	—	—	—	10.53	0.11	17.65	0.18	—	—	—	—	—
<i>Amblyopone</i>	—	—	—	—	40.82	0.45	36.84	0.58	5.88	0.06	—	—	7.69	0.08	—
<i>Anochetus</i>	—	—	—	—	—	—	—	—	17.65	0.18	—	—	30.77	0.31	—
<i>Anochetomyrma</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Anoplolepis</i>	—	—	—	—	—	—	—	—	—	—	—	—	15.38	0.15	—
<i>Aphaenogaster</i>	30.43	0.30	8.16	0.08	—	—	—	—	5.88	0.06	—	—	—	—	—
<i>Apierostigma</i>	—	—	22.45	0.27	—	—	—	—	—	—	—	—	—	—	—
<i>Azteca</i>	—	—	2.04	0.02	—	—	—	—	—	—	—	—	—	—	—
<i>Basisceros</i>	—	—	6.12	0.08	—	—	—	—	—	—	—	—	—	—	—
<i>Belonopelta</i>	—	—	2.04	0.02	—	—	—	—	—	—	—	—	—	—	—
<i>Brachymyrmex</i>	8.70	0.09	48.98	0.82	10.53	0.11	—	—	—	—	—	—	—	—	—
<i>Camponotus</i>	4.35	0.04	6.12	0.06	10.53	0.11	—	—	—	—	—	—	15.38	0.15	—
<i>Cardiocondyla</i>	—	—	—	—	—	—	—	—	—	—	—	—	23.08	0.23	—
<i>Cerapachys</i>	—	—	—	—	—	—	10.53	0.11	5.88	0.06	—	—	38.46	0.46	—
<i>Colobostruma</i>	—	—	—	—	—	—	—	—	17.65	0.18	—	—	—	—	—
<i>Crematogaster</i>	8.70	0.09	32.65	0.53	5.26	0.05	17.65	0.24	—	—	38.46	0.38	—	—	—
<i>Cryptopone</i>	—	—	10.20	0.10	—	—	—	—	29.41	0.59	—	—	30.77	0.31	—
<i>Cyphomyrmex</i>	—	—	67.35	1.04	—	—	—	—	—	—	—	—	—	—	—
Dacetini gen. indet.	—	—	2.04	0.02	—	—	—	—	—	—	—	—	—	—	—
<i>Dacetinops</i>	—	—	—	—	—	—	—	—	5.88	0.06	—	—	—	—	—
<i>Discothyrea</i>	—	—	20.41	0.20	—	—	—	—	23.53	0.29	—	—	15.38	0.15	—
<i>Dolichoderus</i>	—	—	2.04	0.02	—	—	—	—	—	—	—	—	—	—	—
<i>Echinopla</i>	—	—	2.04	0.02	—	—	—	—	—	—	—	—	7.69	0.08	—
<i>Ecitonoma</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

<i>Formica</i>	13.04	0.13	—	—	—	—	—	—	—	—	—	—
Gen. nov.	—	—	—	—	—	—	—	—	—	—	—	—
(Madagascar)												
<i>Glamyrmex</i>	—	—	6.12	0.06	—	—	—	—	—	15.38	0.31	—
<i>Gnamptogenys</i>	—	—	51.02	0.80	—	—	—	—	—	—	—	—
<i>Gynatormyrmex</i>	—	—	2.04	0.02	—	—	—	—	—	—	—	—
<i>Heteroponera</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Hylomyrma</i>	—	—	18.37	0.20	—	—	—	—	—	—	—	—
<i>Hypoponera</i>	17.39	0.17	83.67	2.73	100.00	2.95	—	—	—	61.54	0.85	—
<i>Knidris</i>	—	—	—	—	15.79	0.16	—	—	—	7.69	0.08	—
<i>Lobidus</i>	4.35	0.04	8.16	0.08	—	—	—	—	—	—	—	—
<i>Lachnomyrmex</i>	—	—	8.16	0.08	—	—	—	—	—	—	—	—
<i>Lasius</i>	43.48	0.48	—	—	—	—	—	—	—	—	—	—
<i>Lenomyrmex</i>	—	—	2.04	0.02	—	—	—	—	—	—	—	—
<i>Leptogenys</i>	—	—	2.04	0.02	15.79	0.16	5.88	0.06	7.69	0.08	—	—
<i>Leptocephalus</i>	56.52	0.61	2.04	0.02	—	—	—	—	—	—	—	—
<i>Linepithema</i>	—	—	8.16	0.08	—	—	—	—	—	—	—	—
<i>Liomyrmex</i>	—	—	—	—	—	—	5.88	0.06	—	53.85	0.54	—
<i>Lophomyrmex</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Lordomyrma</i>	—	—	—	—	—	—	29.41	0.41	—	—	—	—
<i>Mayriella</i>	—	—	—	—	—	—	11.76	0.12	7.69	0.08	—	—
<i>Megalomyrmex</i>	—	—	6.12	0.06	—	—	—	—	—	—	—	—
<i>Meranoplus</i>	—	—	—	—	—	—	84.21	2.11	5.88	0.06	15.38	0.15
<i>Monomorium</i>	4.35	0.04	—	4.08	0.04	—	52.94	0.82	—	92.31	1.77	—
<i>Mycoceptrus</i>	—	—	—	—	—	—	—	—	17.65	0.24	—	—
<i>Myopias</i>	—	—	—	—	—	—	—	—	5.88	0.06	—	—
<i>Myoponera</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Myrmecina</i>	13.04	0.13	2.04	0.02	—	—	35.29	0.41	—	76.92	1.00	—
<i>Myrmicocrypta</i>	—	—	20.41	0.22	—	—	—	—	—	—	—	—
<i>Myrmoteras</i>	—	—	—	—	—	5.26	0.05	5.88	0.06	30.77	0.31	—
<i>Mystrium</i>	—	—	—	—	—	—	—	—	—	—	—	—
<i>Nevamyrmex</i>	—	—	4.08	0.04	—	—	—	—	—	—	—	—
<i>Neostreuma</i>	—	—	34.69	0.37	—	—	—	—	—	11.76	0.12	—
<i>Nothoncus</i>	—	—	10.20	0.10	—	—	—	—	—	—	—	—
<i>Ochetomyrmex</i>	—	—	—	—	—	—	—	—	—	—	—	—

Continued on next page

Table 8.12 continued

Genus	Nearctic		Neotropical		Madagascar		Australian		Oriental	
	Percentage	No. spp.	Percentage	No. spp.	Percentage	No. spp.	Percentage	No. spp.	Percentage	No. spp.
<i>Ocstrosoma</i>	—	—	44.90	0.61	—	—	—	—	—	—
<i>Odontomachus</i>	—	—	30.61	0.33	—	—	11.76	0.12	69.23	0.69
<i>Odontoponera</i>	—	—	—	—	—	—	—	—	84.62	0.85
<i>Oligomyrmex</i>	—	—	36.73	0.51	57.89	0.68	70.59	1.35	92.31	1.54
<i>Orectognathus</i>	—	—	—	—	—	—	11.76	0.12	—	—
<i>Oxyepoecus</i>	—	—	2.04	0.02	—	—	—	—	—	—
<i>Pachycondyla</i>	4.35	0.04	57.14	0.94	57.89	0.74	41.18	0.82	38.46	0.54
<i>Paratrechina</i>	4.35	0.04	61.22	0.94	78.95	1.47	70.59	0.88	15.38	0.31
<i>Perissomyrmex</i>	—	—	2.04	0.02	—	—	—	—	—	—
<i>Pheidole</i>	8.70	0.30	89.80	5.45	100.00	4.21	94.12	3.41	84.62	2.23
<i>Pheidoloegeton</i>	—	—	—	—	—	—	5.88	0.06	30.77	0.31
<i>Plagiolepis</i>	—	—	—	—	10.53	0.11	—	—	—	—
<i>Polyrhachis</i>	—	—	—	—	—	—	5.88	0.06	15.38	0.15
<i>Ponera</i>	4.35	0.04	2.04	0.02	5.26	0.05	58.82	0.88	15.38	0.23
<i>Prenolepis</i>	13.04	0.13	—	—	—	—	—	—	—	—
<i>Prionopelta</i>	—	—	24.49	0.35	31.58	0.47	29.41	0.29	—	—
<i>Pristomyrmex</i>	—	—	—	—	—	—	29.41	0.41	38.46	0.38
<i>Probolomyrmex</i>	—	—	—	—	—	—	—	—	7.69	0.08
<i>Proceratium</i>	—	—	10.20	0.10	5.26	0.05	5.88	0.06	—	—
<i>Prolasius</i>	—	—	—	—	—	—	29.41	0.41	—	—
<i>Protalaridris</i>	—	—	2.04	0.02	—	—	—	—	—	—
<i>Pseudolasius</i>	—	—	—	—	—	—	17.65	0.18	38.46	0.38
<i>Rhopalothrix</i>	—	—	2.04	0.02	—	—	—	—	—	—
<i>Rhytidoponera</i>	—	—	—	—	—	—	52.94	0.71	—	—
<i>Rogeria</i>	8.70	0.09	53.06	0.94	—	—	11.76	0.12	—	—
<i>Rostromyrmex</i>	—	—	—	—	—	—	—	—	30.77	0.31
<i>Sericomyrmex</i>	—	—	10.20	0.14	—	—	—	—	—	—
<i>Serrastruma</i>	—	—	—	—	10.53	0.11	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—

<i>Solenopsis</i>	17.39	0.22	91.84	3.14	5.26	0.05	76.47	1.06	30.77	0.31
<i>Sphinctomyrmex</i>	—	—	—	—	—	—	—	11.76	0.12	—
<i>Stegomyrmex</i>	—	—	2.04	0.02	—	—	—	—	—	—
<i>Stenamma</i>	69.57	1.00	22.45	0.57	—	—	—	—	—	—
<i>Stigmacros</i>	—	—	—	—	—	—	5.88	0.06	—	—
<i>Strumigenys</i>	4.35	0.04	79.59	1.82	89.47	1.84	94.12	2.53	100.00	2.46
<i>Tapinoma</i>	8.70	0.09	—	—	—	—	—	11.76	0.12	—
<i>Tauhidris</i>	—	—	4.08	0.04	—	—	—	—	—	—
<i>Technomyrmex</i>	—	—	—	—	5.26	0.05	5.88	0.06	23.08	0.23
<i>Tetramorium</i>	—	—	2.04	0.02	89.47	3.11	47.06	0.76	100.00	2.54
<i>Thaumatomyrmex</i>	—	—	2.04	0.02	—	—	—	—	—	—
<i>Trachymyrmex</i>	—	—	10.20	0.10	—	—	—	—	—	—
<i>Typhlomyrmex</i>	—	—	10.20	0.16	—	—	—	—	—	—
<i>Vollenhovia</i>	—	—	—	—	—	—	17.65	0.18	46.15	0.54
<i>Wasmannia</i>	—	—	55.10	0.57	—	—	—	—	—	—
Total no. samples	23	49	49	19	19	17	17	13	13	13

^aValues are based on the Winkler leaf litter survey discussed in this chapter. "Percentage" is percentage of samples occupied, with values greater than 25% in boldface. "No. spp." is mean number of species per sample.

Leaf Litter Ant Diversity and Composition: Ecological Trends

Thus far we have considered differences in ant diversity and faunal composition without reference to the ecological roles of the constituent taxa. In fact, for leaf litter ants, which are mostly small in size and cryptic in habits, this is largely terra incognita. There does appear to be substantial variation in functional roles, from host-specific predators (e.g., Cerapachyinae, some Ponerinae, and myrmicine tribes such as Basicerotini, Dacetonini, and Myrmecinini) to generalist predators (many Ponerinae), seed harvesters (some *Pheidole* and *Acanthomyrmex*), and omnivores or scavengers (many myrmicinae and formicinae). For many regionally prominent leaf litter ants (e.g., species of *Brachymyrmex*, *Rogeria*, *Stenamma*, *Tetramorium*, *Vollenhovia*) and even members of such cosmopolitan genera as *Oligomyrmex* and *Pheidole*, we know little about their feeding habits and ecological effects. It may be possible to assign a functional group label of "cryptic species" or "tropical climate specialist" to such leaf litter ants (cf. Andersen 1995), but this reveals little about their biology.

Some ecological variation in leaf litter ant communities appears to have a strong geographical component. For example, the relative prevalence of species of Ponerinae, a group of mostly predaceous ants, is strongly negatively correlated with latitude ($r = -0.698$, $P = 0.000$; proportions arcsine-transformed) (Fig. 8.4). Ponerine species are also overrepresented in leaf litter samples from the Indo-Australian region compared to other tropical continents, as noted previously. Other ecologically well-defined ant taxa (e.g., leaf litter species of the fungus-growing tribe Attini; army ants of the subfamily Ecitoninae; mite-catching *Myrmecina*; some of the collembolan-hunting dacetine genera) also have geographically restricted distributions. All of this hints at complex geo-

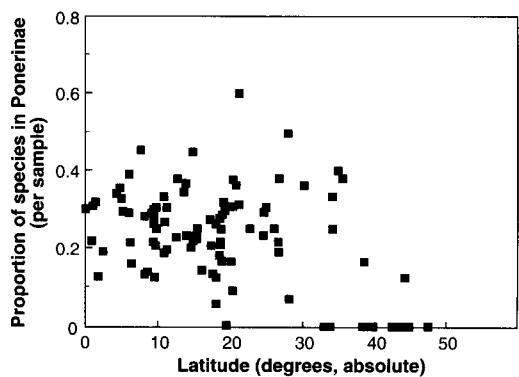


Figure 8.4. Proportion of ant species in a sample belonging to the subfamily Ponerinae as a function of latitude.

graphical variation in leaf litter community structure that we have hardly begun to investigate.

Latitudinal gradients have been reported in ant worker body size (Cushman et al. 1993) and in ant colony size (Kaspari and Vargo 1995). These studies were not specifically concerned with the leaf litter habitat, but many of the ant species from which data were taken, especially in the colony size study, are leaf litter inhabitants. In both studies the authors favored the hypothesis that abiotic factors select for larger body or colony sizes at higher latitudes, as a buffer against starvation. It would be interesting to have comparable data for elevation gradients.

Caveats and Concluding Remarks

This study is an attempt to characterize large-scale geographical variation in ant leaf litter communities. The analysis is based primarily on a series of Winkler litter samples, and the results should be considered provisional. The samples cover a broad but by no means comprehensive set of geographical locations. All samples in this study come from moist leaf litter in woodland and forest habitats. Xeric environments, to which the Winkler method is poorly suited, have been largely ignored (only 6 of the

110 Winkler samples are from sites that could be characterized as tropical dry forest). Questions can also be raised about the appropriateness of the Winkler method for exhaustive sampling of the leaf litter ant fauna, although this procedure appears to work better than any other single method (Olson 1991; Fisher 1996a, 1998). Some taxa are nevertheless under-sampled, especially the “army ant” groups (Aenictinae, Dorylinae, Ecitoninae). These ants are nomadic and hence episodic in their occurrence at any given site. Yet there is evidence that they have a potent impact on the leaf litter ant fauna (Franks and Bossert 1983; Gotwald 1995).

Habitat-based differences in ant abundance and diversity (independent of biogeographic region) certainly exist but have not been explored in detail here. Future studies focusing on the effects of habitat on the diversity and composition of leaf litter ant communities would benefit from the adoption of a standard classification of forest communities.

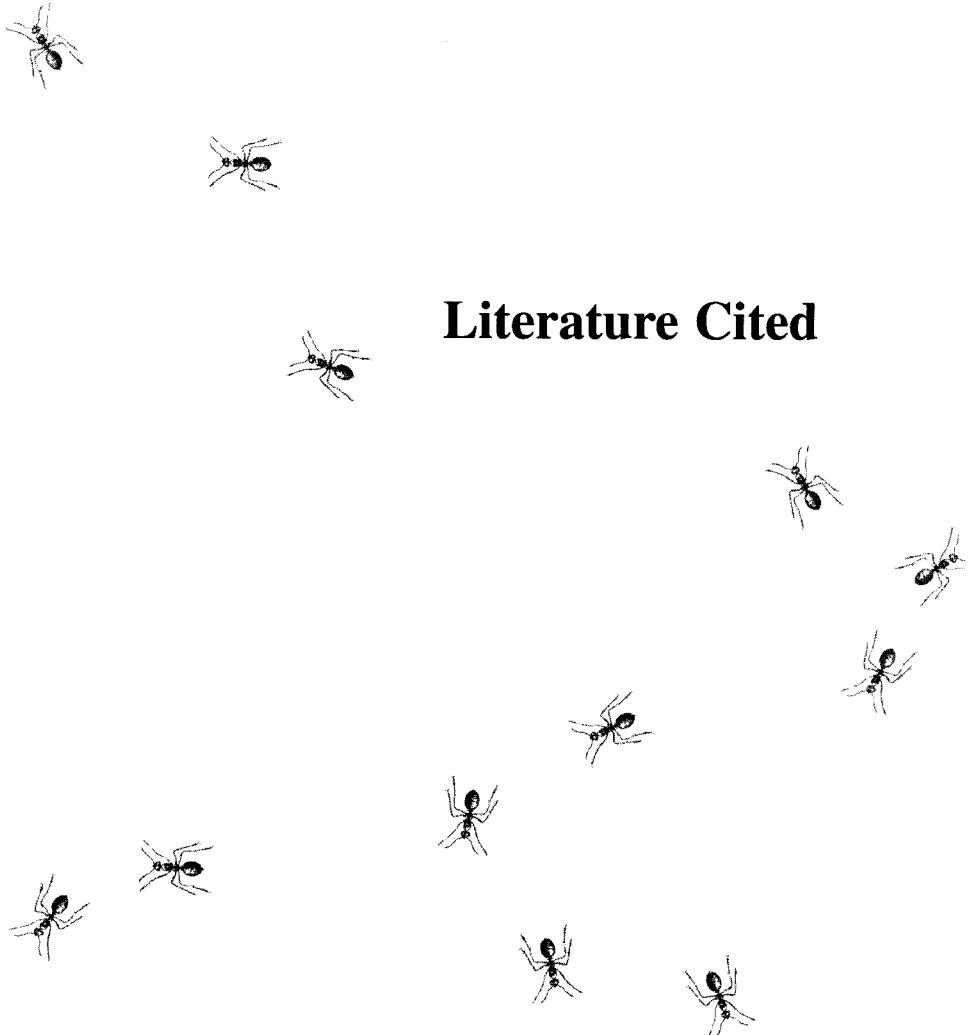
A comprehensive assessment of species turnover (beta diversity) has not been attempted. Knowledge of beta diversity patterns is essential for a better understanding of biological diversity and for intelligent conservation planning, but measurement of species-level beta diversity in groups such as leaf litter ants is frustrated by the “taxonomic impediment” (Taylor 1983) imposed by the lack of high-quality descriptive taxonomy. Many of the most prevalent and species-rich leaf litter ant genera (Tables 8.4 and 8.11) have never had the benefit of a modern taxonomic revision. Three genera alone—*Hypoponera*, *Pheidole*, and *Solenopsis*—constitute, on average, 32% of the species in a given leaf litter sample (this figure increases to 40% for the Neotropics), and all of them are in

a state of taxonomic anarchy. These three genera, and others such as *Pachycondyla* and *Paratrechina*, should be high on the list of priorities for revisionary studies.

Some results of the present study appear to be robust and unaffected by taxonomic constraints. One is the finding of significant heterogeneity in faunal composition at the level of ant genera and subfamilies across major biogeographic regions. This observation argues against the use of subsets of “indicator taxa” to assess overall diversity patterns over large geographical scales. A second finding is that the taxonomic diversity of leaf litter ant communities is strongly affected by latitude and altitude (Figures 8.2 and 8.3), with a general trend toward increasing diversity at lower latitudes and altitudes. In tropical regions, however, species richness appears to reach a maximum at about 500 m and then decline slightly at lower elevations. Finally, whereas species alpha diversity shows no differences among biogeographic regions other than those predicted by variation in latitude and elevation, local genus richness is lower in the insular Malagasy region than in comparable continental areas. This finding implicates historical constraints on genus richness, which nevertheless do not prevent the achievement of climatically characteristic levels of local species richness.

ACKNOWLEDGMENTS

I thank Alan Andersen, Brian Fisher, and Mike Kaspari for valuable discussions; Barry Bolton and Annette Malsch for sharing data; and Donat Agosti for his invitation to participate in the leaf litter ant conference. In addition, I extend my gratitude to the many persons, too numerous to list, who have facilitated my field work on ants in various parts of the world.



Literature Cited

- Abensperg-Traun, M., and D. Steven. 1995. The effects of pitfall trap diameter on ant species richness (Hymenoptera: Formicidae) and species composition of the catch in a semi-arid eucalypt woodland. *Australian Journal of Ecology* 20:282–287.
- _____. 1997. Ant- and termite-feeding in Australian mammals and lizards: A comparison. *Australian Journal of Ecology* 22:9–17.
- Abensperg-Traun, M., G. W. Arnold, D. E. Steven, G. T. Smith, L. Atkins, J. J. Viveen, and M. Gutter. 1996. Biodiversity indicators in semi-arid, agricultural Western Australia. *Pacific Conservation Biology* 2:375–389.
- Adams, E. S. 1994. Territory defense by the ant *Azteca trigona*: Maintenance of an arboreal ant mosaic. *Oecologia* 97:202–208.
- Adams, E., and W. Tschinkel. 1995. Density-dependent competition in fire ants: Effects on colony survivorship and size variation. *Journal of Animal Ecology* 64:315–324.
- Adis, J. 1979. Problems of interpreting arthropod sampling with pitfall traps. *Zoologisher Anzeiger* 202:177–184.
- Adis J., Y. D. Lubin, and G. G. Montgomery. 1984. Arthropods from the canopy of inundated and terra firme forests near Manaus, Brazil, with critical considerations on the pyrethrum-fogging technique. *Studies on Neotropical Fauna and Environment* 4:223–236.
- Adis, J., J. W. de Moraes, and H. Guimarães de Mesquita. 1987. Vertical distribution and abundance of arthropods in the soil of a Neotropical secondary forest during the rainy season. *Studies on Neotropical Fauna and Environment* 22:189–197.
- Agosti, D. 1990. Review and reclassification of *Cataglyphis* (Hymenoptera, Formicidae). *Journal of Natural History* 24:1457–1505.
- _____. 1991. Revision of the oriental ant genus *Cladomyrma*, with an outline of the higher classification of the Formicinae (Hymenoptera:

- Formicidae). *Systematic Entomology* 16:293–310.
- _____. 1992. Revision of the ant genus *Myrmoteras* of the Malay Archipelago (Hymenoptera, Formicidae). *Revue Suisse de Zoologie* 99:405–429.
- _____. 1994a. The phylogeny of the ant tribe Formicinae (Hymenoptera: Formicidae) with the description of a new genus. *Systematic Entomology* 19:93–117.
- _____. 1994b. A revision of the South American species of the ant genus *Probolomyrmex* (Hymenoptera: Formicidae). *Journal of the New York Entomological Society* 102:429–434.
- Agosti, D., J. Majer, L. Alonso, and T. R. Schultz (eds.). 2000. *Sampling Ground-dwelling Ants: Case Studies from the Worlds' Rain Forests*. Curtin University of Technology, Perth, Western Australia.
- Agosti, D., M. Maryati, and C. Y. C. Arthur. 1994. Has the diversity of tropical ant fauna been underestimated? An indication from leaf litter studies in a West Malaysian lowland rain forest. *Tropical Biodiversity* 2:270–275.
- Agosti, D., J. Moog, and U. Maschwitz. 1999. Revision of the Oriental plant-ant genus *Cladomyrma*. *American Museum Novitates* 3283, December 8, 1999.
- Alexander, R. D. 1974. The evolution of social behavior. *Annual Review of Ecology and Systematics* 5:325–383.
- Allen, C., R. Lutz, and S. Demarais. 1995. Red imported fire ant impacts on northern bobwhite populations. *Ecological Applications* 5:632–638.
- Allen, G. E., and W. F. Buren. 1974. Microsporidian and fungal diseases of *Solenopsis invicta* Buren in Brazil. *Journal of the New York Entomological Society* 82:125–130.
- Allen, G. E., and A. Silveira-Guido. 1974. Occurrence of microsporidia in *Solenopsis richteri* and *Solenopsis* sp. in Uruguay and Argentina. *Florida Entomologist* 57:327–329.
- Allen, M. F., J. A. MacMahon, and D. C. Andersen. 1984. Reestablishment of Endogonaceae on Mount St. Helens: Survival of residuals. *Mycologia* 76(6):1031–1038.
- Andersen, A. N. 1983. A brief survey of ants of Glenaladale National Park, with particular reference to seed-harvesting. *Victorian Naturalist* 100:233–237.
- _____. 1986a. Diversity, seasonality and community organization of ants at adjacent heath and woodland sites in southeastern Australia. *Australian Journal of Zoology* 34:53–64.
- _____. 1986b. Patterns of ant community organization in mesic southeastern Australia. *Australian Journal of Ecology* 11:87–99.
- _____. 1988. Immediate and longer-term effects of fire on seed predation by ants in sclerophyllous vegetation of southeastern Australia. *Australian Journal of Ecology* 13:285–293.
- _____. 1990. The use of ant communities to evaluate change in Australian terrestrial ecosystems: A review and a recipe. *Proceedings of the Ecological Society of Australia* 16:347–357.
- _____. 1991a. Parallels between ants and plants: Implications for community ecology. Pp. 539–558. In C. R. Huxley and D. F. Cutler (eds.), *Ant-Plant Interactions*. Oxford University Press, Oxford.
- _____. 1991b. Seed-harvesting by ants in Australia. Pp. 493–503. In C. R. Huxley and D. F. Cutler (eds.), *Ant-Plant Interactions*. Oxford University Press, Oxford.
- _____. 1991c. Sampling communities of ground-foraging ants: Pitfall catches compared with quadrat counts in an Australian tropical savanna. *Australian Journal of Ecology* 16:273–279.
- Andersen, A. N. 1991d. Responses of ground-foraging ant communities to three experimental fire regimes in a savanna forest of tropical Australia. *Biotropica* 23:575–585.
- _____. 1992. The rainforest ant fauna of the northern Kimberley region of Western Australia (Hymenoptera: Formicidae). *Journal of the Australian Entomological Society* 31:187–192.
- _____. 1995. A classification of Australian ant communities, based on functional groups which parallel plant life-forms in relation to stress and disturbance. *Journal of Biogeography* 20:15–29.
- _____. 1996. Fire ecology and management. Pp. 179–195. In C. M. Finlayson and I. Von Oertzen (eds.), *Landscape and Vegetation Ecology of the Kakadu Region, Northern Australia*. Kluwer Academic Publishers, Amsterdam.
- _____. 1997a. Functional groups and patterns of organization in North American ant communities: A comparison with Australia. *Journal of Biogeography* 24:433–460.
- _____. 1997b. Using ants as bioindicators: Multi-scale issues in ant community ecology. *Conservation Ecology* [online] 1, Article 8.
- Andersen, A. N., and R. E. Clay. 1996. The ant fauna of Danggali Conservation park in semi-arid

