Anyone who has spent an extended period in the tropics has an idea, through caring for others or first-hand experience, just what it is like to be a primate parasite host. Monkeys and apes often share parasites with humans, for example the HIV viruses which evolved from related viruses of chimpanzees and sooty mangabeys, and so understanding the ecology of infectious diseases in non-human primates is of paramount importance. Furthermore, there is accumulating evidence that environmental change may promote contact between humans and non-human primates and increase the possibility of sharing infectious disease. Written for graduate students and academic researchers, this book addresses these issues and provides up-to-date information on the methods of study, natural history, and ecology/theory of the exciting field of primate parasite ecology.

MICHAEL A. HUFFMAN is an Associate Professor, and the first tenured non-Japanese faculty member, at Kyoto University’s Primate Research Institute, Japan. He is currently an editor for the American Journal of Primatology. His research on host–parasite relationships and primate self-medication has involved multi-disciplinary international collaborations on species around the world, spanning over 15 countries.

COLIN A. CHAPMAN is a Professor in the Department of Anthropology and McGill School of Environment at McGill University and a Canada Research Chair in Primate Ecology and Conservation. He has been an associate scientist with the Wildlife Conservation Society since 1995 and for the last 18 years has conducted research in the Kibale National Park, Uganda.
Primate Parasite Ecology

The Dynamics and Study of Host–Parasite Relationships

Edited by

MICHAEL A. HUFFMAN
Kyoto University, Japan

COLIN A. CHAPMAN
McGill University, Montréal
Contents

List of contributors  ix
Preface  xv

Part I Methods to study primate–parasite interactions  1

1 Collection methods and diagnostic procedures for primate parasitology  3
Ellis C. Greiner and Antoinette McIntosh

2 Methods of collection and identification of minute nematodes from the feces of primates, with special application to coevolutionary study of pinworms  29
Hideo Hasegawa

3 The utility of molecular methods for elucidating primate–pathogen relationships – the Oesophagostomum bifurcum example  47
Robin B. Gasser, Johanna M. de Gruijter, and Anton M. Polderman

4 The application of endocrine measures in primate parasite ecology  63
Michael P. Muehlenbein

5 Using agent-based models to investigate primate disease ecology  83
Charles L. Nunn
Contents

Part II The natural history of primate–parasite interactions

6 What does a parasite see when it looks at a chimpanzee? 113
   Michael V. K. Sukhdeo and Suzanne C. Sukhdeo

7 Primate malarias: evolution, adaptation, and species jumping 141
   Anthony Di Fiore, Todd Disotell, Pascal Gagneux, and Francisco J. Ayala

8 Disease avoidance and the evolution of primate social connectivity: Ebola, bats