- South Australia: A comparison with Wyperfield (Vic.) and Cape Arid (W.A.) National Parks. *Australian Journal of Entomology* 35:289–295.
- Andersen, A. N., and J. D. Majer. 1991. The structure and biogeography of rainforest ant communities in the Kimberley region of northwestern Australia. Pp. 333–346. In N. L. McKenzie, R. B. Johnston, and P. J. Kendrick (eds.), *Kimberley Rainforests of Australia*. Surrey Beatty and Sons, Chipping Norton, NSW.
- Andersen, A. N., and M. E. McKaige. 1987. Ant communities at Rotamah Island, Victoria, with particular reference to disturbance and *Rhytidoponera tasmaniensis*. *Proceedings of the Royal Society of Victoria* 99:141–146.
- Andersen, A. N., and A. D. Patel. 1994. Meat ants as dominant members of Australian ant communities: An experimental test of their influence on the foraging success and forager abundance of other species. *Oecologia* 98:15–24.
- Andersen, A. N., and H. Reichel. 1994. The ant (Hymenoptera: Formicidae) fauna of Holmes Jungle, a rainforest patch in the seasonal tropics of Australia's Northern Territory. *Journal of the Australian Entomological Society* 33:153–158.
- Andersen, A. N., and A. V. Spain. 1996. The ant fauna of the Bowen Basin, in the semi-arid tropics of central Queensland (Hymenoptera: Formicidae). *Australian Journal of Entomology* 35:213–221.
- Andersen, A. N., and A. L. Yen. 1985. Immediate effects of fire on ants in the semi-arid mallee region of north-western Victoria. *Australian Journal of Ecology* 10:25–30.
- . 1992. Canopy ant communities in the semi-arid Mallee region of North-western Victoria. *Australian Journal of Zoology* 40:205–214.
- Andersen, A. N., M. S. Blum, and T. M. Jones. 1991. Venom alkaloids in *Monomorium "rothsteini"* Forel repel other ants: Is this the secret to success by *Monomorium* in Australian ant communities? *Oecologia* 88:157–160.
- Andersen, A. N., S. Morrison, and L. Belbin. 1996. The Role of Ants in Minesite Restoration in the Kakadu Region of Australia's Northern Territory, with Particular Reference to Their Use as Bio-indicators. Final Report to the Environmental Research Institute of the Supervising Scientist, Australia.
- Andrade, M. L. de. 1998. Fossil and extant species of *Cylindromyrmex* (Hymenoptera: Formicidae). *Revue Suisse de Zoologie* 105(3):581–664.
- Andrade, M. L. de and C. Baroni Urbani. 1999. Diversity and adaption in the ant genus *Cephalotes*, past and present (Hymenoptera, Formicidae). *Stuttgarter Beiträge zur Naturkunde, Serie B* 271:1–889.
- Andrewartha, H., and L. Birch. 1954. The distribution and abundance of animals. University of Chicago Press, Chicago.
- Arnett, R. H., Jr. 1985. *American Insects*. Van Nostrand Reinhold, New York.
- Arnett, R. H., Jr., and M. E. Arnett. 1990. *The Naturalists Directory and Almanac (International): An Index to Contemporary Naturalists of the World and Their Special Interests*, 45th ed. Sandhill Crane Press, Gainesville, Florida.
- Arnett, R. H., Jr., and G. A. Samuelson. 1986. *The Insect and Spider Collections of the World*. E. J. Brill/Flora and Fauna Publications, Gainesville, Florida.
- Arnett, R. H., Jr., G. A. Samuelson, and G. M. Nishida. 1993. *The Insect and Spider Collections of the World*, 2nd ed. Sandhill Crane Press, Gainesville, Florida.
- Arnoldi, K. V. 1930. Studien über die Systematik der Ameisen. IV. *Aulacopone*, eine neue Ponerinengattung (Formicidae) in Russland. *Zoologischer Anzeiger* 89:139–144.
- . 1970. Review of the ant genus *Myrmica* (Hymenoptera, Formicidae) in the European part of the USSR. *Zoologicheskii Zhurnal* 49:1829–1844. [In Russian.]
- . 1975. A review of the species of the genus *Stenamma* (Hymenoptera, Formicidae) of the USSR and description of new species. *Zoologicheskii Zhurnal* 54:1819–1829. [In Russian.]
- . 1976a. Review of the genus *Aphaenogaster* (Hymenoptera, Formicidae) in the USSR. *Zoologicheskii Zhurnal* 55:1019–1026. [In Russian.]
- . 1976b. Ants of the genus *Myrmica* Latr. from Central Asia and the southern Kazakhstan. *Zoologicheskii Zhurnal* 55:547–558. [In Russian.]
- . 1977. Review of the harvester ants of the genus *Messor* (Hymenoptera, Formicidae) in the fauna of the USSR. *Zoologicheskii Zhurnal* 56:1637–1648. [In Russian.]
- Atsatt, P. R. 1981. Lycaenid butterflies and ants: Selection for enemy-free space. *American Naturalist* 118:538–654.
- Autuori, M. 1942. Contribuição para o conhecimento da saúva (*Atta* spp. Hymenoptera: Formicidae).

- III. Excavação de um saúveiro (*Atta sexdens rubropilosa* Forel, 1908). *Archivos do Instituto de Biolóico*, São Paulo 13:137–148.
- Bailey, I. W. 1920. Some relations between ants and fungi. *Ecology* 1:174–189.
- _____. 1922a. Notes on neotropical ant-plants. I. *Cecropia angulata*, sp. nov. *Botanical Gazette* 74:369–391.
- _____. 1922b. The anatomy of certain plants from the Belgian Congo, with special reference to Myrmecophytism. *Bulletin of the American Museum of Natural History* 45:585–622, plates 26–45.
- Balazy, S., A. Lenoir, and J. Wisniewski. 1986. *Aegeritella rousillonensis* n. sp. (Hymomycetales, Blastosporae), une espèce nouvelle de champignon épizoïque sur les fourmis *Cataglyphis cursor* (Fonscolombe) (Hymenoptera, Formicidae) en France. *Cryptogamie, Mycologie* 7:37–45.
- Banschbach, V. S., and J. M. Herbers. 1996. Complex colony structure in social insects. I. Ecological determinants and genetic consequences. *Evolution* 50:285–297.
- Baroni Urbani, C. 1968. Über die eigenartige Morphologie der männlichen Genitalien des Genus *Diplorhoptrum* Mayr und die taxonomischen Schlussfolgerungen. *Zeitschrift für Morphologie der Tiere* 63:63–74.
- Baroni Urbani, C. 1969. Gli *Strongylognathus* del gruppo *huberi* nell'Europa occidentale: Saggio di una revisione basata sulla casta operaia (Hymenoptera Formicidae). *Bollettino de la Società Entomologica Italiana* 99–101:132–168.
- _____. 1975a. Primi reperti del genere *Calyptomyrmex* Emery nel subcontinente Indiano. *Entomologica Basiliensis* 1:395–411.
- _____. 1975b. Contributo alla conoscenza dei generi *Belonopelta* Mayr e *Leiopelta* gen. n. (Hymenoptera: Formicidae). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 48:295–310.
- _____. 1977. Ergebnisse der Bhutan-Expedition 1972 des Naturhistorischen Museums in Basel. Hymenoptera: Fam. Formicidae Genus *Mayriella*. *Entomologica Basiliensis* 2:411–414.
- _____. 1978a. Contributo alla conoscenza del genere *Amblyopone* Erichson (Hymenoptera: Formicidae). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 51:39–51.
- _____. 1978b. Materiali per una revisione dei *Leptocephalus* neotropicali appartenenti al sotto-genere *Macromischa* Roger, n. comb. (Hymenoptera: Formicidae). *Entomologica Basiliensis* 3:395–618.
- Baroni Urbani, C., and M. L. De Andrade. 1993. *Perissomyrmex monticola* n. sp., from Bhutan: The first natural record for a presumed Neotropical genus with a discussion on its taxonomic status. *Tropical Zoology* 6:89–95.
- Baroni Urbani, C., B. Bolton, and P. S. Ward. 1992. The internal phylogeny of ants (Hymenoptera: Formicidae). *Systematic Entomology* 17:301–329.
- Barrer, P. M., and J. M. Cherrett. 1972. Some factors affecting the site and pattern of leaf-cutting activity in the ant *Atta cephalotes* L. *Journal of Entomology* 47:15–27.
- Basset, Y., N. D. Springate, H. P. Aberlenc, and G. Delvare. 1997. A review of methods for sampling arthropods in tree canopies. Pp. 27–52. In N. Stork, J. Adis, and R. K. Didham (eds.), *Canopy Arthropods*. Chapman and Hall, London.
- Beattie, A. J. 1985. The Evolutionary Ecology of Ant-Plant Mutualisms. Cambridge University Press, New York.
- Beattie, A., and I. Oliver. 1994. Taxonomic minimalism. *Trends in Evolution and Ecology* 9:488–490.
- Beattie, A. J., C. Turnbull, R. B. Knox, and E. G. Williams. 1984. Ant inhibition of pollen function: A possible reason why ant pollination is rare. *American Journal of Botany* 71:421–426.
- Beattie, A. J., C. Turnbull, T. Hough, S. Jobson, and R. B. Knox. 1985. The vulnerability of pollen and fungal spores to ant secretions: Evidence and some evolutionary implications. *American Journal of Botany* 72:606–614.
- Beattie, A. J., C. L. Turnbull, T. Hough, and R. B. Knox. 1986. Antibiotic production: A possible function for the metapleural glands of ants (Hymenoptera: Formicidae). *Annals of the Entomological Society of America* 79:448–450.
- Beccaloni, G. W., and K. J. Gaston. 1995. Predicting the richness of Neotropical forest butterflies: Ithomiinae (Lepidoptera: Nymphalidae) as indicators. *Biological Conservation* 71:77–86.
- Belshaw, R., and B. Bolton. 1993. The effect of forest disturbance on leaf litter ant fauna in Ghana. *Biodiversity and Conservation* 2:656–666.
- _____. 1994a. A survey of the leaf litter ant fauna in Ghana, West Africa (Hymenoptera: Formicidae). *Journal of Hymenoptera Research* 3:5–16.

- _____. 1994b. A new myrmicine ant genus from cocoa leaf litter in Ghana (Hymenoptera: Formicidae). *Journal of Natural History* 28:631–634.
- Belt, T. 1874. *The Naturalist in Nicaragua*. John Murray, London.
- Benson, W. W., and A. Y. Harada. 1988. Local diversity of tropical and temperate ant faunas. *Acta Amazonica* 18:275–289.
- Bequaert, J. 1922. Ants in their diverse relations to the plant world. *Bulletin of the American Museum of Natural History* 45:333–584, plates 26–29.
- Bernard, F. 1954. Fourmis moissonneuses nouvelles ou peu connues des montagnes d'Algérie et révision des *Messor* du groupe *strutor* (Latr.). *Bulletin de la Société d'Histoire Naturelle de l'Afrique du Nord* 45:354–365.
- _____. 1956. Révision des *Leptocephalus* (Hyménoptères Formicidae) d'Europe occidentale, basée sur la biométrie et les genitalia mâles. *Bulletin de la Société Zoologique de France* 81:151–165.
- _____. 1979. *Messor carthaginensis* n. sp., de Tunis, et révision des *Messor* du groupe *barbara* (Hym. Formicidae). *Bulletin de la Société Entomologique de France* 84:265–269.
- Bernstein, R. A. 1979. Schedules of foraging activity in species of ants. *Journal of Animal Ecology* 48:921–930.
- Bernstein, R. A., and M. Gobbel. 1979. Partitioning of space in communities of ants. *Journal of Animal Ecology* 48:931–942.
- Beschers, S., and J. Traniello. 1994. The adaptiveness of worker demography in the attine ant *Trachymyrmex septentrionalis*. *Ecology* 75:763–775.
- Bestelmeyer, B. T. 1997. Stress tolerance in some Chacoan dolichoderine ants: Implications for community organization and distribution. *Journal of Arid Environments* 35:297–310.
- Bestelmeyer, B. T., and J. A. Wiens. 1996. The effects of land use on the structure of ground-foraging ant communities in the Argentine chaco. *Ecological Applications* 6:1225–1240.
- Besuchet, C., D. H. Burckhardt, and I. Löbl. 1987. The "Winkler/Moczarski" elector as an efficient extractor for fungus and litter coleoptera. *The Coleopterists' Bulletin* 41:392–394.
- Billen, J. P. J. 1990. Phylogenetic aspects of exocrine gland development in the Formicidae. Pp. 317–318. In G. K. Veeresh, B. Mallik, and C. A. Viraktamath (eds.), *Social Insects and the Environment*. Proceedings of the 11th International Congress of IUSSI, 1990. Oxford and IBH, New Delhi.
- Bingham, C. T. 1903. The fauna of British India, including Ceylon and Burma. In *Hymenoptera*, Vol. II. Ants and Cuckoo-Wasps. Taylor and Francis, London.
- Black, R. W. II. 1987. The biology of leaf nesting ants in a tropical wet forest. *Biotropica* 19:319–325.
- Blackburn, T., P. Harvey, and M. Pagel. 1990. Species number, population density and body size relationships in natural communities. *Journal of Animal Ecology* 59:335–345.
- Bolton, B. 1972. Two new species of the ant genus *Epitritus* from Ghana, with a key to the world species (Hym., Formicidae). *Entomologists' Monthly Magazine* 107:205–208.
- _____. 1973a. A remarkable new arboreal ant genus (Hym. Formicidae) from West Africa. *Entomologists' Monthly Magazine* 108:234–237.
- _____. 1973b. The ant genus *Polyrhachis* F. Smith in the Ethiopian region (Hymenoptera: Formicidae). *Bulletin of the British Museum (Natural History)*. Entomology 28:283–369.
- _____. 1973c. New synonymy and a new name in the ant genus *Polyrhachis* F. Smith (Hym., Formicidae). *Entomologists' Monthly Magazine* 109:172–180.
- _____. 1974a. A revision of the Palaeotropical arboreal ant genus *Cataulacus* F. Smith (Hymenoptera: Formicidae). *Bulletin of the British Museum (Natural History)*. Entomology 30:1–105.
- _____. 1974b. A revision of the ponerine ant genus *Plectroctena* F. Smith (Hymenoptera: Formicidae). *Bulletin of the British Museum (Natural History)*. Entomology 30:309–338.
- _____. 1975a. A revision of the ant genus *Leptogenys* Roger (Hymenoptera: Formicidae) in the Ethiopian region with a review of the Malagasy species. *Bulletin of the British Museum (Natural History)*. Entomology 31:235–305.
- _____. 1975b. A revision of the African ponerine ant genus *Psalidomyrmex* André (Hymenoptera: Formicidae). *Bulletin of the British Museum (Natural History)*. Entomology 32:1–16.
- _____. 1975c. The *sexspinosa*-group of the ant genus *Polyrhachis* F. Smith (Hym. Formicidae). *Journal of Entomology Series B* 44:1–14.
- _____. 1976. The ant tribe *Tetramoriini* (Hymenoptera: Formicidae). Constituent genera, review of smaller genera and revision of *Triglyphothrix*

- Forel. Bulletin of the British Museum (Natural History). Entomology 34:281–379.
- . 1977. The ant tribe Tetramoriini (Hymenoptera: Formicidae). The genus *Tetramorium* Mayr in the Oriental and Indo-Australian regions, and in Australia. Bulletin of the British Museum (Natural History). Entomology 36:67–151.
- . 1979. The ant tribe Tetramoriini (Hymenoptera: Formicidae). The genus *Tetramorium* Mayr in the Malagasy region and in the New World. Bulletin of the British Museum (Natural History). Entomology 38:129–181.
- . 1980. The ant tribe Tetramoriini (Hymenoptera: Formicidae). The genus *Tetramorium* Mayr in the Ethiopian zoogeographical region. Bulletin of the British Museum (Natural History). Entomology 40:193–384.
- . 1981a. A revision of the ant genera *Meranoplus* F. Smith, *Dicroaspis* Emery and *Calyptomyrmex* Emery (Hymenoptera: Formicidae) in the Ethiopian zoogeographical region. Bulletin of the British Museum (Natural History). Entomology 42:43–81.
- . 1981b. A revision of six minor genera of Myrmicinae (Hymenoptera: Formicidae) in the Ethiopian zoogeographical region. Bulletin of the British Museum (Natural History). Entomology 43:245–307.
- . 1982. Afrotropical species of the myrmicine ant genera *Cardiocondyla*, *Leptothorax*, *Melissotarsus*, *Messor* and *Cataulacus* (Formicidae). Bulletin of the British Museum (Natural History). Entomology 45:307–370.
- . 1983. The Afrotropical dacetine ants (Formicidae). Bulletin of the British Museum (Natural History). Entomology 46:267–416.
- . 1984. Diagnosis and relationships of the myrmicine ant genus *Ishakidris* gen. n. (Hymenoptera: Formicidae). Systematic Entomology 9:373–382.
- . 1986. A taxonomic and biological review of the tetramorine ant genus *Rhoptromyrmex* (Hymenoptera: Formicidae). Systematic Entomology 11:1–17.
- . 1987. A review of the *Solenopsis* genus-group and revision of Afrotropical *Monomorium* Mayr (Hymenoptera: Formicidae). Bulletin of the British Museum (Natural History). Entomology 54:263–452.
- . 1988a. *Secostruma*, a new subterranean tetramoriine ant genus (Hymenoptera: Formicidae). Systematic Entomology 13:263–270.
- . 1988b. A review of *Paratopula* Wheeler, a forgotten genus of myrmicine ants (Hym., Formi-
- cidae). Entomologists' Monthly Magazine 124: 125–143.
- . 1990a. Abdominal characters and status of the cerapachyne ants (Hymenoptera, Formicidae). Journal of Natural History 24:53–68.
- . 1990b. [Untitled. A key to the living subfamilies of ants, based on the worker caste.] Pp. 33–34. In B. Hölldobler and E. O. Wilson, *The Ants*. Harvard University Press, Cambridge, Massachusetts.
- . 1990c. Army ants reassessed: The phylogeny and classification of the doryline section (Hymenoptera, Formicidae). Journal of Natural History 24:1339–1364.
- . 1990d. The higher classification of the ant subfamily Leptanillinae (Hymenoptera: Formicidae). Systematic Entomology 15:267–282.
- . 1991. New myrmicine genera from the Oriental Region (Hymenoptera: Formicidae). Systematic Entomology 16:1–13.
- . 1992. A review of the ant genus *Recurvidris* (Hym.: Formicidae), a new name for *Trigono-gaster* Forel. Psyche (Cambridge) 99:35–48.
- . 1994. Identification Guide to the Ant Genera of the World. Harvard University Press, Cambridge, Massachusetts.
- . 1995a. A taxonomic and zoogeographical census of the extant ant taxa (Hymenoptera: Formicidae). Journal of Natural History 29:1037–1056.
- . 1995b. A New General Catalogue of the Ants of the World. Harvard University Press, Cambridge, Massachusetts.
- . 1999. Ant genera of the tribe Dacetonini (Hymenoptera: Formicidae). Journal of Natural History 33:1639–1689.
- Bolton, B., and R. Belshaw. 1993. Taxonomy and biology of the supposedly lestobiotic ant genus *Paedalgus* (Hymenoptera: Formicidae). Systematic Entomology 18:181–189.
- Bolton, B., and A. C. Marsh. 1989. The Afrotropical thermophilic ant genus *Ocymyrmex* (Hymenoptera: Formicidae). Journal of Natural History 23:1267–1308.
- Bond, W., and P. Slingsby. 1984. Collapse of an ant-plant mutualism: The Argentine ant (*Iridomyrmex humilis*) and myrmecochorous proteaceae. Ecology 65:1031–1037.
- Bonham, C. D. 1989. Measurements for Terrestrial Vegetation. John Wiley and Sons, New York.
- Borgmeier, T. 1955. Die Wanderameisen der neotropischen Region. Studia Entomologica 3: 1–720.

- . 1959. Revision der Gattung *Atta* Fabricius (Hymenoptera, Formicidae). *Studia Entomologica* (n.s.) 2:321–390.
- . 1963. Revision of the North American phorid flies. Part I. The Phorinae, Aenigmatinae, and Metopininae, except Megaselia (Diptera: Phoridae). *Studia Entomologica* (n.s.) 6:1–256.
- Borror, D., C. Triplehorn, and N. Johnson. 1989. *An Introduction to the Study of Insects*. W. B. Saunders, Philadelphia.
- Brandão, C. R. F. 1989. *Belonopelta minima*, a new species from Brazil. *Revista Brasileira de Entomologia* 33:135–138.
- . 1990. Systematic revision of the neotropical ant genus *Megalomyrmex* Forel (Hymenoptera: Formicidae: Myrmicinae) with the description of thirteen new species. *Arquivos de Zoologia (Museu de Zoologia da Universidade de São Paulo)* 31:411–481.
- . 1991. Adendos ao Catálogo Abreviado das Formigas da Região Neotropical (Hymenoptera: Formicidae). *Revista Brasileira de Entomologia* 35(2):319–412.
- Brandão, C. R. F., and J. E. Lattke. 1990. Description of a new Ecuadorian *Gnamptogenys* species (Hymenoptera: Formicidae), with a discussion on the status of the *alfaria* group. *Journal of the New York Entomological Society* 98:489–494.
- Brandão, C. R. F., and R. V. S. Paiva. 1994. The Galapagos ant fauna and the attributes of colonizing ant species. Pp. 1–10. In D. F. Williams (ed.), *Exotic Ants: Biology, Impact, and Control of Introduced Species*. Westview Press, Boulder, Colorado.
- Brandão, C. R. F., and P. E. Vanzolini. 1985. Notes on incubatory inquilinism between squamata (Reptilia) and the neotropical fungus-growing ant genus *Acromyrmex* (Hymenoptera: Formicidae). *Papeis Avulsos de Zoologia (São Paulo)* 36:31–36.
- Brandão, C. R. F., J. L. M. Diniz, and E. M. Tomotake. 1991. *Thaumatomyrmex* strip millipedes for prey: A novel predatory behaviour in ants, and the first case of sympatry in the genus (Hymenoptera: Formicidae). *Insectes Sociaux* 38:335–344.
- Brandão, C. R. F., J. L. M. Diniz, D. Agosti, and J. H. Delabie. 1999. Revision of the Neotropical ant subfamily Leptanilloidinae. *Systematic Entomology* 24:17–36.
- Brian, M. V. 1964. Ant distribution in a southern English heath. *Journal of Animal Ecology* 33:451–461.
- Brian, M. V., and A. D. Brian. 1951. Insolation and ant populations in the west of Scotland. *Transactions of the Royal Entomological Society of London* 102:303–330.
- Brian, M. V., M. D. Mountford, A. Abbott, and S. Vincent. 1976. The changes in ant species distribution during ten years' post-fire regeneration of a heath. *Journal of Animal Ecology* 45:115–133.
- Brothers, D. J. 1975. Phylogeny and classification of the aculeate Hymenoptera, with special reference to Mutillidae. *University of Kansas Science Bulletin* 50:483–648.
- Brothers, D. J., and J. M. Carpenter. 1993. Phylogeny of Aculeata: Chrysidoidea and Vespoidea (Hymenoptera). *Journal of Hymenoptera Research* 2:227–304.
- Brown, B. V. 1993. Taxonomy and preliminary phylogeny of the parasitic genus *Apocephalus*, subgenus *Mesophora* (Diptera: Phoridae). *Systematic Entomology* 18:191–230.
- Brown, B. V., and D. H. Feener Jr. 1991a. Behavior and host location cues of *Apocephalus paraponerae* (Diptera: Phoridae), a parasitoid of the giant tropical ant, *Paraponera clavata* (Hymenoptera: Formicidae). *Biotropica* 23:182–187.
- . 1991b. Life history parameters and description of the larva of *Apocephalus paraponerae* (Diptera: Phoridae), a parasitoid of the giant tropical ant *Paraponera clavata* (Hymenoptera: Formicidae). *Journal of Natural History* 25:221–231.
- Brown, J. H. 1995. *Macroecology*. University of Chicago Press, Chicago.
- Brown, J. H., T. Valone, and C. Curtin. 1997. Reorganization of an arid ecosystem in response to recent climate change. *Proceedings of the National Academy of Sciences* 94:9729–9733.
- Brown, W. L., Jr. 1945. An unusual behavior pattern observed in a Szechuanese ant. *Journal of the West China Border Research Society, Series B* 15:185–186.
- . 1948. A preliminary generic revision of the higher Dacetini (Hymenoptera: Formicidae). *Transactions of the American Entomological Society* 74:101–129.
- . 1949a. Synonymic and other notes on Formicidae (Hymenoptera). *Psyche (Cambridge)* 56:41–49.
- . 1949b. Revision of the ant tribe Dacetini. III. *Epitritus* Emery and *Quadristrumma* new genus (Hymenoptera: Formicidae). *Transactions of the American Entomological Society* 75:43–51.

- _____. 1949c. Revision of the ant tribe Dacetini. I. Fauna of Japan, China and Taiwan. Mushi 20: 1–25.
- _____. 1949d. Revision of the ant tribe Dacetini. IV. Some genera properly excluded from the Dacetini, with the establishment of the Basicerotini new tribe. Transactions of the American Entomological Society 75:83–96.
- _____. 1950. Revision of the ant tribe Dacetini. II. *Glamyromyrnex* Wheeler and closely related small genera. Transactions of the American Entomological Society 76:27–36.
- _____. 1952. On the identity of *Adlerzia* Forel (Hymenoptera: Formicidae). Pan-Pacific Entomologist 28:173–177.
- _____. 1953a. Revisionary studies in the ant tribe Dacetini. American Midland Naturalist 50:1–137.
- _____. 1953b. Characters and synonymies among the genera of ants. Part II. Breviora 18:1–8.
- _____. 1953c. Revisionary notes on the ant genus *Myrmecia* of Australia. Bulletin of the Museum of Comparative Zoology, Harvard University 111:1–35.
- _____. 1954a. (1953) The Indo-Australian species of the ant genus *Strumigenys* Fr. Smith: S. wallacei Emery and relatives. Psyche (Cambridge) 60:85–89.
- Brown, W. L., Jr. 1954b. Remarks on the internal phylogeny and subfamily classification of the family Formicidae. Insectes Sociaux 1:22–31.
- _____. 1955. A revision of the Australian ant genus *Notoncus* Emery, with notes on the other genera of Melophorini. Bulletin of the Museum of Comparative Zoology, Harvard College 113:471–494.
- _____. 1958. Contributions toward a reclassification of the Formicidae. II. Tribe Ectatommini (Hymenoptera). Bulletin of the Museum of Comparative Zoology, Harvard University 118:173–362.
- _____. 1959. A revision of the dacetine ant genus *Neostruma*. Breviora 107:1–13.
- _____. 1960. Contributions toward a reclassification of the Formicidae. III. Tribe Amblyoponini (Hymenoptera). Bulletin of the Museum of Comparative Zoology, Harvard University 122:143–230.
- _____. 1962. The neotropical species of the ant genus *Strumigenys* Fr. Smith: Synopsis and keys to the species. Psyche (Cambridge) 69:238–267.
- _____. 1964. The ant genus *Smithistruma*: A first supplement to the World revision (Hymenoptera: Formicidae). Transactions of the American Entomological Society 89:183–200.
- _____. 1965. Contributions to a reclassification of the Formicidae. IV. Tribe Typhlomyrmecini (Hymenoptera). Psyche (Cambridge) 72:65–78.
- _____. 1967. Studies on North American ants. II. *Myrmecina*. Entomological News 78:233–240.
- _____. 1972. *Aasketogenys acubecca*, a new genus and species of dacetine ants from Malaya (Hymenoptera: Formicidae). Psyche (Cambridge) 79:23–26.
- _____. 1973. A comparison of the Hylean and Congo-West African rain forest ant faunas. Pp. 161–185. In B. J. Meggers, E. S. Ayensu, and W. D. Duckworth (eds.), Tropical Forest Ecosystems in Africa and South America: A Comparative Review. Smithsonian Institution Press, Washington, D.C.
- _____. 1974a. A supplement to the revision of the ant genus *Basiceros* (Hymenoptera: Formicidae). Journal of the New York Entomological Society 82:131–140.
- _____. 1974b. *Concoctio* genus nov. Pilot Register of Zoology. Card No. 29.
- _____. 1974c. *Concoctio concentra* species nov. Pilot Register of Zoology. Card No. 30.
- _____. 1974d. *Dolioponera* genus nov. Pilot Register of Zoology. Card No. 31.
- _____. 1974e. *Dolioponera fustigera* species nov. Pilot Register of Zoology. Card No. 32.
- _____. 1975. Contributions toward a reclassification of the Formicidae. V. Ponerinae, tribes Platythyreini, Cerapachyini, Cylindromyrmecini, Acanthostichini, and Aenictogitini. Search Agriculture (Ithaca, N.Y.) 5(1):1–115.
- _____. 1976a. *Cladarogenys* genus nov. Pilot Register of Zoology. Card No. 33.
- _____. 1976b. *Cladarogenys lasia* species nov. Pilot Register of Zoology. Card No. 34.
- _____. 1976c. Contributions toward a reclassification of the Formicidae. Part VI. Ponerinae, tribe Ponerini, subtribe Odontomachiti. Section A. Introduction, subtribal characters. Genus *Odontomachus*. Studia Entomologica 19:67–171.
- _____. 1977a. An aberrant new genus of myrmicine ant from Madagascar. Psyche (Cambridge) 84:218–224.
- _____. 1977b. A supplement to the world revision of *Odontomachus* (Hymenoptera: Formicidae). Psyche (Cambridge) 84:281–285.
- _____. 1978. Contributions toward a reclassification of the Formicidae. Part VI. Ponerinae, tribe

- Ponerini, subtribe Odontomachiti. Section B. Genus *Anochetus* and bibliography. *Studia Entomologica* 20:549–638.
- . 1979. A remarkable new species of *Proceratium*, with dietary and other notes on the genus (Hymenoptera: Formicidae). *Psyche* (Cambridge) 86:337–346.
- . 1980a. *Protalaridris* genus nov. *Pilot Register of Zoology*. Card No. 36.
- . 1980b. *Protalaridris armata* species nov. *Pilot Register of Zoology*. Card No. 37.
- . 1985. *Indomyrma dasypyx*, new genus and species, a myrmicine ant from peninsular India (Hymenoptera: Formicidae). *Israel Journal of Entomology* 19:37–49.
- Brown, W. L., Jr., and R. G. Boisvert. 1979. The dacetine ant genus *Pentastrum*. *Psyche* (Cambridge) 85:201–207.
- Brown, W. L., Jr., and W. W. Kempf. 1960. A world revision of the ant tribe Basicerotini. *Studia Entomologica* (n.s.) 3:161–250.
- . 1967. *Tatuidris*, a remarkable new genus of Formicidae (Hymenoptera). *Psyche* (Cambridge) 74:183–190.
- . 1969. A revision of the neotropical dacetine ant genus *Acanthognathus* (Hymenoptera: Formicidae). *Psyche* (Cambridge) 76:87–109.
- Brown, W. L., Jr., W. H. Gotwald Jr., and J. Lévieux. 1970. A new genus of ponerine ants from West Africa (Hymenoptera: Formicidae) with ecological notes. *Psyche* (Cambridge) 77:259–275.
- Brues, C. T. 1925. *Scyphodon*, an anomalous genus of Hymenoptera of doubtful affinities. *Treubia* 6:93–96.
- Buckley, R. C. 1982a. Ant-plant interactions: A world review. Pp. 111–141. In R. C. Buckley (ed.), *Ant-Plant Interactions in Australia*. Dr. W. Junk, The Hague.
- . 1982b. A world bibliography of ant-plant interactions. Pp. 143–162. In R. C. Buckley (ed.), *Ant-Plant Interactions in Australia*. Dr. W. Junk, The Hague.
- Bukowski, T. C. 1991. Solifugae in *Atta* foraging columns. P. 70. In B. A. Loiselle and C. K. Augspurger (eds.), OTS 91-1: Tropical Biology: An Ecological Approach. Organization for Tropical Studies, Duke University, Durham, North Carolina.
- Bunge, J., and M. Fitzpatrick. 1993. Estimating the number of species: A review. *Journal of the American Statistical Association* 88:364–373.
- Bünzli, G. H. 1935. Untersuchungen über coccophile Ameisen aus den Kaffeefeldern von Surinam. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 16:453–593.
- Burbridge, A. H., K. Leicester, S. McDavitt, and J. D. Majer. 1992. Ants as indicators of disturbance at Yanchep National Park, Western Australia. *Journal of the Royal Society of Western Australia* 75:89–95.
- Buren, W. F. 1968a. Some fundamental taxonomic problems in *Formica* (Hymenoptera: Formicidae). *Journal of the Georgia Entomological Society* 3:25–40.
- . 1968b. A review of the species of *Crematogaster*, sensu stricto, in North America (Hymenoptera, Formicidae). Part II. Descriptions of new species. *Journal of the Georgia Entomological Society* 3:91–121.
- Burnham, K. P., and W. S. Overton. 1978. Estimation of the size of a closed population when capture probabilities vary among animals. *Biometrika* 65:623–633.
- . 1979. Robust estimation of population size when capture probabilities vary among animals. *Ecology* 60:927–936.
- Buschinger, A. 1981. Biological and systematic relationships of social parasitic Leptocephalini from Europe and North America. Pp. 211–222. In P. E. Howse and J.-L. Clement (eds.), *Biosystematics of Social Insects*. Systematics Association Special Volume No. 19. Academic Press, London.
- . 1989. Evolution, speciation, and inbreeding in the parasitic ant genus *Epimyrma* (Hymenoptera, Formicidae). *Journal of Evolutionary Biology* 2:265–283.
- Buschinger, A., and U. Winter. 1983. *Myrmicinospidium durum* Hölldobler 1933, Parasit bei Ameisen (Hym., Formicidae) in Frankreich, der Schweiz und Jugoslawien wieder aufgefunden. *Zoologischer Anzeiger* 210:393–398.
- Buschinger, A., J. Heinze, K. Jessen, P. Douwes, and U. Winter. 1987. First European record of a queen ant carrying a mealybug during her mating flight. *Naturwissenschaften* 74:139–140.
- Buschinger, A., W. Ehrhardt, K. Fischer, and J. Ofer. 1988. The slave-making ant genus *Chalepoxenus* (Hymenoptera, Formicidae). I. Review of literature, range, slave species. *Zoologische Jahrbücher. Abteilung für Systematik, Ökologie und Geographie der Tiere* 115:383–401.

- Buschinger, A., R. G. Kleespies, and R. D. Schumann. 1995. A gregarine parasite of *Leptothorax* ants from North America. *Insectes Sociaux* 42:219–222.
- Byrne, M. M. 1994. Ecology of twig-dwelling ants in a wet lowland tropical forest. *Biotropica* 26:61–72.
- Caetano, F. H. 1989. Endosymbiosis of ants with intestinal and salivary gland bacteria. In W. Schwemmle and G. Gassner (eds.), *Insect Endosymbionts: Morphology, Physiology, Genetics, Evolution*. CRC Press, Boca Raton, Florida.
- Caetano, F. H., and C. Cruz-Landim. 1985. Presence of microorganisms in the alimentary canal of ants of the tribe Cephalotini (Myrmicinae): Location and relationship with intestinal structures. *Naturalia* 10:37–47.
- Cagniant, H. 1997. The ant genus *Tetramorium* (Hymenoptera: Formicidae) in Morocco. *Annales de la Société Entomologique de France* 33(1):89–100.
- Cagniant, H., and X. Espadaler. 1997a. *Leptothorax*, *Epimyrma* and *Chalepoxenus* of Morocco (Hymenoptera: Formicidae). Key and catalogue of species. *Annales de la Société Entomologique de France* 33(3):259–284.
- Cagniant, H., and X. Espadaler. 1997b. The ant genus *Messor* in Morocco (Hymenoptera: Formicidae). *Annales de la Société Entomologique de France* 33(4):419–434.
- Camilo, G. R., and S. A. Phillips Jr. 1990. Evolution of ant communities in response to invasion by the fire ant *Solenopsis invicta*. Pp. 190–198. In R. K. Vander Meer, K. Jaffe, and A. Cedeno (eds.), *Applied Myrmecology: A World Perspective*. Westview Press, Boulder, Colorado.
- Cammell, M. E., M. J. Way, and M. R. Paiva. 1996. Diversity and structure of ant communities associated with oak, pine, eucalyptus, and arable habitats in Portugal. *Insectes Sociaux* 43:37–46.
- Carpenter, S., T. Frost, J. Kitchell, and T. Kratz. 1993. Species dynamics and global environmental change: A perspective from ecosystem experiments. Pp. 267–279. In P. Kareiva, J. Kingsolver, and R. Huey (eds.), *Biotic Interactions and Global Change*. Sinauer Associates, Sunderland, Massachusetts.
- Chao, A. 1984. Non-parametric estimation of the number of classes in a population. *Scandinavian Journal of Statistics* 11:265–270.
- . 1987. Estimating the population size for capture-recapture data with unequal catchability. *Biometrics* 43:783–791.
- Chao, A., and S. M. Lee. 1992. Estimating the number of classes via sample coverage. *Journal of the American Statistical Association* 87:210–217.
- Chao, A., M. C. Ma, and M. C. K. Yang. 1993. Stopping rules and estimation for recapture debugging with unequal failure rates. *Biometrika* 80:193–201.
- Chapela, I. H., S. A. Rehner, T. R. Schultz, and U. G. Mueller. 1994. Evolutionary history of the symbiosis between the fungus-growing ants and their fungi. *Science* 266:1691–1694.
- Chapman, T. A. 1920. Contributions to the life history of *Lycaena euphemus* Hb. *Transactions of the Royal Entomological Society of London* 1919:450–465.
- Chazdon, R. L., R. K. Colwell, J. S. Denslow, and M. R. Guariguata. 1998. Statistical methods for estimating species richness of woody regeneration in primary and secondary rain forests of northeastern Costa Rica. Pp. 285–309. In F. Dallmeier and J. A. Comiskey (eds.), *Forest Biodiversity Research, Monitoring and Modeling: Conceptual Background and Old World Case Studies*. Parthenon, Paris.
- Chen, Y.-C., W.-H. Hwang, A. Chao, and C.-Y. Kuo. 1995. Estimating the number of common species. Analysis of the number of common bird species in Ke-Yar Stream and Chung-Kang Stream. *Journal of the Chinese Statistical Association* 33:373–393. [In Chinese with English abstract.]
- Cherrett, J. M. 1986. History of the leaf-cutting ant problem. Pp. 10–17. In C. S. Lofgren and R. K. Vander Meer (eds.), *Fire Ants and Leaf Cutting Ants: Biology and Management*. Westview Press, Boulder, Colorado.
- Chew, R. M. 1995. Aspects of the ecology of three species of ants (*Myrmecocystus* spp., *Aphaenogaster* sp.) in desertified grassland in southeastern Arizona, 1958–1993. *American Midland Naturalist* 134:75–83.
- Chew, R. M., and J. De Vita. 1980. Foraging characteristics of a desert ant assemblage: Functional morphology and species separation in Cochise County, Arizona. *Journal of Arid Environments* 3:75–83.
- Christian, K., and S. R. Morton. 1992. Extreme thermophilia in a central Australian ant, *Melophorus bagoti*. *Physiological Zoology* 65:885–905.
- Clark, D. B., C. Guayasamín, O. Pazmiño, C. Donoso, and Y. Páez de Villacís. 1982. The tramp ant *Wasmannia auropunctata*: Autecology and effects

- on ant diversity and distribution on Santa Cruz Island, Galapagos. *Biotropica* 14:196–207.
- Clark, J. 1930. The Australian ants of the genus *Dolichoderus* (Formicidae). Subgenus *Hypoclinea* Mayr. *Australian Zoologist* 6:252–268.
- . 1936. A revision of Australian species of *Rhytidoponera* Mayr (Formicidae). *Memoirs of the National Museum of Victoria* 9:14–89.
- . 1951. The Formicidae of Australia, Vol. 1: Subfamily Myrmeciinae. CSIRO, Melbourne.
- Clausen, C. P. 1940a. *Entomophagous Insects*. McGraw-Hill, New York.
- . 1940b. The immature stages of the Eucharidae. *Proceedings of the Entomological Society of Washington* 42:161–170.
- . 1940c. The oviposition habits of the Eucharidae (Hymenoptera). *Journal of the Washington Academy of Sciences* 30:504–516.
- . 1941. The habits of the Eucharidae. *Psyche* (Cambridge) 48:57–69.
- Clements, R. O. 1982. Sampling and extraction techniques for collecting invertebrates from grassland. *Entomologists' Monthly Magazine* 118:133–142.
- Clench, H. K. 1979. How to make regional lists of butterflies: Some thoughts. *Journal of the Lepidopterist Society* 33:216–231.
- Cobabe, E. A., and W. D. Allmon. 1994. Effects of sampling on paleoecologic and taphonomic analyses in high-diversity fossil accumulations: An example from the Eocene Gosport Sand, Alabama. *Lethaia* 27:167–178.
- Coddington, J. A., L. H. Young, and F. A. Coyle. 1996. Estimating spider species richness in a southern Appalachian cove hardwood forest. *Journal of Arachnology* 24:111–128.
- Coenen-Stass D., Schaarschmidt, and I. Lamprecht. 1980. Temperature distribution and calorimetric determination of heat production in the nest of the wood ant, *Formica polyctena* (Hymenoptera: Formicidae). *Ecology* 61:238–244.
- Cole, A. C., Jr. 1940. A guide to the ants of the Great Smoky Mountains National Park, Tennessee. *American Midland Naturalist* 24:1–88.
- . 1949. Notes on *Gesomyrmex* (Hymenoptera: Formicidae). *Entomological News* 60:181.
- . 1968. *Pogonomyrmex* Harvester Ants: A Study of the Genus in North America. University of Tennessee Press, Knoxville.
- Colwell, R. K. 1997. EstimateS: Statistical estimation of species richness and shared species from samples. Version 5. User's guide and application published at: <http://viceroy.eeb.uconn.edu/> estimates.
- Colwell, R. K., and J. A. Coddington. 1994. Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society of London, Series B* 345:101–118.
- Colwell, R. K., and G. C. Hurtt. 1994. Nonbiological gradients in species richness and a spurious Rapaport effect. *American Naturalist* 144:570–595.
- Connell, J. 1978. Diversity in tropical rain forests and coral reefs. *Science* 199:1302–1310.
- Connell, J., and W. Sousa. 1983. On the evidence needed to judge ecological stability or persistence. *American Naturalist* 121:789–824.
- Convention on Biological Diversity. 1992.
- Convention on Biological Diversity. United Nations Conference on Environment and Development, Rio de Janeiro.
- Cover, S. P., J. E. Tobin, and E. O. Wilson. 1990. The ant community of a tropical lowland rain forest site in Peruvian Amazonia. Pp. 699–700. In G. K. Veeresh, B. Mallik, and C. A. Viraktamath (eds.), *Social Insects and the Environment*. Proceedings of the 11th International Congress of IUSSI, 1990. Oxford and IBH Publishing, New Delhi.
- Cowling, R. M., and J. J. Midgely. 1996. The influence of regional phenomena on an emerging global ecology. *Global Ecology and Biogeography Letters* 5:63–65.
- Cranston, P. S., and J. W. H. Trueman. 1997. "Indicator" taxa in invertebrate biodiversity assessment. *Memoirs of the Museum of Victoria* 56(2):267–274.
- Creighton, W. S. 1950. The ants of North America. *Bulletin of the Museum of Comparative Zoology, Harvard College* 104:1–585.
- . 1957. A study of the genus *Xenomyrmex* (Hymenoptera, Formicidae). *American Museum Novitates* 1843:1–14.
- Crist, T. O., and J. A. Wiens. 1994. Scale effects of vegetation structure on forager movements and seed harvesting by ants. *Oikos* 69:37–46.
- . 1996. The distribution of ant colonies in a semiarid landscape: Implications for community and ecosystem processes. *Oikos* 76:301–311.
- Crosland, M. W. J. 1988. Effect of a gregarine parasite on the color of *Myrmecia pilosula* (Hymenoptera: Formicidae). *Annals of the Entomological Society of America* 81:481–484.

- Crowell, K. L. 1968. Rates of competitive exclusion by the Argentine ant in Bermuda. *Ecology* 49:551–555.
- Crozier, R. H. 1990. From population genetics to phylogeny: Uses and limits of mitochondrial DNA. *Australian Systematic Botany* 3:111–124.
- Culver, D. S. 1974. Species packing in Caribbean and North temperate ant communities. *Ecology* 55:974–988.
- Cushman, J. H., J. H. Lawton, and B. F. J. Manly. 1993. Latitudinal patterns in European ant assemblages: Variation in species richness and body size. *Oecologia* 95:30–37.
- Darlington, P. J., Jr. 1971. The carabid beetles of New Guinea. Part IV. General considerations; analysis and history of fauna; taxonomic supplement. *Bulletin of the Museum of Comparative Zoology, Harvard College* 142:129–337.
- Davidson, D. W. 1977a. Species diversity and community organization in desert seed-eating ants. *Ecology* 58:711–724.
- . 1977b. Foraging ecology and community organization in desert seed-eating ants. *Ecology* 58:725–737.
- . 1978. Size variability in the worker caste of a social insect (*Veromessor pergandei* Mayr) as a function of the competitive environment. *American Naturalist* 112:523–532.
- . 1980. Some consequences of diffuse competition in a desert ant community. *American Naturalist* 116:92–105.
- . 1988. Ecological studies of Neotropical ant gardens. *Ecology* 69:1138–1152.
- . 1997. The role of resource imbalances in the evolutionary ecology of tropical arboreal ants. *Biological Journal of the Linnean Society* 61:153–181.
- . 1998. Resource discovery versus resource domination in ants: A functional mechanism for breaking the tradeoff. *Ecological Entomology* 23:484–490.
- Davidson, D. W., and L. Patrell-Kim. 1996. Tropical arboreal ants: Why so abundant? Pp. 127–140. In A. C. Gibson (ed.), *Neotropical Biodiversity and Conservation*. University of California, Los Angeles Botanical Garden Publication Number 1. University of California, Los Angeles.
- Davidson, D. W., J. H. Brown, and R. S. Inouye. 1980. Competition and the structure of granivore communities. *BioSciences* 30(4):233–238.
- Davidson, D. W., J. T. Longino, and R. R. Snelling. 1988. Pruning of host plant neighbors by ants: An experimental approach. *Ecology* 69:801–808.
- Davidson, D. W., R. R. Snelling, and J. T. Longino. 1989. Competition among ants for myrmecophytes and the significance of plant trichomes. *Biotropica* 21:64–73.
- De Kock, A. E., and J. H. Giliomee. 1989. A survey of the Argentine ant, *Iridomyrmex humilis* (Mayr) (Hymenoptera: Formicidae) in South African fynbos. *Journal of the Entomological Society of Southern Africa* 52:157–164.
- De Vries, P. J., D. Murray, and R. Lande. 1997. Species diversity in vertical, horizontal, and temporal dimensions of a fruit-feeding butterfly community in an Ecuadorian rainforest. *Biological Journal of the Linnean Society* 62:343–364.
- Delabie, J. H. C. 1995. Inquilinismo simultâneo de duas espécies de *Centromyrmex* (Hymenoptera; Formicidae; Ponerinae) em cupinzeiros de *Syntermes* sp. (Isoptera; Termitidae; Nasutitermitinae). *Revista Brasileira de Entomologia* 39:605–609.
- Delabie, J. H. C., and H. G. Fowler. 1995. Soil and litter cryptic ant assemblages of Bahian cocoa plantations. *Pedobiologia* 39:423–433.
- Delabie, J. H. C., I. C. do Nascimento, and C. dos S. F. Mariano. 2000. Importance de l'agriculture cacaoyère pour le maintien de la biodiversité: Étude comparée de la myrmécofaune de différents milieux du sud-est de Bahia, Brésil (Hymenoptera; Formicidae). In *Proceedings for the 12th International Cocoa Research Conference*, Lagos, Nigeria.
- Delabie, J. H. C., A. B. Casimiro, I. C. do Nascimento, A. L. B. do Souza, M. Furst, A. M. V. da Encarnação, M. R. B. Smith, and I. M. Cazorla. 1994. Stratification de la communauté de fourmis (Hymenoptera: Formicidae) dans une cacaoyère brésilienne et conséquences pour le contrôle naturel des ravageurs du cacaoyer. Pp. 823–831. In *Proceedings of the 11th International Cocoa Research Conference*, Lagos, Nigeria.
- Delabie, J. H. C., I. C. do Nascimento, P. Pacheco, and A. B. Casimiro. 1995. Community structure of house-infesting ants (Hymenoptera: Formicidae) in Southern Bahia, Brazil. *Florida Entomologist* 78:264–270.
- Deslippe, R. J., and R. Savolainen. 1994. Role of food supply in structuring a population of *Formica* ants. *Journal of Animal Ecology* 63:756–764.

- Deyrup, M., J. Trager, and N. Carlin. 1985. The genus *Odontomachus* in the southeastern United States (Hymenoptera: Formicidae). Entomological News 96:188–195.
- Di Castri, F., J. Robertson Vernhes, and T. Younes. 1992. Inventorying and monitoring biodiversity. Biology International. 27:1–27.
- Diniz, J. L. M. 1990. Revisão sistemática da tribo Stegomyrmicinae, com a descrição de uma nova espécie (Hymenoptera, Formicidae). Revista Brasileira de Biologia 34:277–295.
- Diniz, J. L. M., and C. R. F. Brandão. 1993. Biology and myriapod egg predation by the Neotropical myrmicine ant *Stegomyrmex vizottoi* (Hymenoptera: Formicidae). Insectes Sociaux 40:301–311.
- Dixon, A. F. G. 1985. Aphid Ecology. Chapman and Hall, New York.
- Dlussky, G. M. 1964. The ants of the subgenus *Coptoformica* of the genus *Formica* (Hymenoptera, Formicidae) of the USSR. Zoologicheskii Zhurnal 43:1026–1040. [In Russian.]
- . 1965. Ants of the genus *Formica* L. of Mongolia and northeast Tibet (Hymenoptera, Formicidae). Annales Zoologici (Warsaw) 23:15–43.
- . 1967. Ants of the Genus *Formica* (Hymenoptera, Formicidae, g. *Formica*). Nauka, Moscow. [In Russian.]
- . 1969. Ants of the genus *Proformica* Ruzs. of the USSR and contiguous countries (Hymenoptera, Formicidae). Zoologicheskii Zhurnal 48: 218–232. [In Russian.]
- Dlussky, G. M., and B. Pisarski. 1971. Rewizja polskich gatunków mrówek (Hymenoptera: Formicidae) z rodzaju *Formica* L. Fragmenta Faunistica (Warsaw) 16:145–224.
- Dlussky, G. M., and A. G. Radchenko. 1994. Ants of the genus *Diplorhoptrum* (Hymenoptera, Formicidae) from the central Palearctic. Zoologicheskii Zhurnal 73(2):102–111. [In Russian.]
- Dlussky, G. M., and O. S. Soyunov. 1988. Ants of the genus *Temnothorax* Mayr (Hymenoptera: Formicidae) of the USSR. Izvestiya Akademii Nauk Turkmenstkoj SSR, Seriya Biologicheskikh Nauk 1988(4):29–37. [In Russian.]
- Donisthorpe, H. 1946. *Ireneopone gibber* (Hym., Formicidae), a new genus and species of myrmicine ant from Mauritius. Entomologists' Monthly Magazine 82:242–243.
- Dorow, W. H. O., and R. J. Kohout. 1995. A review of the subgenus *Hemiptocha* Roger of the genus *Polyrhachis* Fr. Smith with description of a new species (Hymenoptera: Formicidae: Formicinae). Zoologische Mededelingen (Leiden) 69(1–14): 93–104.
- DuBois, M. B. 1981. Two new species of inquiline *Monomorium* from North America (Hymenoptera: Formicidae). University of Kansas Science Bulletin 52:31–37.
- . 1986. A revision of the native New World species of the ant genus *Monomorium* (*minimum* group) (Hymenoptera: Formicidae). University of Kansas Science Bulletin 53:65–119.
- . 1998. A revision of the ant genus *Stenamma* in the Palaearctic and Oriental regions (Hymenoptera: Formicidae: Myrmicinae). Sociobiology 32(2):193–403.
- Dumpert, K. 1981. The Social Biology of Ants. Translated by C. Johnson. Pitman, Boston.
- . 1985. *Camponotus (Karavaievia) texens* sp. n. and *C. (K.) gombaki* sp. n. from Malaysia in comparison with other *Karavaievia* species (Formicidae: Formicinae). Psyche (Cambridge) 92:557–573.
- Dumpert, K., U. Maschwitz, A. Weissflog, K. Rosciszewski, and I. H. Azarae. 1995. Six new weaver ant species from Malaysia: *Camponotus (Karavaievia) striaticeps*, *C. (K.) melanus*, *C. (K.) nigripes*, *C. (K.) belumensis*, *C. (K.) gentingensis*, and *C. (K.) micragyne*. Malaysian Journal of Science 16A:87–105.
- Eisner, T. 1957. A comparative morphological study of the proventriculus of ants (Hymenoptera: Formicidae). Bulletin of the Museum of Comparative Zoology, Harvard College 116:439–490.
- Elmes, G. W. 1991. Ant colonies and environmental disturbance. Pp. 15–32. In P. S. Meadows and A. Meadows (eds.), Environmental Impact of Burrowing Animals and Animal Burrows. Clarendon Press, Oxford.
- Emery, C. 1897. Revisione del genere *Diacamma* Mayr. Rendiconti delle Sessioni dell' Accademia delle Scienze dell Istituto di Bologna (n.s.) 1:147–167.
- . 1901. Notes sur les sous-familles des Dorylines et Ponérines (Famille des Formicides). Annales de la Société Entomologique de Belgique 45:32–54.
- . 1910. Hymenoptera. Fam. Formicidae. Subfam. Dorylinae. Genera Insectorum 102:1–34.
- . 1911. Hymenoptera. Fam. Formicidae. Subfam. Ponerinae. Genera Insectorum 118:1–125.

- _____. 1913 (1912). Hymenoptera. Fam. Formicidae. Subfam. Dolichoderinae. Genera Insectorum 137:1–50.
- _____. 1920. La distribuzione geografica attuale delle formiche. Tentativo di spiegarne la genesi col soccorso di ipotesi filogenetiche e paleogeografiche. Atti della Reale Accademia dei Lincei. Memorie. Classe di Scienze, Fisiche, Matematiche e Naturali (5)13:357–450.
- _____. 1921. Hymenoptera. Fam. Formicidae. Subfam. Myrmicinae. [part] Genera Insectorum 174A:1–94 + 7 plates.
- _____. 1922. Hymenoptera. Fam. Formicidae. Subfam. Myrmicinae. [part] Genera Insectorum 174B:95–206.
- _____. 1925a. Hymenoptera. Fam. Formicidae. Subfam. Formicinae. Genera Insectorum 183:1–302.
- _____. 1925b. Revision des espèces paléarctiques du genre *Tapinoma*. Revue Suisse Zoologique 32:45–64.
- Entomological Society of Canada. 1978. Collections of Canadian Insects and Certain Related Groups. Entomological Society of Canada, Ottawa.
- Erickson, J. M. 1971. The displacement of native ant species by the introduced Argentine ant *Iridomyrmex humilis* Mayr. *Psyche* (Cambridge) 78:257–266.
- Erwin, T. L. 1983. Beetles and other arthropods of tropical forest canopies at Manaus, Brazil, sampled by insecticidal fogging. Pp. 59–79. In S. L. Sutton, T. C. Whitmore, and A. C. Chadwick (eds.), *Ecology and Management of Tropical Rainforest*. Blackwell, Oxford.
- _____. 1986. The tropical forest canopy: The heart of biotic diversity. Pp. 123–129. In E. O. Wilson (ed.), *Biodiversity*. National Academy Press, Washington, D.C.
- _____. 1989. Sorting tropical forest canopy samples (an experimental project for networking information). *Insect Collection News* 2(1):8.
- Espadaler, X. 1982. *Myrmicinopsporidium* sp., parasite interne des fourmis: Etude au meb de la structure externe. Pp. 239–241. In A. deHaro and X. Espadaler (eds.), *La Communication chez les Sociétés d'Insectes*. Colloque Internationale de l'Union Internationale pour l'Etude des Insectes Sociaux, Section française, Barcelona, 1982. Universidad Autónoma de Barcelona, Bellaterra.
- Ettershank, G. 1966. A generic revision of the world Myrmicinae related to *Solenopsis* and *Pheidolegeton* (Hymenoptera: Formicidae). *Australian Journal of Zoology* 14:73–171.
- Evans, H. E. 1962. A review of nesting behavior of digger wasps of the genus *Aphilanthops*, with special attention to the mechanics of prey carriage. *Behavior* 19:239–260.
- _____. 1977. Prey specificity in *Clypeadon* (Hymenoptera: Sphecidae). *Pan-Pacific Entomologist* 53:144.
- Farquharson, C. O. 1914. The growth of fungi on the shelters built over Coccidae by *Cremastogaster*-ants. *Transactions of the Entomological Society of London* 1914:42–50.
- _____. 1918. *Harpagomyia* and other Diptera fed by *Cremastogaster* ants in S. Nigeria. *Proceedings of the Entomological Society of London* 1918:29–39.
- Feener, D. H., Jr. 1981. Competition between ant species: Outcome controlled by parasitic flies. *Science* 214:815–817.
- Feener, D. H., Jr., and K. A. G. Moss. 1990. Defense against parasites by hitchhikers in leaf-cutting ants: A quantitative assessment. *Behavioral Ecology and Sociobiology* 26:17–29.
- Feener, D. H., Jr., L. F. Jacobs, and J. O. Schmidt. 1996. Specialized parasitoid attracted to a pheromone of ants. *Animal Behavior* 51:61–66.
- Fellers, G. M., and J. H. Fellers. 1982. Scavenging rates of invertebrates in an eastern deciduous forest. *American Midland Naturalist* 107:389–392.
- Fellers, J. H. 1987. Interference and exploitation in a guild of woodland ants. *Ecology* 68:1466–1478.
- _____. 1989. Daily and seasonal activity in woodland ants. *Oecologia* 78:69–76.
- Fernández, C. F., and M. L. H. Baena. 1997. Ants of Colombia VII: New species of the genera *Lachnomyrmex* Wheeler and *Megalomyrmex* Forel (Hymenoptera: Formicidae). *Caldasia* 19(1–2): 109–114.
- Fernández, C. F. and E. E. Palacio. 1997. Key to northern South America's *Pogonomyrmex* (Hymenoptera: Formicidae) with description of a new species. *Revista de Biología Tropical* 45(4): 1649–1661.
- Ferreira, L. V., and G. T. Prance. 1998. Species richness and floristic composition in four hectares in the Jaú National Park in upland forests in Central Amazonia. *Biodiversity and Conservation* 7:1349–1364.
- Fisher, B. L. 1996a. Ant diversity patterns along an elevational gradient in the Réserve Naturelle Intégrale d'Andringitra, Madagascar. *Fieldiana: Zoology* (n.s.) 85:93–108.

- _____. 1996b. Origins and affinities of the ant fauna of Madagascar. Pp. 457–465. In W. L. Lourenço (ed.), Biogéographie de Madagascar. Editions ORSTOM, Paris.
- _____. 1997. Biogeography and ecology of the ant fauna of Madagascar (Hymenoptera: Formicidae). *Journal of Natural History* 31:269–302.
- _____. 1998. Ant diversity patterns along an elevational gradient in the Réserve Spéciale d'Anjanaharibe-Sud and on the western Masoala Peninsula, Madagascar. *Fieldiana: Zoology* (n.s.) 90:39–67.
- _____. 1999a. Improving inventory efficiency: A case study of leaf litter diversity in Madagascar. *Ecological Applications* 9:714–731.
- _____. 1999b. Ant diversity patterns along an elevational gradient in the Réserve Naturelle Intégrale d'Andohahela, Madagascar. *Fieldiana: Zoology* (n.s.) 94:129–147.
- Fisher, B. L., and S. Razafimandimbry. 1997. Les fourmis (Hymenoptera: Formicidae). Pp. 104–109. In O. Langrand and S. M. Goodman (eds.), Inventaire Biologique Forêts de Vohibasia et d'Isoky-Vohimena. Recherches pour le Développement, Série Sciences Biologiques No. 12. Centre d'Information et de Documentation Scientifique et Technique and World Wide Fund for Nature, Antananarivo, Madagascar.
- Fisher, B. L., H. Ratsirarson, and S. Razafimandimbry. 1998. Les Fourmis (Hymenoptera: Formicidae). Pp. 107–131. In J. Ratsirarson and S. M. Goodman (eds.), Inventaire Biologique de la Forêt Littorale de Tampolo (Fenoarivo Atsinanana). Recherches pour le Développement, Série Sciences Biologiques No. 14. Centre d'Information et de Documentation Scientifique et Technique and World Wide Fund for Nature. Antananarivo, Madagascar.
- Fittkau, E. J., and H. Klinge. 1973. On biomass and trophic structure of the Central Amazonian rain forest ecosystem. *Biotropica* 5:2–14.
- Fluker, S. S., and J. W. Beardsley. 1970. Sympatric associations of three ants: *Iridomyrmex humilis*, *Pheidole megacephala*, and *Anoplolepis longipes* in Hawaii. *Annals of the Entomological Society of America* 63:1290–1296.
- Forel, A. 1901. Fourmis termitophages, lestobiose, *Atta tardigrada*, sous-genres d'*Euponera*. *Annales de la Société Entomologique de Belgique* 45:389–398.
- Fowler, H. G. 1988. Taxa of the neotropical grass-cutting ants, *Acromyrmex* (Hymenoptera: Formicidae: Attini). *Científica (Jaboticabal)* 16:281–295.
- _____. 1995. Biodiversity estimates: Ant communities and the rare ant species (Hymenoptera: Formicidae) in a fauna of a sub-tropical island. *Revista de Matemática e Estatística, São Paulo* 13:29–38.
- Fowler, H. G., J. V. E. Bernardi, and L. F. T. di Romagnano. 1990. Community structure and *Solenopsis invicta* in São Paulo. Pp. 199–207. In R. K. Vander Meer, K. Jaffe, and A. Cedeno (eds.), *Applied Myrmecology: A World Perspective*. Westview Press, Boulder, Colorado.
- Fox, M. D., and B. J. Fox. 1982. Evidence for inter-specific competition influencing ant species diversity in a regenerating heathland. Pp. 99–110. In R. C. Buckley (ed.), *Ant-Plant Interactions in Australia*. Dr. W. Junk, The Hague.
- Francoeur, A. 1973. Révision taxonomique des espèces néarctiques du groupe *fusca*, genre *Formica* (Formicidae, Hymenoptera). *Mémoires de la Société Entomologique du Québec* 3:1–316.
- Francoeur, A. 1985. *Formicoxenus quebecensis* Francoeur sp. nov. Pp. 378–379. In A. Francoeur, R. Loiselle, and A. Buschinger. *Biosystématique de la tribu Leptothoracini (Formicidae, Hymenoptera). 1. Le genre Formicoxenus dans la région holarctique*. *Naturaliste Canadian (Québec)* 112:343–403.
- Franks, N. R., and W. H. Bossert. 1983. The influence of swarm raiding army ants on the patchiness and diversity of a tropical leaf-litter ant community. Pp. 151–163. In S. L. Sutton, T. C. Whitmore, and A. C. Chadwick (eds.), *Tropical Rain Forest: Ecology and Management*. Blackwell, Oxford.
- Friese, C. F., and M. F. Allen. 1988. The interaction of harvester ant activity and VA mycorrhizal fungi. *Proceedings of the Royal Society of Edinburgh* 94B:176.
- _____. 1993. The interaction of harvester ants and vesicular-arbuscular mycorrhizal fungi in a patchy semi-arid environment: The effects of mound structure on fungal dispersion and establishment. *Functional Ecology* 7:13–20.
- Gadagkar, R., K. Chandrashekara, and P. Nair. 1990. Insect species diversity in tropics: Sampling methods and a case study. *Journal of the Bombay Natural History Society* 87(3):337–353.
- Gadagkar, R., P. Nair, K. Chandrashekara, and D. M. Bhat. 1993. Ant species richness and diver-

- sity in some selected localities in Western Ghats, India. *Hexapoda* 5:79–94.
- Gaedike, R., 1995. Colecciones entomologicae (1961–1994). *Nova Supplementa. Entomologica* (Berlin) 6:1–83.
- Gallardo, A. 1929. Note sur les moeurs de la fourmi *Pseudoatta argentina*. *Revista de la Sociedad Entomológica Argentina* 2:197–202.
- Gallardo, J. M. 1951. Sobre um Teiidae (Reptilia, Sauria) poco conocido para la fauna Argentina. *Comunicaciones Instituto Nacional de Investigaciones en Ciencia Naturales* 2:8.
- Gallé, L. 1991. Structure and succession of ant assemblages in a north European sand dune area. *Holarctic Ecology* 14:31–37.
- Gaston, K. 1994. *Rarity*. Chapman and Hall, New York.
- . 1996. Species richness: Measure and measurement. Pp. 77–113. In K. J. Gaston (ed.), *Biodiversity: A Biology of Numbers and Difference*. Blackwell, Cambridge.
- Gauch, H. G., Jr. 1982. *Multivariate Analysis in Community Structure*. Cambridge University Press, Cambridge.
- Gauld, I., and B. Bolton. 1988. *The Hymenoptera*. Oxford University Press, New York.
- Goeldi, E. 1897. Die Fortpflanzungsweise von 13 brasilianischen Reptilien. *Zoologische Jahrbücher, Abteilung für Systematik, Geographie und Biologie der Tiere* 10:640–674.
- Goldstein, E. L. 1975. Island biogeography of ants. *Evolution* 29:750–762.
- Goldstein, P. Z. 1999. Functional ecosystems and biodiversity buzzwords. *Conservation Biology* 13:247–255.
- Goncalves, C. R. 1961. O genero *Acromyrmex* no Brasil (Hym. Formicidae). *Studia Entomologica* 4:113–180.
- Gösswald, K. 1932. Ökologische Studien über die Ameisenfauna des mittleren Maingebietes. *Zeitschrift für Wissenschaftliche Zoologie* 142: 1–156.
- Gotelli, N. J. 1993. Ant lion zones: Causes of high-density predator aggregations. *Ecology* 74:226–237.
- . 1996. Ant community structure: Effects of predatory ant lions. *Ecology* 77:630–638.
- Gotwald, W. H., Jr. 1969. Comparative morphological studies of the ants, with particular reference to the mouthparts (Hymenoptera: Formicidae). *Memoirs of the Cornell University Agricultural Experimental Station* 408:1–150.
- . 1982. Army ants. Pp. 157–254. In H. R. Hermann (ed.), *Social Insects*, Vol. 4. Academic Press, New York.
- . 1995. *Army Ants: The Biology of Social Predation*. Cornell University Press, Ithaca, New York.
- Gotwald, W. H., Jr., and W. L. Brown Jr. 1966. The ant genus *Simopelta* (Hymenoptera: Formicidae). *Psyche* (Cambridge) 73:261–277.
- Goulet, H., and J. T. Huber (eds.). 1993. *Hymenoptera of the World: An Identification Guide to Families*. Publication 1894/E. Center for Land and Biological Resources Research, Research Branch, Agriculture Canada, Ottawa, Ontario.
- Greenslade, P., and P. J. M. Greenslade. 1971. The use of baits and preservatives in pitfall traps. *Journal of the Australian Entomological Society* 10:253–260.
- Greenslade, P. J. M. 1964. Pitfall trapping as a method for studying populations of Carabidae (Coleoptera). *Journal of Animal Ecology* 33:301–310.
- . 1971. Interspecific competition and frequency changes among ants in Solomon Islands coconut plantations. *Journal of Applied Ecology* 8:323–352.
- . 1972. Comparative ecology of four tropical ant species. *Insectes Sociaux* 19:195–212.
- . 1973. Sampling ants with pitfall traps: Digging-in effects. *Insectes Sociaux* 20:343–353.
- . 1978. Ants. Pp. 109–113. In W. A. Low (ed.), *The Physical and Biological Features of Kunoth Paddock in Central Australia*. Technical Paper No. 4. CSIRO Division of Land Resources, Canberra.
- . 1979. *A Guide to Ants of South Australia*. South Australian Museum, Adelaide.
- Greenslade, P. J. M., and P. Greenslade. 1977. Some effects of vegetation cover and disturbance on a tropical ant fauna. *Insectes Sociaux* 24:163–182.
- Gregg, R. E. 1959 (1958). Key to the species of *Pheidole* (Hymenoptera: Formicidae) in the United States. *Journal of the New York Entomological Society* 66:7–48.
- . 1963. *The Ants of Colorado*. University of Colorado Press, Boulder.
- Grimaldi, D., Agosti, D., and J. M. Carpenter. 1997. New and rediscovered primitive Ants (Hymenoptera: Formicidae) in Cretaceous Amber from New Jersey, and their phylogenetic Relationships. *American Museum Novitates* 3208:1–43.

- Grime J. P. 1979. Plant Strategies and Vegetation Processes. John Wiley and Sons, Chichester, U.K.
- Haines, B. L. 1978. Element and energy flows through colonies of the leaf-cutting ant, *Atta colombica*, in Panama. *Biotropica* 10:270–277.
- . 1983. Leaf-cutting ants bleed mineral elements out of rainforest in southern Venezuela. *Tropical Ecology* 24:85–93.
- Hamilton, W. D. 1964. The genetical evolution of social behaviour. I. *Journal of Theoretical Biology* 7:1–16.
- Hamilton, W. D. 1972. Altruism and related phenomena, mainly in social insects. *Annual Review of Ecology and Systematics* 3:193–232.
- Handel, S. N., and A. J. Beattie. 1990a. La dispersion des graines par les fourmis. *Pour la Science* 156:54–61.
- . 1990b. Seed dispersal by ants. *Scientific American* 263:76–83.
- Handel, S. N., S. B. Fisch, and G. E. Schatz. 1981. Ants disperse a majority of herbs in a mesic forest community in New York State. *Bulletin of the Torrey Botanical Club* 108:430–437.
- Harada, A. Y., and A. G. Bandeira. 1994. Estratificação e densidade de invertebrados em solo arenoso sob floresta primária e plantios arbóreos na Amazônia central durante estação seca. *Acta Amazonica* 24:103–118.
- Harris, R. A. 1979. A glossary of surface sculpturing. California Department of Food and Agriculture Laboratory Services/Entomology Occasional Papers in Entomology 28:1–31.
- Hashimoto, Y. 1996. Skeletomuscular modifications associated with the formation of an additional petiole on the anterior abdominal segments in aculeate Hymenoptera. *Japanese Journal of Entomology* 64:340–356.
- Hashmi, A. A. 1973. A revision of the Neotropical ant subgenus *Myrmothrix* of genus *Camponotus* (Hymenoptera: Formicidae). *Studia Entomologica* 16:1–140.
- Haskins, C. P., and E. F. Haskins. 1965. *Pheidole megacephala* and *Iridomyrmex humilis* in Bermuda—Equilibrium or slow replacement? *Ecology* 46:736–740.
- . 1988. Final observations on *Pheidole megacephala* and *Iridomyrmex humilis* in Bermuda. *Psyche (Cambridge)* 95:177–184.
- Hayek, L. C., and M. A. Buzas. 1996. Surveying Natural Populations. Columbia University Press, New York.
- Heinze, J., and B. Hölldobler. 1994. Ants in the cold. *Memorabilia Zoologica* 48:99–108.
- Heltshe, J. F., and N. E. Forrester. 1983. Estimating species richness using the jackknife procedure. *Biometrics* 39:1–11.
- Heppner, J. B., and G. Lamas. 1982. Acronyms for world museum collections of insects, with an emphasis on Neotropical Lepidoptera. *Bulletin of the Entomological Society of America* 28: 305–316.
- Heraty, J. M. 1985. A revision of the Nearctic Eucharitinae (Hymenoptera: Chalcidoidea: Eucharitidae). *Proceedings of the Entomological Society of Ontario* 116:61–103.
- . 1986. *Pseudochalcura* (Hymenoptera: Eucharitidae), a New World genus of chalcidoids parasitic on ants. *Systematic Entomology* 11:183–212.
- Heraty, J. M., and D. C. Darling. 1984. Comparative morphology of the planidial larvae of the Eucharitidae and Perilampidae (Hymenoptera: Chalcidoidea). *Systematic Entomology* 9:309–328.
- Herbers, J. M. 1985. Seasonal structuring of a north temperate ant community. *Insectes Sociaux* 32: 224–240.
- . 1989. Community structure in north temperate ants: Temporal and spatial variation. *Oecologia* 81:201–211.
- . 1994. Structure of an Australian ant community with comparisons to North American counterparts (Hymenoptera: Formicidae). *Sociobiology* 24:293–306.
- Herbers, J. M., and S. Grieco. 1994. Population structure of *Leptothorax ambiguus*, a facultatively polygynous and polydomous ant species. *Journal of Evolutionary Biology* 7:581–598.
- Heyer, W. R., M. A. Donnelly, R. W. McDiarmid, L.-A. C. Hayek, and M. S. Foster. 1994. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.
- Hinkle, G., J. K. Wetterer, T. R. Schultz, and M. L. Sogin. 1994. Phylogeny of the attine ant fungi based on analysis of small subunit ribosomal RNA gene sequences. *Science* 266: 1695–1697.
- Hinton, H. E. 1951. Myrmecophilous Lycaenidae and other Lepidoptera—A summary. *Proceedings and Transactions of the South London Entomological and Natural History Society (1949–1950)*: 111–175.

- Hölldobler, B. 1967. Zur Physiologie der Gast-Wirt-Beziehungen (Myrmecophilie) bei Ameisen. I. Das Gastverhältnis der *Atemeles-* und *Lomechusa*-Larven (Col. Staphylinidae) zu *Formica* (Hym. Formicidae). Zeitschrift für Vergleichende Physiologie 56:1–121.
- . 1968. Verhaltensphysiologische Untersuchungen zur Myrmecophilie einiger Staphylinidenlarven. In W. Herre (ed.), Verhandlungen der Deutschen Zoologischen Gesellschaft (Heidelberg, 1967), Zoologischer Anzeiger, Supplement 31:428–434.
- . 1983. Territorial behavior in the green tree ant (*Oecophylla smaragdina*). Biotropica 15:241–250.
- Hölldobler, B., and C. J. Lumsden. 1980. Territorial strategies in ants. Science 210:732–739.
- Hölldobler, B., and Wilson, E. O. 1977. The number of queens: an important trait in ant evolution. Naturwissenschaften 64:8–15.
- . 1990. The Ants. Belknap Press, Cambridge, Massachusetts.
- Hölldobler, K. 1929. Über eine merkwürdige Parasitenerkrankung von *Solenopsis fugax*. Zeitschrift für Parasitenkunde 2:67–72.
- . 1933. Weitere Mitteilungen über Haplosporidien in Ameisen. Zeitschrift für Parasitenkunde 6:91–100.
- Holway, D. A. 1995. Distribution of the Argentine ant (*Linepithema humile*) in Northern California. Conservation Biology 9:1634–1637.
- Holway, D. A., A. V. Suarez, and T. J. Case. 1998. Loss of intraspecific aggression in the success of a widespread invasive social insect. Science 282:949–952.
- Hood, W. G., and W. R. Tschinkel. 1990. Desiccation resistance in arboreal and terrestrial ants. Physiological Entomology 15:23–35.
- Horn, W., and I. Kahle. 1935a. Über Entomologische Sammlungen, Entomologen, und Entomo-Museologie. Entomologische Beihefte, Berlin-Dahlem.
- . 1935b. Supplement to: Über Entomologische Sammlungen, Entomologen, und Entomo-Museologie. Entomologische Beihefte, Berlin-Dahlem.
- Horn, W., I. Kahle, G. Friese, and R. Gaedike. 1990. Colecciones Entomologicae. Ein Kompendium über den Verbleib Entomologischer Sammlungen der Welt bis 1960. Edition Akademischer Landwirtschaftswissenschaften, Berlin.
- Horvitz, C., and D. Schemske. 1990. Spatiotemporal variation in insect mutualists of a neotropical herb. Ecology 71:1085–1097.
- Hudson, K., and A. Nichols (eds.). 1975. The Directory of World Museums. Columbia University Press, New York.
- Huggert, L., and L. Masner. 1983. A review of myrmecophilic-sympatric diapriid wasps in the Holarctic realm, with descriptions of new taxa and a key to genera (Hymenoptera: Proctotrupoidea: Diapriidae). Contributions of the American Entomological Institute 20:63–89.
- Hughes, R. G. 1986. Theories and models of species abundance. American Naturalist 128:879–899.
- Human, K., and D. Gordon. 1996. Exploitative and interference competition between the Argentine ant and native ant species. Oecologia 105:405–412.
- Hung, A. C. F. 1967. A revision of the ant genus *Polyrhachis* at the subgeneric level. Transactions of the American Entomological Society 93:395–422.
- . 1970. A revision of ants of the subgenus *Polyrhachis* Fr. Smith (Hymenoptera: Formicidae: Formicinae). Oriental Insects 4:1–36.
- Huxley, C. R. 1978. The ant-plants *Myrmecodia* and *Hydnophytum* (Rubiaceae), and the relationships between their morphology, ant occupants, physiology and ecology. New Phytologist 80:231–268.
- Huxley, C. R., and D. F. Cutler (eds.). 1991. Ant-Plant Interactions. Oxford University Press, Oxford.
- Iwanami, Y., and T. Iwadare. 1978. Inhibiting effects of myrmecacin on pollen growth and pollen tube mitosis. Botanical Gazette 139:42–45.
- Jackson, D. A. 1984. Ant distribution patterns in a Cameroonian cocoa plantation: Investigation of the ant mosaic hypothesis. Oecologia 62:318–324.
- Jacobson, E. 1909. Ein Mosquito als Gast und diebischer Schmarotzer der *Cremastogaster diffinis* Smith und eine andere schmarotzende Fliege. Tijdschrift voor Entomologie 52:158–164.
- Jaeger, E. C. 1955. A Source-Book of Biological Names and Terms (3rd ed.). Charles C. Thomas, Springfield, Illinois.
- Janet, C. 1897. Sur les rapports de l'*Antennophorus uhlmanni* Haller avec le *Lasius mixtus* Nyl. Comptes Rendus de l'Académie des Sciences Paris 124:583–585.
- Janos, D. P. 1993. Vesicular-arbuscular mycorrhizae of epiphytes. Mycorrhiza 4:1–4.
- Janzen, D. H. 1966. Coevolution of mutualism between ants and acacias in Central America. Evolution 20:249–275.

- _____. 1967. Interaction of the bull's-horn acacia (*Acacia cornigera* L.) with an ant inhabitant (*Pseudomyrmex ferruginea* F. Smith) in eastern Mexico. University of Kansas Science Bulletin 47:315–558.
- Janzen, D. H., M. Ataroff, M. Fariñas, S. Reyes, N. Rincon, A. Soler, P. Soriano, and M. Vera. 1976. Changes in the arthropod community along an elevational transect in the Venezuelan Andes. *Biotropica* 8:193–203.
- Jeanne, R. L. 1979. A latitudinal gradient in rates of ant predation. *Ecology* 60:1211–1224.
- Jebb, M. 1991. Cavity structure and function in the tuberous Rubicaceae. Pp. 374–389. In C. R. Huxley and D. F. Cutler (eds.), *Ant-Plant Interactions*. Oxford University Press, Oxford.
- Johnson, R. A. 1992. Soil texture as an influence on the distribution of the desert seed-harvester ants *Pogonomyrmex rugosus* and *Messor pergandei*. *Oecologia* 89:118–124.
- Jolivet, P. 1996. *Ants and Plants: An Example of Coevolution (Enlarged Edition)*. Backhuys, Leiden, Netherlands.
- Jongman, R. H. G., C. J. F. ter Braak, and O. F. R. van Tongeren. 1995. *Data Analysis in Community and Landscape Ecology*. Cambridge University Press, Cambridge.
- Jouvenaz, D. P. 1986. Diseases of fire ants: Problems and opportunities. Pp. 327–338. In C. S. Lofgren and R. K. Vander Meer (eds.), *Fire Ants and Leaf-Cutting Ants: Biology and Management*. Westview Press, Boulder, Colorado.
- Jouvenaz, D. P., and D. W. Anthony. 1979. *Mattesia geminata* sp. n. (Neogregarinida: Ophrocystidae), a parasite of the tropical fire ant, *Solenopsis geminata* (Fabricius). *Journal of Protozoology* 26:354–356.
- Jouvenaz, D. P., G. E. Allen, W. A. Banks, and D. P. Wojcik. 1977. A survey for pathogens of fire ants, *Solenopsis* spp., in the Southeastern United States. *Florida Entomologist* 60:275–279.
- Kane, M. D. 1997. Microbial fermentation in insect guts. Pp. 231–265. In R. I. Mackie and B. A. White (eds.), *Ecology and Physiology of Gastrointestinal Microbes*. Vol. 1. *Gastrointestinal Fermentations and Ecosystems*. Chapman and Hall, New York.
- Karawajew, W. 1906. Weitere Beobachtungen über Arten der Gattung *Antennophorus*. *Mémoires de la Société des Naturalistes de Kiew* 20:209–230.
- Kareiva, P., J. Kingsolver, and R. Huey. 1993. *Biotic Interactions and Global Change*. Sinauer Associates, Sunderland, Massachusetts.
- Kaspari, M. 1993a. Body size and microclimate use in Neotropical granivorous ants. *Oecologia* 96:500–507.
- _____. 1993b. Removal of seeds from Neotropical frugivore droppings. *Oecologia* 95:81–99.
- _____. 1996a. Litter ant patchiness at the 1 m² scale: Disturbance dynamics in three Neotropical forests. *Oecologia* 107:265–273.
- _____. 1996b. Testing resource-based models of patchiness in four Neotropical litter ant assemblages. *Oikos* 76:443–454.
- _____. 1996c. Worker size and seed size selection by harvester ants in a Neotropical forest. *Oecologia* 105:397–404.
- Kaspari, M., and M. Byrne. 1995. Caste allocation in litter *Pheidole*. *Behavioral Ecology and Sociobiology* 37:255–263.
- Kaspari, M., and E. L. Vargo. 1995. Colony size as a buffer against seasonality: Bergmann's rule in social insects. *American Naturalist* 145:610–632.
- Kaspari, M., and M. Weiser. 1999. The size–grain hypothesis and interspecific scaling in ants. *Functional Ecology* 13:530–538.
- Kaspari, M., and S. Yanoviak. In press. Bait use in tropical litter and canopy ants—evidence for differences in nutrient limitation. *Biotropica*.
- Kaspari, M., L. Alonso, and S. O'Donnell. 2000a. Three energy variables predict ant abundance at a geographic scale. *Proceedings of the Royal Society B* 267:485–490.
- Kaspari, M., S. O'Donnell, and J. Kercher. 2000b. Energy, density, and constraints to species richness: Studies of ant assemblages along a productivity gradient. *American Naturalist* 155:280–293.
- Keeler, K. 1993. Fifteen years of colony dynamics in *Pogonomyrmex occidentalis*, the western harvester ant, in western Nebraska. *Southwestern Naturalist* 38:286–289.
- Kempf, W. W. 1951. A taxonomic study on the ant tribe Cephalotini (Hymenoptera: Formicidae). *Revista Entomologica (Rio de Janeiro)* 22:1–244.
- _____. 1952. A synopsis of the *pinelii*-complex in the genus *Paracryptocerus* (Hym. Formicidae). *Studia Entomologica* 1:1–30.
- _____. 1957. Sôbre algumas espécies de *Procryptocerus* com a descrição duma espécie nova (Hymenoptera, Formicidae). *Revista Brasileira de Biologia* 17:395–404.

- _____. 1958a. New studies of the ant tribe Cephalotini (Hym. Formicidae). *Studia Entomologica* (n.s.) 1:1–168.
- _____. 1958b. Estudos sobre *Pseudomyrmex* II. (Hymenoptera: Formicidae). *Studia Entomologica* (n.s.) 1:433–462.
- _____. 1958c. Sobre algumas formigas neotrópicas do gênero *Lepto thorax* Mayr. *Anais da Academia Brasileira de Ciencias* 30:91–102.
- _____. 1959. Two new species of *Gymnomymrmex* Borgmeier, 1954 from southern Brazil, with remarks on the genus (Hymenoptera, Formicidae). *Revista Brasileira de Biologia* 19:337–344.
- _____. 1960a. *Phalacromyrmex*, a new ant genus from southern Brazil (Hymenoptera, Formicidae). *Revista Brasileira de Biologia* 20:89–92.
- _____. 1960b. A review of the ant genus *Mycetarotes* Emery (Hymenoptera, Formicidae). *Revista Brasileira de Biologia* 20:277–283.
- _____. 1960c. Estudo sobre *Pseudomyrmex* I. (Hymenoptera: Formicidae). *Revista Brasileira de Entomologia* 9:5–32.
- _____. 1961a. A survey of the ants of the soil fauna in Surinam (Hymenoptera: Formicidae). *Studia Entomologica* 4:481–524.
- _____. 1961b. Estudos sobre *Pseudomyrmex* III. (Hymenoptera: Formicidae). *Studia Entomologica* 4:369–408.
- _____. 1962. Retoques à classificação das formigas neotropicais do gênero *Heteroponera* Mayr (Hym., Formicidae). *Papéis Avulsos de Zoologia* (São Paulo) 15:29–47.
- _____. 1963. A review of the ant genus *Mycoceropurus* Forel, 1893 (Hymenoptera: Formicidae). *Studia Entomologica* 6:417–432.
- _____. 1964. A revision of the Neotropical fungus-growing ants of the genus *Cyphomyrmex* Mayr. Part I: Group of *strigatus* Mayr (Hym., Formicidae). *Studia Entomologica* 7:1–44.
- _____. 1965. A revision of the Neotropical fungus-growing ants of the genus *Cyphomyrmex* Mayr. Part II: Group of *rimosus* (Spinola) (Hym., Formicidae). *Studia Entomologica* 8:161–200.
- _____. 1967a. A synopsis of the Neotropical ants of the genus *Centromyrmex* Mayr (Hymenoptera: Formicidae). *Studia Entomologica* 9:401–410.
- _____. 1967b. Estudos sobre *Pseudomyrmex*. IV (Hymenoptera: Formicidae). *Revista Brasileira de Biologia* 12:1–12.
- _____. 1967c. Three new South American ants (Hym. Formicidae). *Studia Entomologica* 10:353–360.
- _____. 1967d. A new revisionary note on the genus *Paracryptocerus* Emery (Hym. Formicidae). *Studia Entomologica* 10:361–368.
- _____. 1968. A new species of *Cyphomyrmex* from Colombia, with further remarks on the genus (Hymenoptera, Formicidae). *Revista Brasileira de Biologia* 28:35–41.
- _____. 1971. A preliminary review of the ponerine ant genus *Dinoponera* Roger (Hymenoptera: Formicidae). *Studia Entomologica* 14:369–394.
- _____. 1972. Catálogo Abreviado das Formigas da Região Neotropical (Hymenoptera: Formicidae). *Studia Entomologica* 15:3–344.
- _____. 1973a. A revision of the Neotropical myrmicine ant genus *Hylomyrma* Forel (Hymenoptera: Formicidae). *Studia Entomologica* 16:225–260.
- _____. 1973b. A new *Zacryptocerus* from Brazil, with remarks on the generic classification of the tribe Cephalotini (Hymenoptera: Formicidae). *Studia Entomologica* 16:449–462.
- _____. 1974a. A review of the Neotropical ant genus *Oxyepoecus* Santschi (Hymenoptera: Formicidae). *Studia Entomologica* 17:471–512.
- _____. 1975a. A revision of the Neotropical ponerine ant genus *Thaumatomyrmex* Mayr (Hymenoptera: Formicidae). *Studia Entomologica* 18:95–126.
- _____. 1975b. Miscellaneous studies on neotropical ants. VI. (Hymenoptera, Formicidae). *Studia Entomologica* 18:341–380.
- Kempf, W. W., and K. Lenko. 1968. Novas observações e estudos sobre *Gigantiops destructor* (Fabricius) (Hymenoptera: Formicidae). *Papéis Avulsos de Zoologia* (São Paulo) 21:209–230.
- Kent, M., and P. Coker. 1992. *Vegetation Description and Analysis: A Practical Approach*. Belhaven Press, London.
- King, J. R., A. N. Andersen, and A. D. Cutter. 1998. Ants as bioindicators of habitat disturbance: Validation of the functional group model for Australia's humid tropics. *Biodiversity and Conservation* 7:1627–1638.
- Kistner, D. H. 1979. Social and evolutionary significance of social insect symbionts. Pp. 339–413. In H. R. Hermann (ed.), *Social Insects*, Vol. 1. Academic Press, New York.
- _____. 1982. The social insects' bestiary. Pp. 1–244. In H. R. Hermann (ed.), *Social Insects*, Vol. 3. Academic Press, New York.
- Kitching, R. L. 1993. Rainforest canopy arthropods: problems for rapid biodiversity assessment. Pp.

- 26–30. In A. J. Beattie (ed.), *Rapid Biodiversity Assessment: Proceedings of the Biodiversity Assessment Workshop*. Macquarie University, Sydney, Australia.
- Kleinfeldt, S. E. 1978. Ant-gardens: The interaction of *Codonanthe crassifolia* (Gesneriaceae) and *Crematogaster longispina* (Formicidae). *Ecology* 59:449–456.
- . 1986. Ant-gardens: Mutual exploitation. Pp. 283–294. In B. Juniper and T. R. E. Southwood (eds.), *Insects and the Plant Surface*. Edward Arnold, London.
- Koch, C. F. 1987. Prediction of sample size effects on the measured temporal and geographic distribution patterns of species. *Paleobiology* 13:100–107.
- Kohout, R. J. 1988. New nomenclature of the Australian ants of the *Polyrhachis gab* Forel species complex (Hymenoptera: Formicidae: Formicinae). *Australian Entomological Magazine* 15:49–52.
- . 1989. The Australian ants of the *Polyrhachis relucens* species-group (Hymenoptera: Formicidae: Formicinae). *Memoirs of the Queensland Museum* 27:509–516.
- . 1990. A review of the *Polyrhachis viehmeyeri* species-group (Hymenoptera: Formicidae: Formicinae). *Memoirs of the Queensland Museum* 28:499–508.
- Kohout, R. J., and R. W. Taylor. 1990. Notes on Australian ants of the genus *Polyrhachis* Fr. Smith, with a synonymic list of the species (Hymenoptera: Formicidae: Formicinae). *Memoirs of the Queensland Museum* 28:509–522.
- Kremen, C. 1992. Assessing the indicator properties of species assemblages for natural area monitoring. *Ecological Applications* 2:203–217.
- Kremen, C., R. K. Colwell, T. L. Erwin, D. D. Murphy, R. F. Noss, and M. A. Sanjayan. 1994. Terrestrial arthropod assemblages: Their use in conservation planning. *Conservation Biology* 7:796–808.
- Kugler, C. 1978. A comparative study of the myrmicine sting apparatus (Hymenoptera: Formicidae). *Studia Entomologica* 20:413–548.
- Kugler, C. 1994. A revision of the ant genus *Rogeria* with description of the sting apparatus (Hymenoptera: Formicidae). *Journal of Hymenoptera Research* 3:17–89.
- Kugler, C., and W. L. Brown Jr. 1982. Revisionary and other studies on the ant genus *Ectatomma*, including the description of two new species. *Search Agriculture* (Ithaca, N.Y.) 24:1–8.
- Kugler, J. 1986. The Leptanillinae (Hymenoptera: Formicidae) of Israel and a description of a new species from India. *Israel Journal of Entomolgy* 20:45–57.
- Kupyanskaya, A. N. 1980. Ants of the genus *Formica* Linnaeus (Hymenoptera, Formicidae) of the Soviet Far East. Pp. 95–108. In P. A. Ler (ed.), *Taxonomy of Insects of the Far East*. Akademiya Nauk SSSR, Vladivostok. [In Russian.]
- . 1986. Ants (Hymenoptera, Formicidae) of the group *Myrmica lobicornis* Nylander from the Far East. Pp. 83–90. In P. A. Ler (ed.), *Systematics and Ecology of Insects from the Far East*. Akademiya Nauk SSSR, Vladivostok. [In Russian.]
- Kusnezov, N. 1951a. El género *Pogonomyrmex* Mayr (Hym., Formicidae). *Acta Zoologica Lilloana* (Tucuman) 11:227–333.
- . 1951b. *Myrmelachista* en la Patagonia (Hymenoptera, Formicidae). *Acta Zoologica Lilloana* (Tucuman) 11:353–365.
- . 1951c. El género *Pheidole* en la Argentina (Hymenoptera, Formicidae). *Acta Zoologica Lilloana* (Tucuman) 12:5–88.
- . 1951d. El género *Camponotus* en la Argentina (Hymenoptera, Formicidae). *Acta Zoologica Lilloana* (Tucuman) 12:183–252.
- . 1951e. El estado real del grupo *Dorymyrmex* Mayr (Hymenoptera, Formicidae). *Acta Zoologica Lilloana* (Tucuman) 10:427–448.
- . 1955. Zwei neue Ameisengattungen aus Tucuman (Argentinien). *Zoologischer Anzeiger* 154:268–277.
- . 1957. Numbers of species of ants in faunae of different latitudes. *Evolution* 11:298–299.
- Kutter, H. 1931. *Forelophilus*, eine neue Ameisen-gattung. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 15:193–195.
- . 1945. Ein neue Ameisengattung. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 19:485–487.
- . 1950. Über eine neue, extrem parasitische Ameise. 1. Mitteilung. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 23:81–94.
- . 1973. Zur Taxonomie der Gattung *Chalepoxenus* (Hymenoptera, Formicidae, Myrmicinae). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 46:269–280.
- Laakso, J., and H. Setälä. 1997. Nest mounds of red wood ants (*Formica aquilonia*): Hot spots for litter-dwelling earthworms. *Oecologia* 111:565–569.

- Lagerheim, G. 1900. Über *Lasius fuliginosus* und seine Pilzzucht. Entomologisk Tidskrift 21:17–29.
- Lamas, G., R. K. Robbins, and D. J. Harvey. 1991. A preliminary survey of the butterfly fauna of Pakitza, Parque Nacional del Manu, Peru, with an estimate of its species richness. Publicaciones del Museo de Historia Natural, Universidad Nacional Mayor de San Marcos A 40:1–19.
- Lambeck, R. J. 1997. Focal species: A multi-species umbrella for nature conservation. *Conservation Biology* 11:849–856.
- Lambson, J., and H. M. Platt. 1985. Structural patterns of marine benthic assemblages and their relationships with empirical statistical models. Pp. 371–380. In P. E. Gibbs (ed.), *Proceedings of the 19th European Marine Biology Symposium*, Plymouth, 1984. Cambridge University Press, Cambridge.
- Landres, P. B., J. Verner, and J. W. Thomas. 1988. Ecological uses of vertebrate indicator species: A critique. *Conservation Biology* 2:316–328.
- Lattke, J. E. 1986. Two new species of neotropical *Anochetus* Mayr (Hymenoptera: Formicidae). *Insectes Sociaux* 33:352–358.
- . 1990. A new genus of myrmicine ants (Hymenoptera: Formicidae) from Venezuela. *Entomologica Scandinavica* 21:173–178.
- . 1991. Studies of neotropical *Amblyopone* Erichson (Hymenoptera: Formicidae). *Contributions in Science*. Los Angeles County Museum 428:1–7.
- . 1995. Revision of the ant genus *Gnamptogenys* in the New World (Hymenoptera: Formicidae). *Journal of Hymenoptera Research* 4:137–193.
- . 1997. Revisión del género *Apterostigma* Mayr (Hymenoptera: Formicidae). *Arquivos de Zoologia (Museu de Zoologia da Universidade de São Paulo)* 34:121–221.
- Lattke, J., and W. Goitia. 1997. El genero *Strumigenys* (Hymenoptera: Formicidae) en Venezuela. *Caldasia* 19(3):367–396.
- Launer, A. E., and D. D. Murphy. 1994. Umbrella species and the conservation of habitat fragments: A case of a threatened butterfly and a vanishing grassland ecosystem. *Biological Conservation* 69:145–153.
- Lavorel, S., S. McIntyre, J. Landsberg, and T. D. A. Forbes. 1997. Plant functional classifications: From general groups to specific groups based on response to disturbance. *Trends in Ecology and Systematics* 12:474–478.
- Lawton, J. 1994. What do species do in ecosystems? *Oikos* 71:364–374.
- Lawton, J. H., D. E. Bifnell, B. Bolton, G. F. Blommers, P. Eggleton, P. M. Hammond, M. Hodda, R. D. Holt, T. B. Larsen, N. A. Mawdsley, N. E. Stork, D. S. Srivastava, and A. D. Watt. 1998. Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. *Nature* 391:72–76.
- Leary, R., and F. Allendorf. 1989. Fluctuating asymmetry as an indicator of stress: Implications for conservation biology. *Trends in Ecology and Evolution* 4:214–217.
- Lee, S. M., and Chao, A. 1994. Estimating population size via sample coverage for closed capture-recapture models. *Biometrics* 50:88–97.
- Le Masne, G. 1941. *Tubicera lichtwardti* Schmitz (Dipt. Phoridae), hôte de *Plagiolepis pygmaea* Latr. (Hym. Formicidae). *Bulletin de la Société Entomologique de France* 46:110–111.
- Lesica, P. 1993. Using plan community diversity in reserve design for pothole prairie on the Blackfeet Indian Reservation, Montana, USA. *Biological Conservation* 65:69–75.
- Lesica, P., and P. Kannowski. 1998. Ants create hummocks and alter structure and vegetation of a mountain fen. *American Midland Naturalist* 139:58–68.
- Lévieux, J. 1976. Étude de la structure du nid de quelques espèces terricoles de fourmis tropicales. *Annales de l'Université d'Abidjan, Serie C: Sciences* 12:23–33.
- . 1983. The soil fauna of tropical savannas. IV. The ants. Pp. 525–540. In F. Bourlière (ed.), *Tropical Savannas: Ecosystems of the World*. Elsevier, Amsterdam.
- Levings, S. C. 1983. Seasonal, annual and among-site variation in the ground ant community of a deciduous tropical forest: Some causes of patchy species distributions. *Ecological Monographs* 53:435–455.
- Levings, S. C., and Traniello, J. F. A. 1981. Territoriality, nest dispersion, and community structure in ants. *Psyche (Cambridge)* 88:265–319.
- Levy R. 1996. Interspecific colony dispersion and niche relations of three large tropical rain forest ant species. Pp. 331–340. In D. S. Edwards, W. E. Booth, and S. C. Choy (eds.), *Tropical Rainforest Research*. Kluwer Academic Publishers, Dordrecht.

- Lieberburg, I., P. M. Kranz, and A. Seip. 1975. Bermudian ants revisited: The status and interaction of *Pheidole megacephala* and *Iridomyrmex humilis*. *Ecology* 56:473–478.
- Lincoln, R. J., and G. A. Boxshall. 1987. *The Cambridge Illustrated Dictionary of Natural History*. Cambridge University Press, Cambridge.
- Linnaeus, C. 1758–1759. *Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis* (10th ed.). Homiae, Salvii. 2v.
- Littledyke, M., and J. M. Cherrett. 1976. Direct ingestion of plant sap from cut leaves by leaf-cutting ants *Atta cephalotes* (L.) and *Acromyrmex octospinosus* (Reich) (Formicidae, Attini). *Bulletin of Entomological Research* 66:205–217.
- Longino, J. T. 1991. *Azteca* ants in Cecropia trees: Taxonomy, colony structure, and behaviour. Pp. 271–288. In C. R. Huxley and D. F. Cutler (eds.), *Ant-Plant Interactions*. Oxford University Press, Oxford.
- . 1994. How to measure arthropod diversity in a tropical rainforest. *Biology International* 28:3–13.
- Longino, J. T., and R. K. Colwell. 1997. Biodiversity assessment using structured inventory: Capturing the ant fauna of lowland tropical rainforest. *Ecological Applications* 7:1263–1277.
- Longino, J. T., and D. A. Hartley. 1994. *Perissomyrmex snyderi* (Hymenoptera: Formicidae) is native to Central America and exhibits worker polymorphism. *Psyche* (Cambridge) 101:195–202.
- Lubin, Y. D. 1984. Changes in the native fauna of the Galápagos Islands following invasion by the little red fire ant, *Wasmannia auropunctata*. *Biological Journal of the Linnean Society* 21:229–242.
- Ludwig, J. A., and J. F. Reynolds. 1988. *Statistical Ecology: A Primer on Methods and Computing*. John Wiley and Sons, New York.
- Luff, M. L. 1975. Some features influencing the efficiency of pitfall traps. *Oecologia* 19: 345–357.
- Lyford, W. H., 1963. Importance of ants to brown podzolic soil genesis in New England. *Harvard Forest Papers* 7.
- Lynch, J. F. 1981. Seasonal, successional, and vertical segregation in a Maryland ant community. *Oikos* 37:183–198.
- MacArthur, R., and E. O. Wilson. 1967. *The Theory of Island Biogeography*. Princeton University Press, Princeton, New Jersey.
- Mack, A. L. (ed.). 1998. A biological assessment of the Lakekamu basin, Papua New Guinea. RAP Working Papers No. 9. Conservation International, Washington, D.C.
- MacKay, W. P. 1993. A review of the New World ants of the genus *Dolichoderus* (Hymenoptera: Formicidae). *Sociobiology* 22:1–148.
- . 1996. A revision of the ant genus *Acanthostichus* (Hymenoptera: Formicidae). *Sociobiology* 27:129–179.
- . 1997. A revision of the Neotropical ants of the genus *Camponotus*, subgenus *Myrmostenus* (Hymenoptera: Formicidae). *Proceedings of the Entomological Society of Washington* 99(1): 194–203.
- . 2000. A review of the New World ants of the subgenus *Myrafant*, genus *Lepto thorax* (Hymenoptera: Formicidae). *Sociobiology* 36(2): 263–444.
- MacKay, W. P., and E. Mackay. 1997. A revision of the Neotropical ants of the *montivagus* species complex, genus *Camponotus*, subgenus *Myrmecoma* (Hymenoptera: Formicidae). *Sociobiology* 30(3):319–334.
- MacKay, W. P., and S. B. Vinson. 1989. A guide to the species identification of the New World ants. *Sociobiology* 16:3–47.
- Magurran, A. E. 1988. *Ecological Diversity and Its Measurement*. Princeton University Press, Princeton, New Jersey.
- Majer, J. D. 1976. The maintenance of the ant mosaic in Ghana cocoa farms. *Journal of Applied Ecology* 13:123–144.
- . 1980. The influence of ants on broadcast and naturally spread seeds in rehabilitated bauxite mined areas. *Reclamation Review* 3:3–9.
- . 1983. Ants: Bioindicators of minesite rehabilitation, land-use, and land conservation. *Environmental Management* 7(4):375–383.
- . 1984. Recolonisation by ants in rehabilitated open-cut mines in Northern Australia. *Reclamation and Revegetation Research* 2:279–298.
- . 1985. Recolonization by ants of rehabilitated mineral sand mines on North Stradbroke Island, Queensland, with particular reference to seed removal. *Australian Journal of Ecology* 10: 31–48.

- _____. 1990. The abundance and diversity of arboreal ants in northern Australia. *Biotropica* 22: 191–199.
- _____. 1992. Ant recolonization of rehabilitated bauxite mines of Poços de Caldos, Brasil. *Journal of Tropical Ecology* 8:97–108.
- _____. 1996. The use of pitfall traps for sampling ants: A critique. *Proceedings of the Museum of Victoria* 56:323–329.
- Majer, J. D., and A. E. de Kock. 1992. Ant recolonization of sand mines near Richards Bay, South Africa: An evaluation of progress with rehabilitation. *South African Journal of Science* 88: 31–36.
- Majer, J. D., and J. H. C. Delabie. 1994. Comparison of the ant communities of annually inundated and terra firme forests at Trombetas in the Brazilian Amazon. *Insectes Sociaux* 41:343–359.
- Majer, J. D., and O. G. Nichols. 1998. Long-term recolonization patterns of ants in rehabilitated bauxite mines, Western Australia. *Journal of Applied Ecology* 35:161–181.
- Majer, J. D., Day, J. E., Kabay, E. D., and Perriman, W. S. 1984. Recolonization by ants in bauxite mines rehabilitated by a number of different methods. *Journal of Applied Ecology* 21:355–375.
- Majer, J. D., J. H. C. Delabie, and N. L. McKenzie. 1997. Ant litter fauna of forest, forest edges and adjacent grasslands in the Atlantic rain forest region of Bahia, Brazil. *Insectes Sociaux* 44:255–266.
- Malicky, H. 1969. Versuch einer Analyse der ökologischen Beziehungen zwischen Lycaeniden (Lepidoptera) und Formiciden (Hymenoptera). *Tijdschrift voor Entomologie* 112:213–298.
- Mann, W. M. 1916. The Stanford Expedition to Brazil, 1911, John C. Branner, Director: The ants of Brazil. *Bulletin of the Museum of Comparative Zoology, Harvard College* 60:399–490.
- _____. 1921. The ants of the Fiji Islands. *Bulletin of the Museum of Comparative Zoology, Harvard College* 64:401–499.
- _____. 1926. Some new neotropical ants. *Psyche (Cambridge)* 33:97–107.
- Marsh, A. C. 1984. The efficacy of pitfall traps for determining the structure of a desert ant community. *Journal of the Entomological Society of South Africa* 47:115–120.
- _____. 1985. Forager abundance and dietary relationships in a Namib Desert ant community. *South African Journal of Zoology* 20:197–203.
- _____. 1986. Ant species richness along a climatic gradient in the Namib Desert. *Journal of Arid Environments* 11:235–241.
- Martin, J. 1977. Collecting, Preparing, and Preserving Insects, Mites, and Spiders. *The Insects and Arachnids of Canada, Part 1*. Agriculture Canada, Ottawa.
- Maschwitz, U. 1974. Vergleichende Untersuchungen zur Funktion der Ameisenmetathorakaldruse. *Oecologia* 16:303–310.
- Maschwitz, U., and H. Hänel. 1985. The migrating herdsman *Dolichoderus (Diabolus) cuspidatus*: An ant with a novel mode of life. *Behavioral Ecology and Sociobiology* 17:171–184.
- Maschwitz, U., and B. Hölldobler. 1970. Der Kartonnestbau bei *Lasius fuliginosus* Latr. (Hym. Formicidae). *Zeitschrift für Vergleichende Physiologie* 66:176–189.
- Maschwitz, U., and P. Schönegge. 1980. Fliegen als Beute- und Bruträuber bei Ameisen. *Insectes Sociaux* 27:1–4.
- Maschwitz, U., K. Koob, and H. Schildknecht. 1970. Ein Beitrag zur Funktion der Metathorakaldruse der Ameisen. *Journal of Insect Physiology* 16:387–404.
- Masner, L. 1976. Notes on the ectophilous diapriid genus *Mimopria* Holmgren (Hymenoptera: Proctotrupoidea, Diapriidae). *Canadian Entomologist* 108:123–126.
- Masuko, K. 1984. Studies on the predatory biology of oriental Dacetine ants (Hymenoptera: Formicidae). I. Some Japanese species of *Strumigenys*, *Pentastruma*, and *Epitritus*, and a Malaysian *Labidogenys*, with special reference to hunting tactics in short-mandibulate forms. *Insectes Sociaux* 31:429–451.
- _____. 1995 (1994). Specialized predation on oribatid mites by two species of the ant genus *Myrmecina* (Hymenoptera: Formicidae). *Psyche (Cambridge)* 101:159–173.
- May, R. M. 1975. Patterns of species abundance and diversity. Pp. 81–120. In M. L. Cody and J. M. Diamond (eds.), *Ecology and Evolution of Communities*. Belknap Press, Cambridge, Massachusetts.
- _____. 1990. How many species? *Philosophical Transactions of the Royal Society of London, Series B* 330 (1257):293–304.
- Mahyé-Nunes, A. 1995. Sinopse do gênero *Mycetarotes* (Hym., Formicidae), com a descrição de duas espécies novas. *Boletim de Entomologia Venezolana* 10(2):197–205.

- Mayr, E. 1942. Systematics and the Origin of Species. Columbia University Press, New York.
- McAreavey, J. 1947. New species of the genera *Prolasius* Forel and *Melophorus* Lubbock (Hymenoptera, Formicidae). Memoirs of the National Museum of Victoria 15:7–27.
- . 1957. Revision of the genus *Stigmachus*. Memoirs of the National Museum of Victoria 21:7–64.
- McArthur, A. J., and M. Adams. 1996. A morphological and molecular revision of the *Camponotus nigriceps* group (Hymenoptera: Formicidae) from Australia. Invertebrate Taxonomy 10(1):1–46.
- McCoy, E. D. 1990. The distribution of insects along elevational gradients. Oikos 58:313–322.
- McGlynn, T. P. 1999a. The biogeography, behavior, and ecology of exotic ants (178 pp.). Ph.D. dissertation, University of Colorado, Boulder, Colorado.
- McGlynn, T. P. 1999b. The worldwide transfer of ants: geographic distribution and ecological invasions. Journal of Biogeography 26:535–548.
- McGlynn, T. P., and C. D. Kelley. 1999. Distribution of a Costa Rican wet forest velvet worm (Onychophora, Peripatidae). Annals of the Entomological Society of America 92:53–55.
- McIlveen, W. D., and H. Cole Jr. 1976. Spore dispersal of Endogonaceae by worms, ants, wasps, and birds. Canadian Journal of Botany 54:1486–1489.
- Medel, R. G., and R. A. Vásquez. 1994. Comparative analysis of harvester ant assemblages of Argentinian and Chilean arid zones. Journal of Arid Environments 26:363–371.
- Menzoli, C. 1929. Revisione delle formiche del genere *Mystrium* Roger. Zoologischer Anzeiger 82:518–536.
- . 1939. Formiche dell'Himalaya e del Karakorum raccolte dalla Spedizione italiana comandata da S. A. R. il Duca di Spoleto (1929). Atti della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale (Milan) 78:285–345.
- Michener, C. D. 1944. Comparative external morphology, phylogeny, and a classification of bees. Bulletin of the American Museum of Natural History 2:151–326.
- Miehe, H. 1911a. Javanische Studien. II. Untersuchungen über die javanische *Myrmecodia*. Abhandlungen der kaiserlichen Sächsischen Gesellschaft der Wissenschaften Mathematisch-physischer Klasse 32:312–361.
- . 1911b. Ueber die javanische *Myrmecodia* und die Beziehung zu ihren Ameisen. Biologisches Zentralblatt 31:733–738.
- Moffett, M. W. 1985. Revision of the genus *Myrmoteras* (Hymenoptera: Formicidae). Bulletin of the Museum of Comparative Zoology, Harvard College 151:1–53.
- . 1986. Revision of the myrmicine genus *Acanthomyrmex* (Hymenoptera: Formicidae). Bulletin of the Museum of Comparative Zoology, Harvard College 151:55–89.
- Moncalvo, J.-M., F. M. Lutzoni, S. A. Rehner, J. Johnson, and R. Vilgalys. 2000. Phylogenetic relationships of agaric fungi based on nuclear large subunit ribosomal DNA sequences. Systematic Biology 49:278–305.
- Morton, S. R., and D. W. Davidson. 1988. Comparative structure of harvester ant communities in arid Australia and North America. Ecological Monographs 58:19–38.
- Moser, J. C. 1964. Inquiline roach responds to trail-marking substance of leaf-cutting ants. Science 143:1048–1049.
- Mueller, U. G., S. A. Rehner, and T. R. Schultz. 1998. The evolution of agriculture in ants. Science 281:2034–2038.
- Munger, J. C. 1992. Reproductive potential of colonies of desert harvester ants (*Pogonomyrmex desertorum*): effects of predation and food. Oecologia 90:276–282.
- Nepstad, D. C., P. Jipp, P. Mautinho, G. Negreiros, and S. Vieira. 1995. Forest recovery following pasture abandonment in Amazonia: Canopy seasonality, fire resistance and ants. Pp. 333–349. In D. J. Rapport, C. L. Gaudet, and P. Calow (eds.): Evaluating and Monitoring the Health of Large-Scale Ecosystems. NATO ASI Series 128.
- New, T. R. 1987. Insect conservation in Australia: Towards rational ecological priorities. Pp. 5–20. In J. D. Majer (ed.), The Role of Invertebrates in Conservation and Biological Survey. Western Australian Department of Conservation and Land Management, Perth, Australia.
- Noss, R. F. 1990. Indicators for monitoring biodiversity: A hierarchical approach. Conservation Biology 4:355–364.
- O'Dowd, D. J. 1982. Pearl bodies as ant food: An ecological role for some leaf emergences of tropical plants. Biotropica 14:40–49.
- Ogata, K. 1982. Taxonomic study of the ant genus *Pheidole* Westwood of Japan, with a description

- of a new species (Hymenoptera, Formicidae). *Kontyû* 50:189–197.
- . 1990. A new species of the ant genus *Epitritus* Emery from Japan (Hymenoptera, Formicidae). *Esakia Special Issue* 1:197–199.
- Ogata, K., and K. Onoyama. 1998. A revision of the ant genus *Smithistruma* Brown of Japan, with descriptions of four new species (Hymenoptera: Formicidae). *Entomological Science* 1(2):277–287.
- Ogata, K., and W. L. Brown Jr. 1991. Ants of the genus *Myrmecia* Fabricius: A preliminary review and key to the named species. *Journal of Natural History* 25:1623–1673.
- Oliveira, P. S. 1988. Ant-mimicry in some Brazilian salticid and clubionid spiders (Araneae: Salticidae, Clubionidae). *Biological Journal of the Linnean Society* 33:1–15.
- Oliveira, P. S., and I. Sazima. 1984. The adaptive bases of ant-mimicry in a Neotropical aphantochilid spider (Araneae: Aphantochilidae). *Biological Journal of the Linnean Society* 22:145–155.
- Oliveira, P. S., M. Galetti, F. Pedroni, and L. P. C. Morellato. 1995. Seed cleaning by *Mycocepurus goeldii* ants (Attini) facilitates germination in *Hymenaea courbaril* (Caesalpiniaceae). *Biotropica* 27:518–522.
- Oliver, I., and A. J. Beattie. 1996a. Invertebrate morphospecies as surrogates for species: A case study. *Conservation Biology* 10:99–109.
- . 1996b. Designing a cost-effective invertebrate survey: A test of methods for rapid assessment of biodiversity. *Ecological Applications* 6:594–607.
- Oliver I., A. J. Beattie, and A. York. 1998. Spatial fidelity of plant, vertebrate and invertebrate assemblages in multiple-use forest in Eastern Australia. *Conservation Biology* 12(4):822–835.
- Olson, D. M. 1991. A comparison of the efficacy of litter sifting and pitfall traps for sampling leaf litter ants (Hymenoptera: Formicidae) in a tropical wet forest, Costa Rica. *Biotropica* 23:166–172.
- . 1992. Rates of predation by ants (Hymenoptera: Formicidae) in the canopy, understory, leaf litter, and edge habitats of a lowland rainforest in southwestern Cameroon. Pp. 101–109. *In* F. Hall and O. Pascal (eds.), *Biologie d'une Canopie de Forêt Equatoriale II*. Fondation Elf, Paris.
- . 1994. The distribution of leaf litter invertebrates along a Neotropical altitudinal gradient. *Journal of Tropical Ecology* 10:129–150.
- Onoyama, K. 1998. Taxonomic notes on the ant genus *Crematogaster* in Japan (Hymenoptera: Formicidae). *Entomological Science* 1(2):227–232.
- Orlóci, L. 1978. *Multivariate Analysis in Vegetation Research*. Dr. W. Junk, The Hague.
- Orr, A. G., and J. K. Charles. 1994. Foraging in the giant forest ant, *Camponotus gigas* (Smith) (Hymenoptera: Formicidae): Evidence for temporal and spatial specialization in foraging activity. *Journal of Natural History* 28:861–872.
- Orr, M. R. 1992. Parasitic flies (Diptera: Phoridae) influence foraging rhythms and caste division of labor in the leaf-cutter ant *Atta cephalotes* (Hymenoptera: Formicidae). *Behavioral Ecology and Sociobiology* 30:395–402.
- Overal, W. L., and A. G. Bandeira. 1985. Nota sobre hábitos de *Cylindromyrmex striatus* Mayr, 1870, na Amazonia (Formicidae, Ponerinae). *Revista Brasileira de Entomologia* 29:521–522.
- Paine, R. 1968. A note on trophic complexity and community stability. *American Naturalist* 102:91–93.
- Palmer, A., and C. Strobeck. 1986. Fluctuating asymmetry: Measurement, analysis, patterns. *Annual Review of Ecology and Systematics* 17:391–421.
- Palacio, E. 1997. Ants of Colombia VI. Two new species of *Octostruma* (Hymenoptera: Formicidae: Basicerotini). *Caldasia* 19(3):409–418.
- Palmer, M., R. Ambrose, and N. Poff. 1997. Ecological theory and community restoration ecology. *Restoration Ecology* 5:291–300.
- Passera, L. 1994. Characteristics of tramp species. Pp. 23–43. *In* D. F. Williams (ed.), *Exotic Ants: Biology, Impact, and Control of Introduced Species*. Westview Press, Boulder, Colorado.
- Peakall, R., S. N. Handel, and A. J. Beattie. 1991. The evidence for, and importance of, ant pollination. Pp. 421–429. *In* C. R. Huxley and D. F. Cutler (eds.), *Ant-Plant Interactions*. Oxford University Press, Oxford.
- Pearson, D. L., and F. Cassola. 1992. World-wide species richness patterns of tiger beetles (Coleoptera: Cicindelidae): Indicator taxon for biodiversity and conservation studies. *Conservation Biology* 6:376–391.
- Peeters, C. 1991. The occurrence of sexual reproduction among ant workers. *Biological Journal of the Linnean Society* 44:141–152.

- Perfecto, I., and R. R. Snelling. 1995. Biodiversity and the transformation of a tropical agroecosystem: Ants in coffee plantations. *Ecological Applications* 5:1084–1097.
- Petal, J., H. Jakubczyk, A. Breymeyer, and E. Olechowicz. 1971. Productivity investigation of two types of meadows in the Vistula Valley. X. Role of the ants as predators in a habitat. *Ekologia polska* 19:213–222.
- Petersen, B. 1968. Some novelties in presumed males of Leptanillinae (Hym., Formicidae). *Entomologiske Meddelelser* 36:577–598.
- Pharo, E. J., A. J. Beattie, and D. Binns. 1999. Vascular plant diversity as a surrogate for bryophyte and lichen diversity. *Conservation Biology* 13:282–292.
- Pielou, E. C. 1966. Species diversity and pattern diversity in the study of ecological succession. *Journal of Theoretical Biology* 10:370–383.
- . 1969. An Introduction to Mathematical Ecology. John Wiley and Sons, New York.
- . 1975. Ecological Diversity. John Wiley and Sons, New York.
- . 1984. The Interpretation of Ecological Data: A Primer on Classification and Ordination. John Wiley and Sons, New York.
- Pierce, N. E. 1987. The evolution and biogeography of association between Lycaenid butterflies and ants. Pp. 89–116. In P. H. Harvey and L. Partridge (eds.), Oxford Surveys in Evolutionary Biology, Vol. 4. Oxford University Press, New York.
- Pierce, N. E., and S. Easteal. 1986. The selective advantage of attendant ants for the larvae of a lycaenid butterfly, *Glaucoopsyche lygdamus*. *Journal of Animal Ecology* 55:451–462.
- Pierce, N. E., and P. S. Mead. 1981. Parasitoids as selective agents in the symbiosis between lycaenid butterfly larvae *Glaucoopsyche lygdamus* and ants. *Outlook* 211:1185–1187.
- Pisarski, B. 1966. Études sur les fourmis du genre *Strongylognathus* Mayr (Hymenoptera, Formicidae). *Annales Zoologici (Warsaw)* 23:509–523.
- Poggi, R., and C. Conci. 1996. Elenco delle collezioni entomologiche conservate nelle strutture pubbliche italiane. *Memorie della Società Entomologica Italiana* 75:3–157.
- Poole, R. W. 1974. An Introduction to Quantitative Ecology. McGraw-Hill, New York.
- Porter, S. D. 1999. FORMIS99: A Master Bibliography of Ant Literature (computer data-base). Published by the author, Gainesville, Florida. <http://cmave.usda.ufl.edu/~formis/>
- Porter, S. D., and M. A. Bowers. 1981. Emigration of an *Atta* colony. *Biotropica* 12:232.
- Porter, S. D., and C. D. Jorgensen. 1988. Longevity of harvester ant colonies in southern Idaho. *Journal of Range Management* 41:104–107.
- Porter, S. D., and D. A. Savignano. 1990. Invasion of polygyne fire ants decimates native ants and disrupts arthropod community. *Ecology* 71:2095–2106.
- Porter, S. D., H. G. Fowler, and W. P. Mackay. 1992. Fire ant mound densities in the United States and Brazil (Hymenoptera: Formicidae). *Journal of Economic Entomology* 85:1154–1161.
- Porter, S. D., H. G. Fowler, S. Campiolo, and M. A. Pesquero. 1995a. Host specificity of several *Pseudacteon* (Diptera: Phoridae) parasites of fire ants (Hymenoptera: Formicidae) in South America. *Florida Entomologist* 78: 70–75.
- Porter, S. D., M. A. Pesquero, S. Campiolo, and H. G. Fowler. 1995b. Growth and development of *Pseudacteon* phorid fly maggots (Diptera: Phoridae) in the heads of *Solenopsis* fire ant workers (Hymenoptera: Formicidae). *Environmental Entomology* 24:475–479.
- Porter, S. D., R. K. Vander Meer, M. A. Pesquero, S. Campiolo, and H. G. Fowler. 1995c. *Solenopsis* (Hymenoptera: Formicidae) fire ant reactions to attacks of pseudacteon flies (Diptera: Phoridae) in southeastern Brazil. *Annals of the Entomological Society of America* 88:570–575.
- Prendergast, J. R., R. M. Quinn, J. H. Lawton, B. C. Eversham, and D. W. Gibbons. 1993. Rare species, the coincidence of diversity hotspots and conservation strategies. *Nature* 365:335–337.
- Preston, F. W. 1948. The commonness, and rarity, of species. *Ecology* 29:254–283.
- Prins, A. J. 1982. Review of *Anoplolepis* with reference to male genitalia, and notes on *Acropyga* (Hymenoptera, Formicidae). *Annals of the South African Museum* 89:215–247.
- . 1983. A new ant genus from southern Africa (Hymenoptera, Formicidae). *Annals of the South African Museum* 94:1–11.
- Quinlan, R. J., and J. M. Cherrett. 1979. The role of substrate preparation in the symbiosis between the leaf cutting ant *Acromyrmex octospinosus* (Reich) and its food fungus. *Ecological Entomology* 2:161–170.

- _____. 1979. The role of fungus in the diet of the leaf-cutting ant *Atta cephalotes* (L.). *Ecological Entomology* 4:151–160.
- Quiroz-Robledo, L., and J. Valenzuela-González. 1995. A comparison of ground ant communities in a tropical rainforest and adjacent grassland in Los Tuxtlas, Veracruz, Mexico. *Southwestern Entomologist* 20:203–213.
- Raaijmakers, J. G. W. 1987. Statistical analysis of the Michaelis-Menten equation. *Biometrics* 43:793–803.
- Radchenko, A. G. 1985. Ants of the genus *Strongylognathus* (Hymenoptera: Formicidae) in the European part of the USSR. *Zoologicheskii Zhurnal* 64:1514–1523. [In Russian.]
- _____. 1989a. The ants of the genus *Chalepoxenus* (Hymenoptera, Formicidae) of the USSR fauna. *Vestnik Zoologii* 1989(2):37–41. [In Russian.]
- _____. 1989b. Ants of the *Plagiolepis* genus of the European part of the USSR. *Zoologicheskii Zhurnal* 68(9):153–156. [In Russian.]
- _____. 1991. Ants of the genus *Strongylognathus* (Hymenoptera, Formicidae) of the USSR fauna. *Zoologicheskii Zhurnal* 70(10):84–90. [In Russian.]
- _____. 1992. Ants of the genus *Tetramorium* (Hymenoptera, Formicidae) of the USSR fauna. Report 1. *Zoologicheskii Zhurnal* 71(8):39–49. [In Russian.]
- _____. 1993. Ants of the subfamily Cerapachyinae from Vietnam. *Zhurnal Ukrains'koho Entomolohichnoho Tovarystva* 1:43–47.
- _____. 1994a. Identification table for ants of the genus *Leptothorax* (Hymenoptera, Formicidae) from central and eastern Palearctic. *Zoologicheskii Zhurnal* 73(7–8):146–158. [In Russian.]
- _____. 1994b. A review of the ant genus *Leptothorax* (Hymenoptera, Formicidae) of the central and eastern Palearctic. Communication 1. Subdivision into groups. Groups *acervorum* and *bulgaricus*. *Vestnik Zoologii* 1994(6):22–28. [In Russian.]
- _____. 1995. Palearctic ants of the genus *Cardiocondyla* (Hymenoptera, Formicidae). *Entomologicheskoe Obozrenie* 74:447–455.
- _____. 1996a. A key of the ant genus *Camponotus* (Hymenoptera, Formicidae) in Palearctic Asia. *Zoologicheskii Zhurnal* 75(8):1195–1203. [In Russian].
- _____. 1996b. Ants of the genus *Plagiolepis* Mayr (Hymenoptera, Formicidae) of Central and Southern Palearctic. *Entomologicheskoe Obozrenie* 75(1):178–187.
- _____. 1997. Review of the ants of *scabriceps* group of the genus *Monomorium* Mayr (Hymenoptera, Formicidae). *Annales Zoologici (Warsaw)* 46(3–4):211–224.
- _____. 1998. A key to ants of the genus *Cataglyphis* Foerster (Hymenoptera, Formicidae) of Asia. *Entomologicheskoe Obozrenie* 77(2):502–508, 527. [In Russian].
- Radchenko, A. G., and G. R. Arakelian. 1990. Murav'i gruppy *Tetramorium ferox* Ruzsky iz Kryma i Kavkaza. *Biologicheskii Zhurnal Armenii* 43:371–378.
- Radchenko, A. G., and G. W. Elmes. 1998. Taxonomic revision of the *ritae* species-group of the genus *Myrmica* (Hymenoptera, Formicidae). *Vestnik Zoologii* 32(4):3–27.
- Radchenko, A. G., W. Czechowski, and W. Czechowska. 1997. The genus *Myrmica* Latr. (Hymenoptera, Formicidae) in Poland—A survey of species and a key for their identification. *Annales Zoologici (Warsaw)* 47(3–4): 481–500.
- Rahbek, C. 1995. The elevational gradient of species richness: A uniform pattern? *Ecography* 18:200–205.
- _____. 1997. The relationship among area, elevation, and regional species richness in Neotropical birds. *American Naturalist* 149:875–902.
- Redford, K. H. 1987. Ants and termites as food: Patterns of mammalian myrmecophagy. Pp. 349–399. In H. H. Genoways (ed.), *Current Mammalogy*, Vol. 1. Plenum Press, New York.
- Reichel, H., and A. N. Andersen. 1996. The rainforest ant fauna of Australia's Northern Territory. *Australian Journal of Zoology* 44:81–95.
- Retana, J., X. Cerdá, and X. Espadaler. 1991. Arthropod corpses in a temperate grassland: A limited supply? *Holarctic Ecology* 14:63–67.
- Rettenmeyer, C. W. 1962. The diversity of arthropods found with Neotropical army ants and observations on the behavior of representative species. *Proceedings of the North Central Branch of the Entomological Society of America* 17:14–15.
- _____. 1963. Behavioral studies of army ants. *University of Kansas Science Bulletin* 44:281–465.
- Rettenmeyer, C. W., R. Chadab Crepet, M. G. Naumann, and L. Morales. 1983. Comparative foraging by Neotropical army ants. Pp. 59–73.

- In P. Jaisson (ed.), Social Insects in the Tropics. Université Paris-Nord, Paris.
- Rettig, E. 1904. Ameisenpflanzen-Pflanzenameisen. Beihete zum Botanischen Zentralblatt 17:89–122.
- Rickson, F. R. 1971. Glycogen plastids in Muellerian body cells of *Cecropia peltata*, a higher green plant. Science 173:344–347.
- Rigato, F. 1994a. *Dacatria templaris* gen. n., sp. n. A new myrmicine ant from the Republic of Korea. Deutsche Entomologische Zeitschrift (Neue Folge) 41:155–162.
- _____. 1994b. Revision of the myrmicine ant genus *Lophomyrmex*, with a review of its taxonomic position (Hymenoptera: Formicidae). Systematic Entomology 19:47–60.
- Rissing, S. W. 1987. Annual cycles in worker size of the seed-harvester ant *Veromessor pergandei* (Hymenoptera: Formicidae). Behavioral Ecology and Sociobiology 20:117–124.
- Robertson, H. G. 1990. Unravelling the *Camponotus fulvopilosus* species complex (Hymenoptera: Formicidae). Pp. 327–328. In G. K. Veeresh, B. Mallik, and C. A. Viraktamath (eds.), Social Insects and the Environment. Proceedings of the 11th International Congress of IUSSI, 1990. Oxford and IBH, New Delhi.
- Robinson, S. R., and J. Terborgh. 1990. Bird communities of the Cocha Cashu Biological Station in Amazonian Peru. Frogs, snakes, and lizards of the INPA-WWF reserves near Manaus, Brazil. Pp. 199–216. In A. H. Gentry (ed.), Four Neotropical Rainforests. Yale University Press, New Haven, Connecticut.
- Roepke, W. 1930. Ueber einen merkwürdigen Fall von "Myrmekophilie" bei einer Ameise (*Cladomyrma* sp.?) auf Sumatra beobachtet. Miscellanea Zoologica Sumatrana 45:1–3.
- Rogerson, C. T. 1970. The hypocrealean fungi (Ascomycetes, Hypocreales). Mycologia 62:865–910.
- Rohlfien, K. 1979. Aus der Geschichte der entomologischen Sammlungen des ehemaligen Deutschen Entomologischen Instituts. Beiträge für Entomologie (Berlin) 29:415–438.
- Romero, H., and K. Jaffe. 1989. A comparison of methods for sampling ants (Hymenoptera: Formicidae) in savannas. Biotropica 21: 348–352.
- Room, P. M. 1971. The relative distribution of ant species in Ghana's cocoa farms. Journal of Animal Ecology 40:735–751.
- _____. 1975. Diversity and organization of the ground foraging ant fauna of forest, grassland and tree crops in Papua New Guinea. Australian Journal of Ecology 23:71–89.
- Rosciszewski, K. 1994. *Rostromyrmex*, a new genus of myrmicine ants from peninsular Malaysia (Hymenoptera: Formicidae). Entomologica Scandinavica 25(2):159–168.
- _____. 1995. Die Ameisenfauna eines tropischen Tieflandregenwaldes in Südostasien: Eine faunistisch und ökologische Bestandsaufnahme. Thesis, Johann Wolfgang Goethe Universität, Frankfurt am Main, Germany.
- Rosengren, R., and P. Pamilo. 1983. The evolution of polygyny and polydomy in mound-building *Formica* ants. Acta Entomologica Fennica 42:65–77.
- Rosenzweig, M. L. 1995. Species Diversity in Space and Time. Cambridge University Press, Cambridge.
- Ross, K. G., and J. C. Trager. 1990. Systematics and population genetics of fire ants (*Solenopsis saevissima* complex) from Argentina. Evolution 44: 2113–2134.
- Roth, D. S., I. Perfecto, and B. Rathcke. 1994. The effects of management systems on ground-foraging ant diversity in Costa Rica. Ecological Applications 4:423–436.
- Ryti, R. T., and T. J. Case. 1988a. Field experiments on desert ants: Testing for competition between colonies. Ecology 69:1993–2003.
- _____. 1988b. The regeneration niche of desert ants: Effects of established colonies. Oecologia 75:303–306.
- _____. 1992. The role of neighborhood competition in the spacing and diversity of ant communities. American Naturalist 139:355–374.
- Sabrosky, C. W. 1959. A revision of the genus *Pholeomyia* in North America (Diptera Milichiidae). Annals of the Entomological Society of America 52:316–331.
- Sachtleben, H. 1961. Second supplement to: Über entomologische Sammlungen, Entomologen, und Entomo-Museologie. Beiträge zur Entomologie 11:481–540.
- Sampson, D. A., E. A. Rickart, and P. C. Gonzales. 1997. Ant diversity and abundance along an elevational gradient in the Philippines. Biotropica 29:349–363.
- Santschi, F. 1923a. Revue des fourmis du genre *Brachymyrmex* Mayr. Anales del Museo Nacional de Historia Natural de Buenos Aires 31:650–678.

- _____. 1923b. Descriptions de nouveaux Formicides éthiopiens et notes diverses. I. Revue de Zoologie Africaine 11:259–295.
- _____. 1929. Fourmis du Maroc, d'Algérie et de Tunisie. Bulletin et Annales de la Société Royale Entomologique de Belgique 69:138–165.
- _____. 1936. Fourmis nouvelles ou intéressantes de la République Argentine. Revista Entomología (Rio de Janeiro) 6:402–421.
- _____. 1937. Les sexués du genre *Anillidris* Santschi. Bulletin de la Société Entomologique de France 42:68–70.
- Savolainen, R. 1990. Colony success of the submissive ant *Formica fusca* within territories of the dominant *Formica polycetna*. Ecological Entomology 15:79–85.
- Savolainen, R., and K. Vepsäläinen. 1988. A competition hierarchy among boreal ants: Impact on resource partitioning and community structure. Oikos 51:135–155.
- Schimpfer, A. F. W. 1888. Die Wechselbeziehungen zwischen Pflanzen und Ameisen im tropischen Amerika. Botanische Mitteilungen aus den Tropen (Jena) 1:1–98.
- _____. 1898. Pflanzengeographie auf Physiologischer Grundlage. Pp. 149–170. Jena.
- Schindler, D. 1990. Experimental perturbations of whole lakes as tests of hypotheses concerning ecosystem structure and function. Oikos 57: 25–41.
- Schmid-Hempel, P. 1992. Worker castes and adaptive demography. Journal of Evolutionary Biology 5:1–12.
- Schödl, S. 1998. Taxonomic revision of Oriental *Meranoplus* F. Smith, 1853 (Insecta: Hymenoptera: Formicidae: Myrmicinae). Annalen des Naturhistorischen Museums In Wien. Serie B. Botanik und Zoologie 100B:361–394.
- Schroth, M., and U. Maschwitz. 1984. Zur Larvalbiologie und Wirtsfindung von *Maculinea teleius* (Lepidoptera: Lycaenidae), eines Parasiten von *Myrmica laevinodis* (Hymenoptera: Formicidae). Entomologia Generalis 9:225–230.
- Schulenberg, T. S., and K. Awbrey (eds.). 1997. The Cordillera del Condor of Ecuador and Peru: A biological assessment. RAP Working Papers No. 7. Conservation International, Washington, D.C.
- Schultz, T. R. 1998. Phylogeny of the fungus-growing ants (Myrmicinae: Attini): Evidence from DNA sequences (nuclear elongation factor-1 alpha and mitochondrial cytochrome oxidase I) and morphology. P. 429. In M. P. Schwarz and K. Hogendoorn (eds.), Social Insects at the Turn of the Millennium: Proceedings of the XIII International Congress of IUSSI, Adelaide, Australia, 29 December 1998–3 January 1999. Flinders University Press, Adelaide, Australia.
- Schultz, T. R., and R. Meier. 1995. A phylogenetic analysis of the fungus-growing ants (Hymenoptera: Myrmicinae: Attini) based on morphological characters of the larvae. Systematic Entomology 20:337–370.
- Schumacher, A., and W. G. Whitford. 1976. Spatial and temporal variation in Chihuahuan desert ant faunas. Southwestern Naturalist 21:1–8.
- Schupp, E. W., and D. H. Feener. 1991. Phylogeny, lifeform, and habitat dependence of ant-defended plants in a Panamanian forest. Pp. 175–197. In C. R. Huxley and D. F. Cutler (eds.), Ant-Plant Interactions. Oxford University Press, Oxford.
- Seastedt, T. R., and D. A. Crossley Jr. 1984. The influence of arthropods on ecosystems. BioScience 34:157–161.
- Seifert, B. 1988a. A revision of the European species of the ant subgenus *Chthonolasius* (Insecta, Hymenoptera, Formicidae). Entomologische Abhandlungen und Berichte aus dem Staatlichen Museum für Tierkunde in Dresden 51:143–180.
- _____. 1988b. A taxonomic revision of the *Myrmica* species of Europe, Asia Minor, and Caucasia (Hymenoptera, Formicidae). Abhandlungen und Berichte des Naturkundemuseums Görlitz 62(3):1–75.
- _____. 1990. Supplementation to the revision of European species of the ant subgenus *Chthonolasius* Ruzsky, 1913 (Hymenoptera: Formicidae). Doriania 6(271):1–13.
- _____. 1992. A taxonomic revision of the Palaeoarctic members of the ant subgenus *Lasius* s. str. (Hymenoptera: Formicidae). Abhandlungen und Berichte des Naturkundemuseums Görlitz 66(5): 1–67.
- Shattuck, S. O. 1987. An analysis of geographic variation in the *Pogonomyrmex occidentalis* complex (Hymenoptera: Formicidae). Psyche (Cambridge) 94:159–179.
- _____. 1990. Revision of the dolichoderine ant genus *Turneria* (Hymenoptera: Formicidae). Systematic Entomology 15:101–117.
- _____. 1991. Revision of the dolichoderine ant genus *Axinidris* (Hymenoptera: Formicidae). Systematic Entomology 16:105–120.

- _____. 1992a. Review of the dolichoderine ant genus *Iridomyrmex* Mayr with descriptions of three new genera (Hymenoptera: Formicidae). *Journal of the Australian Entomological Society* 31:13–18.
- _____. 1992b. Generic revision of the ant subfamily Dolichoderinae (Hymenoptera: Formicidae). *Sociobiology* 21:1–181.
- _____. 1992c. Higher classification of the ant subfamilies Aneuretinae, Dolichoderinae and Formicinae (Hymenoptera: Formicidae). *Systematic Entomology* 17:199–206.
- _____. 1993. Revision of the *Iridomyrmex purpureus* species-group (Hymenoptera: Formicidae). *Invertebrate Taxonomy* 7:113–149.
- _____. 1994. Taxonomic Catalog of the Ant Subfamilies Aneuretinae and Dolichoderinae (Hymenoptera: Formicidae). University of California Publications in Entomology 112.
- Shattuck, S. O. 1996a. Revision of the *Iridomyrmex discors* species-group (Hymenoptera: Formicidae). *Australian Journal of Entomology* 35(1):37–42.
- Shattuck, S. O. 1996b. The Australian ant genus *Froggattella* Forel (Hymenoptera: Formicidae) revisited. *Australian Journal of Entomology* 35(1):43–47.
- Sheela, S., and T. C. Narendran. 1997. A new genus and a new species of Myrmicinae (Hymenoptera: Formicidae) from India. *Journal of Ecobiology* 9(2):88–91.
- Silva, D., and J. A. Coddington. 1996. Spiders of Pakitza (Madre de Dios, Peru): Species richness and notes on community structure. Pp. 253–311. In D. E. Wilson and A. Sandoval (eds.), *Manu: The Biodiversity of Southeastern Peru*. Smithsonian Institution, Washington, D.C.
- Silvestri, F. 1925 (1924). A new myrmecophilous genus of Coccidae (Hemiptera) from India. *Records of the Indian Museum* 26:311–315.
- Skwarra, E. 1934. Ökologie der Lebensgemeinschaften mexikanischer Ameisenpflanzen. *Zeitschrift für Morphologie und Ökologie der Tiere* 29:306–373.
- Smallwood, J. 1982. Nest relocations in ants. *Insectes Sociaux* 29:138–147.
- Smith, J. B. 1906. An Explanation of Terms Used in Entomology. Brooklyn Entomological Society, Brooklyn, New York.
- Smith, M. R. 1944. The genus *Lachnomyrmex*, with the description of a second species (Hymenoptera: Formicidae). *Proceedings of the Entomological Society of Washington* 46:225–228.
- _____. 1947a. Ants of the genus *Apsychomyrmex* Wheeler (Hymenoptera: Formicidae). *Revista Entomologica (Rio de Janeiro)* 17:468–473.
- _____. 1947b. A new genus and species of ant from Guatemala (Hymenoptera, Formicidae). *Journal of the New York Entomological Society* 55:281–284.
- _____. 1953a. A revision of the genus *Rombonella* W. M. Wheeler (Hymenoptera: Formicidae). *Proceedings of the Hawaiian Entomological Society* 15:75–80.
- _____. 1953b. A new *Rombonella* from Palau, and the first description of a *Rombonella* male (Hymenoptera, Formicidae). *Journal of the New York Entomological Society* 61:163–167.
- _____. 1956a. A key to the workers of *Veromessor* Forel of the United States and the description of a new subspecies (Hymenoptera, Formicidae). *Pacific Entomologist* 32:36–38.
- _____. 1956b. A list of the species of *Rombonella* including two generic transfers (Hymenoptera, Formicidae). *Bulletin of the Brooklyn Entomological Society* 51:18.
- _____. 1961. A study of New Guinea ants of the genus *Aphaenogaster* Mayr (Hymenoptera, Formicidae). *Acta Hymenopterologica* 1:213–238.
- _____. 1962. A remarkable new *Stenamma* from Costa Rica, with pertinent facts on other Mexican and Central American species (Hymenoptera: Formicidae). *Journal of the New York Entomological Society* 70:33–38.
- Smith, T. M., H. H. Shugart, and F. I. Woodward (eds.). 1997. *Plant Functional Types: Their Relevance to Ecosystem Properties and Global Change*. Cambridge University Press, Cambridge.
- Snelling, R. R. 1973. Studies on California ants. 7. The genus *Stenamma* (Hymenoptera: Formicidae). *Contributions in Science (Los Angeles County Museum)* 245:1–38.
- _____. 1975. Descriptions of new Chilean ant taxa (Hymenoptera: Formicidae). *Contributions in Science (Los Angeles County Museum)* 274: 1–19.
- _____. 1976. A Revision of the Honey Ants, Genus *Myrmecocystus* (Hymenoptera: Formicidae). *Los Angeles County Museum of Natural History Bulletin* 24.
- _____. 1979a. Three new species of the Palaeotropical arboreal ant genus *Cataulacus* (Hymenoptera: Formicidae). *Contributions in Science (Los Angeles County Museum)* 274: 1–19.

- noptera: Formicidae). Contributions in Science (Los Angeles County Museum) 315:1–8.
- . 1979b. *Aphomomyrmex* and a related new genus of arboreal African ants (Hymenoptera: Formicidae). Contributions in Science (Los Angeles County Museum) 316:1–8.
- . 1981. The taxonomy and distribution of some North American *Pogonomyrmex* and descriptions of two new species (Hymenoptera: Formicidae). Bulletin of the Southern California Academy of Sciences 80:97–112.
- . 1982. A revision of the honey ants, genus *Myrmecocystus*, first supplement (Hymenoptera: Formicidae). Bulletin of the Southern California Academy of Sciences 81:69–86.
- . 1988. Taxonomic notes on Nearctic species of *Camponotus*, subgenus *Myrmentoma* (Hymenoptera: Formicidae). Pp. 55–78. In J. C. Trager (ed.), Advances in Myrmecology. E. J. Brill, Leiden, Netherlands.
- . 1995a. Systematics of Nearctic ants of the genus *Dorymyrmex* (Hymenoptera: Formicidae). Contributions in Science (Los Angeles County Museum) 454:1–14.
- Snelling, R. R., and J. H. Hunt. 1975. The ants of Chile (Hymenoptera: Formicidae). Revista Chilena de Entomología 9:63–129.
- Snelling, R. R., and J. T. Longino. 1992. Revisionary notes on the fungus-growing ants of the genus *Cyphomyrmex, rimosus* group (Hymenoptera: Formicidae: Attini). Pp. 479–494. In D. Quintero and A. Aiello (eds.), Insects of Panama and Mesoamerica: Selected Studies. Oxford University Press, Oxford.
- Snyder, L. E., and J. M. Herbers. 1991. Polydomy and sexual allocation ratios in the ant *Myrmica punctiventris*. Behavioral Ecology and Sociobiology 28:409–415.
- Soberón, M. J., and J. Llorente B. 1993. The use of species accumulation functions for the prediction of species richness. Conservation Biology 7:480–488.
- Southwood, T. R. E. 1978. Ecological Methods: With Particular Reference to the Study of Insect Populations. Chapman and Hall, London.
- Spellerberg, I. F. 1991. Monitoring Ecological Change. Cambridge University Press, Cambridge.
- . 1992. Evaluation and Assessment for Conservation. Chapman and Hall, London.
- Steghaus-Kovac, S., and U. Maschwitz. 1993. Predation on earwigs: A novel diet specialization within the genus *Leptogenys* (Formicidae, Ponerinae). Insectes Sociaux 40:337–340.
- Stein, M. B., H. G. Thorvilson, and J. W. Johnson. 1990. Seasonal changes in bait preference by the red imported fire ant, *Solenopsis invicta* (Hymenoptera: Formicidae). Florida Entomologist 73: 117–123.
- Stevens, G. C. 1989. The latitudinal gradient in geographical range: How so many species coexist in the tropics. American Naturalist 133:240–256.
- . 1992. The elevational gradient in altitudinal range: An extension of Rapoport's latitudinal rule to altitude. American Naturalist 140:893–911.
- Stork, N. E. 1991. The composition of the arthropod fauna of Bornean lowland rain forest trees. Journal of Tropical Ecology 7:161–180.
- Stork, N. E., and T. M. Blackburn. 1993. Abundance, body size and biomass of arthropods in tropical forest. Oikos 67:483–489.
- Stradling, D. J. 1978. The influence of size on foraging in the ant, *Atta cephalotes*, and the effect of some plant defence mechanisms. Journal of Animal Ecology 47:173–188.
- Sudd, J. H. and N. R. Franks. 1987. The Behavioural Ecology of Ants. Blackwell, Glasgow, U.K.
- Sugihara, G. 1980. Minimal community structure: An explanation of species abundance patterns. American Naturalist 116:770–787.
- Talbot, M. 1943. Population studies of the ant *Prenolepis imparis* Say. Ecology 24:31–44.
- . 1975. A list of the ants of the Edwin George Reserve, Livingston Country, Michigan. Great Lakes Entomologist 8:245–246.
- Taylor, L. R. 1978. Bates, Williams, Hutchinson—A variety of diversities. Pp. 1–18. In L. A. Mound and N. Waloff (eds.), Diversity of Insect Faunas: 9th Symposium of the Royal Entomological Society. Blackwell, Oxford.
- Taylor, L. R., I. P. Woiwod, and J. N. Perry. 1978. The density dependence of spatial behavior and the rarity of randomness. Journal of Animal Ecology 47:383–406.
- Taylor, R. W. 1960. Taxonomic notes on the ants *Ponera leae* Forel and *Ponera norfolkensis* (Wheeler) (Hymenoptera: Formicidae). Pacific Science 14:178–180.
- . 1965. A monographic revision of the rare tropicopolitan ant genus *Probolomyrmex* Mayr (Hymenoptera: Formicidae). Transactions of the Royal Entomological Society of London 117: 345–365.

- _____. 1967. A monographic revision of the ant genus *Ponera* Latreille (Hymenoptera: Formicidae). Pacific Insects Monographs 13:1–112.
- _____. 1968a. Notes on the Indo-Australian basicerotine ants (Hymenoptera: Formicidae). Australian Journal of Zoology 16:333–348.
- _____. 1968b. A new Malayan species of the ant genus *Epitritus*, and a related new genus from Singapore (Hymenoptera: Formicidae). Journal of the Australian Entomological Society 7:130–134.
- _____. 1970a. Characterization of the Australian endemic ant genus *Peronomymex* Viehmeyer (Hymenoptera: Formicidae). Journal of the Australian Entomological Society 9:209–211.
- _____. 1970b. Notes on some Australian and Melanesian basicerotine ants (Hymenoptera: Formicidae). Journal of the Australian Entomological Society 9:49–52.
- _____. 1973. Ants of the Australian genus *Mesostruma* Brown (Hymenoptera: Formicidae). Journal of the Australian Entomological Society 12:24–38.
- _____. 1977. New ants of the Australasian genus *Orectognathus*, with a key to the known species (Hymenoptera: Formicidae). Australian Journal of Zoology 25:581–612.
- _____. 1978a. *Nothomyrmecia macrops*: A living-fossil ant rediscovered. Science 201:979–985.
- _____. 1978b. A taxonomic guide to the ant genus *Orectognathus* (Hymenoptera: Formicidae). CSIRO Division of Entomology Reports 3:1–11.
- _____. 1978c. Melanesian ants of the genus *Amblyopone* (Hymenoptera: Formicidae). Australian Journal of Zoology 26:823–839.
- _____. 1979a. New Australian ants of the genus *Orectognathus*, with summary description of the twenty-nine known species (Hymenoptera: Formicidae). Australian Journal of Zoology 27:773–788.
- _____. 1979b. Notes on the Russian endemic ant genus *Aulacopone* Arnoldi (Hymenoptera: Formicidae). Psyche (Cambridge) 86:353–361.
- _____. 1980. Australian and Melanesian ants of the genus *Eurhopalothrix* Brown and Kempf—Notes and new species (Hymenoptera: Formicidae). Journal of the Australian Entomological Society 19:229–239.
- _____. 1983. Descriptive taxonomy: Past, present and future. Pp. 93–134. In E. Highley and R. W. Taylor (eds.), Australian Systematic Entomology: A Bicentenary Perspective. CSIRO, Melbourne.
- _____. 1985. The ants of the Papuan genus *Dacetinops* (Hymenoptera: Formicidae: Myrmicinae). Series Entomologica (Hague) 33:41–67.
- _____. 1989. Australasian ants of the genus *Leptothorax* Mayr (Hymenoptera: Formicidae: Myrmicinae). Memoirs of the Queensland Museum 27:605–610.
- _____. 1990a. [Untitled. Anomalomyrmini Taylor tribe n., *Anomalomyrma* Taylor gen. n., *Protanilla* Taylor gen. n.] Pp. 278–279. In B. Bolton, The higher classification of the ant subfamily Leptanillinae (Hymenoptera: Formicidae). Systematic Entomology 15:267–282.
- _____. 1990b. New Asian ants of the tribe Basicerotini, with an on-line computer interactive key to the twenty-six known Indo-Australian species (Hymenoptera: Formicidae: Myrmicinae). Invertebrate Taxonomy 4:397–425.
- _____. 1990c. The nomenclature and distribution of some Australian and New Caledonian ants of the genus *Meranoplus* Fr. Smith (Hymenoptera: Formicidae: Myrmicinae). General and Applied Entomology 22:31–40.
- _____. 1990d. Notes on the ant genera *Romblonella* and *Willowsiella*, with comments on their affinities, and the first descriptions of Australian species (Hymenoptera: Formicidae: Myrmicinae). Psyche (Cambridge) 97:281–296.
- Tennant, L. E., and S. D. Porter. 1991. Comparison of diets of two fire ant species (Hymenoptera: Formicidae): Solid and liquid components. Journal of Entomological Science 26:450–465.
- Terayama, M. 1985a. Two new species of the ant genus *Myrmecina* (Insecta; Hymenoptera; Formicidae) from Japan and Taiwan. Edaphologia 32: 35–40.
- _____. 1985b. Two new species of the genus *Acropyga* (Hymenoptera, Formicidae) from Taiwan and Japan. Kontyû 53:284–289.
- _____. 1987. A new species of *Amblyopone* (Hymenoptera, Formicidae) from Japan. Edaphologia 36:31–33.
- Terayama, M. 1996. Taxonomic studies on the Japanese Formicidae, part 2. Seven genera of Ponerinae, Cerapachyinae und Myrmicinae. Nature and Human Activities 1:1–8.
- Terayama, M., and K. Ogata. 1988. Two new species of the ant genus *Probolomyrmex* (Hymenoptera, Formicidae) from Japan. Kontyû 56:590–594.

- Terayama, M. and K. Onoyama. 1999. The ant genus *Leptothorax* Mayr (Hymenoptera: Formicidae) in Japan. Memoirs of the Myrmecological Society of Japan 1:71–97.
- Terayama, M., and S. Yamane. 1989. The army ant genus *Aenictus* (Hymenoptera, Formicidae) from Sumatra, with descriptions of three new species. Japanese Journal of Entomology 57:597–603.
- Terayama, M., C.-C. Lin, and W.-J. Wu. 1995. The ant genera *Epitritus* and *Kyidris* from Taiwan (Hymenoptera: Formicidae). Proceedings of the Japanese Society of Systematic Zoology 53:85–89.
- _____. 1996. The Taiwanese species of the ant genus *Smithistruma* (Hymenoptera, Formicidae). Japanese Journal of Entomology 64(2):327–339.
- Terron, G. 1974. Découverte au Cameroun de deux espèces nouvelles du genre *Prionopelta* Mayr (Hym.: Formicidae). Annales de la Faculté des Sciences, Université Fédéral du Cameroun (Yaoundé) 17:105–119.
- _____. 1981. Deux nouvelles espèces éthiopiennes pour le genre *Proceratium* (Hym.: Formicidae). Annales de la Faculté des Sciences, Université Fédéral du Cameroun (Yaoundé) 28:95–103.
- Thaxter, R. 1888. The Entomophthoreæ of the United States. Memoirs of the Boston Society of Natural History 4:133–201.
- _____. 1908. Contribution toward a monograph of the Laboulbeniaceæ, pt. II. Memoirs of the American Academy of Arts and Sciences 13: 217–469.
- Thompson, C. R., and C. Johnson. 1989. Rediscovered species and revised key to the Florida thief ants (Hymenoptera: Formicidae). Florida Entomologist 72:697–698.
- Tillyard, R. J. 1926. The Insects of Australia and New Zealand. Angus and Robertson, Sydney.
- Tilman, D. 1996. Biodiversity: Population versus ecosystem stability. Ecology 77:350–363.
- Tinaut, A. 1990. *Teleutomyrmex kutteri*, spec. nov.: A new species from Sierra Nevada (Granada, Spain). Spixiana 13:201–208.
- Tobin, J. E. 1991. A neotropical rain forest canopy ant community: Some ecological considerations. Pp. 536–538. In C. R. Huxley and D. F. Cutler (eds.), Ant-Plant Interactions. Oxford University Press, Oxford.
- _____. 1994. Ants as primary consumers: Diet and abundance in the Formicidae. Pp 279–307. In J. H. Hunt and C. A. Nalepa (eds.), Nourishment and Evolution in Insect Societies. Westview Press, Boulder, Colorado.
- _____. 1997. Competition and coexistence of ants in a small patch of rainforest canopy in Peruvian Amazonia. Journal of the New York Entomological Society 105:105–112.
- Tohmé, G., and H. Tohmé. 1981. Les fourmis du genre *Messor* en Syrie. Position systématique. Description de quelques ailés et de formes nouvelles. Répartition géographique. Ecologia Mediterranea 7(1):139–153.
- Topoff, H. 1990. Slave-making ants. American Scientist 78:520–528.
- Torre-Bueno, J. R. de la. 1937. A Glossary of Entomology. Brooklyn Entomological Society, Brooklyn, New York.
- Torre-Bueno, J. R. de la. 1989. The Torre-Bueno Glossary of Entomology. Compiled by S.W. Nichols, and including Supplement A by G. S. Tulloch. New York Entomological Society, New York.
- Trager, J. C. 1984. A revision of the genus *Paratrechina* (Hymenoptera: Formicidae) of the continental United States. Sociobiology 9:49–162.
- _____. 1991. A revision of the fire ants, *Solenopsis geminata* group (Hymenoptera: Formicidae: Myrmicinae). Journal of the New York Entomological Society 99:141–198.
- Trivers, R. L., and H. Hare. 1976. Haplodiploidy and the evolution of the social insects. Science 191:249–263.
- Tschinkel, W. R. 1991. Insect sociometry, a field in search of data. Insectes Sociaux 38:77–82.
- _____. 1992. Brood raiding and the population dynamics of founding and incipient colonies of the fire ant, *Solenopsis invicta*. Ecological Entomology 17:179–188.
- _____. 1993. Sociometry and sociogenesis of colonies of the fire ant *Solenopsis invicta* during one annual cycle. Ecological Monographs 63: 425–457.
- Tschinkel, W. R., and Howard, D. F. 1978. Queen replacement in orphaned colonies of the fire ant, *Solenopsis invicta*. Behavioral Ecology and Sociobiology 3:297–310.
- Tulloch, G. S. 1962. Torre-Bueno's Glossary of Entomology, Supplement A. Brooklyn Entomological Society, Brooklyn, New York.
- Turk, F. A. 1953. A new genus and species of pseudoscorpion with some notes on its biology. Proceedings of the Zoological Society of London 122:951–954.

- Ule, E. 1902. Ameisengärten im Amazonasgebiet. *Botanische Jahrbücher für Systematik, Pflanzen geschichte und Pflanzengeographien* 30:45–52.
- Umphrey, G. J., 1996. Morphometric discrimination among sibling species in the *fulva-rudis-texana* complex of the ant genus *Aphaenogaster* (Hymenoptera: Formicidae). *Canadian Journal of Zoology* 74(3):528–559.
- United Nations Environment Programme. 1995. *Global Biodiversity Assessment*. Cambridge University Press, Cambridge.
- Upton, M. 1991. Methods for Collecting, Preserving and Studying Insects and Allied Forms. Australian Entomological Society Miscellaneous Publications [Brisbane, Australia] 3:1–86.
- Valone, T., and J. Brown. 1995. Effects of competition, colonization, and extinction on rodent species diversity. *Science* 267:880–883.
- Vander Meer, R., and L. Alonso. 1998. Pheromone directed behavior in ants. Pp. 159–192. In R. Vander Meer, M. Breed, M. Winston, and K. Espelie (eds.), *Pheromone Communication in Social Insects*. Westview Press, Boulder, Colorado.
- Vasconcelos, H. L., and J. H. C. Delabie. 2000. Ground ant communities from central Amazonia forest fragments. Pp. 59–70. In D. Agosti, J. Majer, L. Alonso, and T. R. Schultz (eds.), *Sampling Ground-Dwelling Ants: Case Studies from the Worlds' Rain Forests*. Curtin University School of Environmental Biology Bulletin No. 18. Perth, Australia.
- Vaz-Ferreira, R., L. C. de Zolessi, and F. Achával. 1970. Oviposicion y desarrollo de Ofidios y Lacertilios en hormigueros de *Acromyrmex*. *Physis* 29:431–459.
- . 1973. Oviposición y desarrollo de ofidos y lacertilios en hormigueros de *Acromyrmex*. II. *Trabajos del Cinco Congresso Latinoamericano de Zoología*, Montevideo 1:232–244.
- Veeragh, M. 1990. The Formicidae of the rain forest in Panguana, Peru: The most diverse local ant fauna ever recorded. Pp. 217–218. In G. K. Veeresh, B. Mallik, and C. A. Viraktamath (eds.), *Social Insects and the Environment*. Proceedings of the 11th International Congress of IUSSI, 1990. Oxford and IBH, New Delhi.
- Vinson, S. B. 1991. Effect of the red imported fire ant (Hymenoptera: Formicidae) on a small plant-decomposing arthropod community. *Environmental Entomology* 20:98–103.
- Von Ihering, H. 1891. Die Wechselbeziehungen zwischen Pflanzen und Ameisen in den Tropen. *Ausland* 1891:474–477.
- Wang, C., and J. Wu. 1991. Taxonomic studies on the genus *Polyrhachis* Mayr of China (Hymenoptera, Formicidae). *Forest Research* 4:596–601. [In Chinese.]
- Wang, C., G. Xiao, and J. Wu. 1989a. Taxonomic studies on the genus *Camponotus* Mayr in China (Hymenoptera, Formicidae) [part]. *Forest Research* 2:221–228. [In Chinese.]
- . 1989b. Taxonomic studies on the genus *Camponotus* Mayr in China (Hymenoptera, Formicidae). [conclusion]. *Forest Research* 2:321–328. [In Chinese.]
- Wang, M. 1993. Taxonomic study of the ant tribe Odontomachini in China (Hymenoptera: Formicidae). *Scientific Treatise on Systematic and Evolutionary Zoology* 2:219–230. [In Chinese.]
- Wang, M., G. Xiao, and J. Wu. 1988. Taxonomic studies on the genus *Tetramorium* Mayr in China (Hymenoptera, Formicidae). *Forest Research* 1:264–274. [In Chinese.]
- Ward, P. S. 1980. A systematic revision of the *Rhytidoponera impressa* group (Hymenoptera: Formicidae) in Australia and New Guinea. *Australian Journal of Zoology* 28:475–498.
- . 1984. A revision of the ant genus *Rhytidoponera* (Hymenoptera: Formicidae) in New Caledonia. *Australian Journal of Zoology* 32:131–175.
- . 1985. The Nearctic species of the genus *Pseudomyrmex* (Hymenoptera: Formicidae). *Quaestiones Entomologicae* 21:209–246.
- . 1987. Distribution of the introduced Argentine ant (*Iridomyrmex humilis*) in natural habitats of the lower Sacramento Valley and its effects on the indigenous ant fauna. *Hilgardia* 55:1–16.
- . 1988. Mesic elements in the western Nearctic ant fauna: Taxonomic and biological notes on *Amblyopone*, *Proceratium*, and *Smithistruma* (Hymenoptera: Formicidae). *Journal of the Kansas Entomological Society* 61:102–124.
- . 1989. Systematic studies on pseudomyrmecine ants: Revision of the *Pseudomyrmex ocularis* and *P. subtilissimus* species groups, with taxonomic comments on other species. *Quaestiones Entomologicae* 25:393–468.
- . 1990. The ant subfamily Pseudomyrmicinae (Hymenoptera: Formicidae): Generic revi-

- sion and relationship to other formicids. *Systematic Entomology* 15:449–489.
- _____. 1993. Systematic studies on *Pseudomyrmex* acacia-ants (Hymenoptera: Formicidae: Pseudomyrmecinae). *Journal of Hymenoptera Research* 2:117–168.
- _____. 1994. *Adetomyrma*, an enigmatic new ant genus from Madagascar (Hymenoptera: Formicidae), and its implications for ant phylogeny. *Systematic Entomology* 19:159–175.
- _____. 1999a. Systematics, biogeography and host plant associations of the *Pseudomyrmex vidiuus* group (Hymenoptera: Formicidae), *Triplaris-* and *Tachigali*-inhabiting ants. *Zoological Journal of the Linnean Society* 126:451–540.
- _____. 1999b. Deceptive similarity in army ants of the genus *Neivamyrmex* (Hymenoptera: Formicidae): Taxonomy, distribution and biology of *N. californicus* (Mayr) and *N. nigrescens* (Cresson). *Journal of Hymenoptera Research* 8:74–97.
- Ward, P. S., B. Bolton, S. O. Shattuck, and W. L. Brown Jr. 1996. A Bibliography of Ant Systematics. University of California Publications in Entomology 116.
- Wasemann, E. 1902. Zur Kenntnis der myrmecophilen *Antennophorus* und anderer auf Ameisen und Termiten reitende Acarinen. *Zoologischer Anzeiger* 25:66–76.
- Watkins, J. F. II. 1976. The identification and distribution of New World army ants (Dorylinae: Formicidae). Baylor University Press, Waco, Texas.
- _____. 1977. The species and subspecies of *Nomamyrmex* (Dorylinae: Formicidae). *Journal of the Kansas Entomological Society* 50:203–214.
- _____. 1982. The army ants of Mexico (Hymenoptera: Formicidae: Ecitoninae). *Journal of the Kansas Entomological Society* 55:197–247.
- _____. 1985. The identification and distribution of the army ants of the United States of America (Hymenoptera, Formicidae, Ecitoninae). *Journal of the Kansas Entomological Society* 58:479–502.
- Watt, J. C. 1979. Abbreviations for entomological collections. *New Zealand Journal of Zoology* 6:519–520.
- Weber, N. A. 1943. Parabiosis in Neotropical “ant gardens.” *Ecology* 24:400–404.
- _____. 1944. The neotropical coccid-tending ants of the genus *Acropyga* Roger. *Annals of the Entomological Society of America* 37:89–122.
- _____. 1947. A revision of the North American ants of the genus *Myrmica* Latreille with a synopsis of the Palearctic species. I. *Annals of the Entomological Society of America* 40:437–474.
- _____. 1948. A revision of the North American ants of the genus *Myrmica* Latreille with a synopsis of the Palearctic species. II. *Annals of the Entomological Society of America* 41:267–308.
- _____. 1950a. The African species of the genus *Oligomyrmex* Mayr (Hymenoptera, Formicidae). *American Museum Novitates* 1442:1–19.
- _____. 1950b. A revision of the North American ants of the genus *Myrmica* Latreille with a synopsis of the Palearctic species. III. *Annals of the Entomological Society of America* 43:189–226.
- _____. 1952. Studies on African Myrmicinae. I (Hymenoptera, Formicidae). *American Museum Novitates* 1548:1–32.
- _____. 1972a. The Attines: The fungus-culturing ants. *American Scientist* 60:448–456.
- _____. 1972b. Gardening Ants: The Attines. American Philosophical Society, Philadelphia.
- Weber, N. A., and J. L. Anderson. 1950. Studies on central African ants of the genus *Pseudolasius* Emery (Hymenoptera, Formicidae). *American Museum Novitates* 1443:1–7.
- Wehner, R., A. C. Marsh, and S. Wehner. 1992. Desert ants on a thermal tightrope. *Nature* 357:586–587.
- Went, F. W., J. Wheeler, and G. C. Wheeler. 1972. Feeding and digestion in some ants (*Veromessor* and *Manica*). *BioScience* 22:82–88.
- Westman, W. 1986. Resilience: Concepts and measures. Pp. 5–19. In B. Dell, A. Hopkins, and B. Lamont (eds.), *Resilience in Mediterranean Ecosystems*. Dr. W. Junk, The Hague.
- Wetterer, J. K. 1991. Allometry and the geometry of leaf-cutting in *Atta cephalotes*. *Behavioral Ecology and Sociobiology* 29:347–351.
- Wetterer, J. K., T. R. Schultz, and R. Meier. 1998. Phylogeny of fungus-growing ants (tribe Attini) based on mtDNA sequence and morphology. *Molecular Phylogenetics and Evolution* 9: 42–47.
- Wheeler, D., and S. Levings. 1988. The impact of the 1983 El Niño drought on the litter arthropods of Barro Colorado Island, Panama. Pp. 309–326. In J. C. Trager (ed.), *Advances in Myrmecology*. E. J. Brill, New York.
- Wheeler, G. C., and E. W. Wheeler. 1930. Two new ants from Java. *Psyche* (Cambridge) 37:193–201.

- Wheeler, G. C., and J. Wheeler. 1986. The Ants of Nevada. Natural History Museum of Los Angeles County, Los Angeles.
- Wheeler, J. 1968. Male genitalia and the taxonomy of *Polyergus* (Hymenoptera: Formicidae). Proceedings of the Entomological Society of Washington 70:156–164. [Erratum: Proceedings of the Entomological Society of Washington 70:254.]
- Wheeler, W. M. 1905. The North American ants of the genus *Liometopum*. Bulletin of the American Museum of Natural History 21:321–333.
- _____. 1908. Studies on myrmecophiles. II. *Hetaerius*. Journal of the New York Entomological Society 16:135–143.
- _____. 1910. Two new myrmecophilous mites of the genus *Antennophorus*. Psyche (Cambridge) 17:1–6.
- _____. 1913. Observations on the Central American *Acacia* ants. Transactions of the Second International Entomological Congress of Oxford (1912) 2:109–139.
- _____. 1914. Notes on the habits of *Liomyrmex*. Psyche (Cambridge) 21:75–76.
- _____. 1918. The Australian ants of the ponerine tribe Cerapachyini. Proceedings of the American Academy of Arts and Sciences 53:215–265.
- _____. 1922a. Ants of the American Museum Congo expedition. A contribution to the myrmecology of Africa. II. The ants collected by the American Museum Congo Expedition. Bulletin of the American Museum of Natural History 45:39–269.
- _____. 1922b. Ants of the American Museum Congo expedition. A contribution to the myrmecology of Africa. VII. Keys to the genera and subgenera of ants. Bulletin of the American Museum of Natural History 45:631–710.
- _____. 1924. Ants of Krakatau and other islands in the Sunda Strait. Treubia 5:239–258.
- _____. 1925. A new guest-ant and other new Formicidae from Barro Colorado Island, Panama. Biological Bulletin of the Marine Biological Laboratory (Woods Hole) 49:150–181.
- _____. 1928. The Social Insects: Their Origin and Evolution. Kegan Paul, Trench, Trubner, London.
- _____. 1934. A second revision of the ants of the genus *Leptomyrmex* Mayr. Bulletin of the Museum of Comparative Zoology, Harvard College 77:69–118.
- _____. 1935. Ants of the genus *Acropyga* Roger, with description of a new species. Journal of the New York Entomological Society 43:321–329.
- _____. 1936. Ecological relations of ponerine and other ants to termites. Proceedings of the American Academy of Arts and Sciences 71:159–243.
- _____. 1942. Studies of Neotropical ant-plants and their ants. Bulletin of the Museum of Comparative Zoology, Harvard University 90:1–262.
- Wheeler, W. M. and W. M. Mann. 1942. [Untitled. *Allomerus decemarticulatus* Mayr subsp. *Nove-marticulatus* Wheeler & Mann, subsp. nov.] Pp. 188–189. In W. M. Wheeler, Studies of Neotropical ant-plants and their ants. Bulletin of the Museum of Comparative Zoology, Harvard College 90:1–262.
- Whitcomb, W. H., A. Bhatkar, and J. C. Nickerson. 1973. Predators of *Solenopsis invicta* queens prior to successful colony establishment. Environmental Entomology 2:1101–1103.
- Whitford, W. G. 1978. Structure and seasonal activity of Chihuahua desert ant communities. Insectes Sociaux 25:79–88.
- Whitford, W. G., and G. Ettershank. 1975. Factors affecting foraging activity in Chihuahuan desert harvester ants. Environmental Entomology 4: 689–696.
- Wiernasz, D. C., and B. J. Cole. 1995. Spatial distribution of *Pogonomyrmex occidentalis*: Recruitment, mortality, and overdispersion. Journal of Animal Ecology 64:519–527.
- Wilcox, B. A. 1984. In situ conservation of genetic resources: Determinants of minimum-area requirements. Pp. 639–647. In J. A. McNeeley and K. R. Miller (eds.), National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society. Proceedings of the World Congress on National Parks, Bali, Indonesia, 11–22 October 1982. Smithsonian Institution Press, Washington, D.C.
- Wilcox, B. A., D. D. Murphy, P. R. Ehrlich, and G. T. Austin. 1986. Insular biogeography of the montane butterfly faunas in the Great Basin: Comparison with birds and mammals. Oecologia 69:188–194.
- Willey, R. B., and W. L. Brown Jr. 1983. New species of the ant genus *Myopias* (Hymenoptera: Formicidae: Ponerinae). Psyche (Cambridge) 90:249–285.
- Williams, D. F. 1994. Exotic ants: Biology, impact, and control of introduced species. Westview Press, Boulder, Colorado.
- Williams, R. N. (ed.). 1978. Worldwide directory of institutions with entomologists, part I: Latin

- America. Bulletin of the Entomological Society of America 24:179–193.
- Willis, E. O. 1983. A study of ant-following birds of northeastern Brazil. Research Reports of the National Geographic Society 15:745–748.
- Willis, E. O., and Y. Oniki. 1978. Birds and army ants. Annual Review of Ecology and Systematics 9:243–263.
- Wilson, D. E., F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster. 1996. Measuring and Monitoring Biological Diversity. Standard Methods for Mammals. Smithsonian Institution Press, Washington, D.C.
- Wilson, E. O. 1953. The ecology of some North American dacetine ants. Annals of the Entomological Society of America 46:479–495.
- . 1955. A monographic revision of the ant genus *Lasius*. Bulletin of the Museum of Comparative Zoology, Harvard College 113:1–201.
- . 1958. Patchy distributions of ant species in New Guinea rain forests. *Psyche* (Cambridge) 65:26–38.
- . 1959. Some ecological characteristics of ants in New Guinea rain forests. *Ecology* 40:437–447.
- . 1961. The nature of the taxon cycle in the Melanesian ant fauna. *American Naturalist* 95: 169–193.
- . 1962a. Behavior of *Dacetum armigerum* (Latrelle), with a classification of self-grooming movements in ants. Bulletin of the Museum of Comparative Zoology, Harvard College 127:401–422.
- . 1962b. The Trinidad cave ant *Erebomyrma* (= *Spelaeomyrmex*) *urichi* (Wheeler), with a comment on cavernicolous ants in general. *Psyche* (Cambridge) 69:63–72.
- . 1964. The true army ants of the Indo-Australian area (Hymenoptera: Formicidae: Dorylinae). *Pacific Insects Monographs* 6:427–483.
- . 1971. The Insect Societies. Belknap Press, Cambridge, Massachusetts.
- . 1976. Which are the most prevalent ant genera? *Studia Entomologica* 19:187–200.
- . 1984. Tropical social parasites in the ant genus *Pheidole*, with an analysis of the anatomical parasitic syndrome (Hymenoptera: Formicidae). *Insectes Sociaux* 31:316–334.
- . 1985. The principles of caste evolution. *Fortschritte der Zoologie* 31:307–324.
- . 1987. The arboreal ant fauna of Peruvian Amazon forests: A first assessment. *Biotropica* 19:245–251.
- . 1989. *Chimaeridris*, a new genus of hook-mandibled myrmicine ants from tropical Asia (Hymenoptera: Formicidae). *Insectes Sociaux* 36:62–69.
- . 1993. The Diversity of Life. W.W. Norton, New York.
- Wilson, E. O., and W. L. Brown Jr. 1953. The sub-species concept and its taxonomic application. *Systematic Zoology* 2:97–111.
- . 1956. New parasitic ants of the genus *Kyidris*, with notes on ecology and behavior. *Insectes Sociaux* 3:439–454.
- . 1984. Behavior of the cryptobiotic predaceous ant *Eurhopalothrix heliscata* n. sp. (Hymenoptera: Formicidae: Basicerotini). *Insectes Sociaux* 31:408–428.
- Wilson, E. O., and R. W. Taylor. 1967. An estimate of the potential evolutionary increase in species density in the Polynesian ant fauna. *Evolution* 21:1–10.
- Wilson, E. O., T. Eisner, G. C. Wheeler, and J. Wheeler. 1956. *Aneuretus simoni* Emery, a major link in ant evolution. *Bulletin of the Museum of Comparative Zoology, Harvard College* 115:81–99.
- Wing, M. W. 1968. Taxonomic revision of the Nearctic genus *Acanthomyops* (Hymenoptera: Formicidae). *Memoirs of the Cornell University Agricultural Experiment Station* 405:1–173.
- Wisdom, W., and W. G. Whitford. 1981. Effects of vegetation change on ant communities of arid rangelands. *Environmental Entomology* 10:893–897.
- Wolda, H. 1992. Trends in abundance of tropical forest insects. *Oecologia* 89:47–52.
- Wu, J. 1990. Taxonomic studies on the genus *Formica* L. of China (Hymenoptera: Formicidae). *Forest Research* 3:1–8. [In Chinese.]
- Wu, J., and C. Wang. 1990. A taxonomic study on the genus *Tetraponera* Smith in China (Hymenoptera: Formicidae). *Scientia Silvae Sinica* 26: 515–518. [In Chinese.]
- Xu, Z. 1994a. A taxonomic study of the ant genus *Lepisiota* Santschi from Southwestern China (Hymenoptera: Formicidae: Formicinae). *Journal of Southwest Forestry College* 14(4):231–237.
- Xu, Z. 1994b. A taxonomic study of the ant genus *Brachyponera* Emery in Southwestern China (Hymenoptera: Formicidae: Ponerinae). *Journal of Southwest Forestry College* 14(3):181–185.
- Xu, Z. 1995a. Two new species of the ant genus *Prenolepis* from Yunnan China (Hymenoptera: Formicidae). *Zoological Research* 16(4):337–341.

- Xu, Z. 1995b. A taxonomic study of the ant genus *Dolichoderus* Lund in China (Hymenoptera: Formicidae: Dolichoderinae). *Journal of Southwest Forestry College* 15(1):33–39.
- Xu, Z. 1997. A taxonomic study of the ant genus *Pseudolasius* Emery in China (Hymenoptera: Formicidae). *Zoological Research* 18(1):1–6.
- Xu, Z. 1999. Systematic studies on the ant genera of *Carebara*, *Rhopalomastix* and *Kartidris* in China (Hymenoptera: Formicidae: Myrmicinae). *Acta Biologica Plateau Sinica* 14:129–136.
- Xu, Z., and W. Zhang. 1996. A new species of the genus *Gnamptogenys* (Hymenoptera: Formicidae: Ponerinae) from southwestern China. *Entomotaxonomia* 18(1):55–58.
- Yamauchi, K. 1978. Taxonomical and ecological studies on the ant genus *Lasius* in Japan (Hymenoptera: Formicidae). I. Taxonomy. *Science Reports of the Faculty of Education, Gifu University (Natural Sciences)* 6:147–181.
- Yasumatsu, K., and W. L. Brown Jr. 1951. Revisional notes on *Camponotus herculeanus* Linné and close relatives in Palearctic regions (Hymenoptera: Formicidae). *Journal of the Faculty of Agriculture, Kyushu University* 10:29–44.
- _____. 1957. A second look at the ants of the *Camponotus herculeanus* group in eastern Asia. *Journal of the Faculty of Agriculture, Kyushu University* 11:45–51.
- Yasumatsu, K., and Y. Murakami. 1960. A revision of the genus *Stenamma* of Japan (Hymenoptera, Formicidae, Myrmicinae). *Esakia* 1:27–31.
- Young, A. M. 1986. Notes on the distribution and abundance of ground- and arboreal-nesting ants (Hymenoptera: Formicidae) in some Costa Rican cacao habitats. *Proceedings of the Entomological Society of Washington* 88:550–571.
- Zhou, S.-Y., and Z.-M. Zheng. 1999. Taxonomic study of the ant genus *Pheidole* Westwood from Guangxi, with descriptions of three new species. *Acta Zootaxonomica Sinica* 24(1):83–88.
- Zimmerman, B. L., and M. T. Rodriguez. 1990. Frogs, snakes, and lizards of the INPA-WWF reserves near Manaus, Brazil. Pp. 426–454. In A. H. Gentry (ed.), *Four Neotropical Rainforests*. Yale University Press, New Haven, Connecticut.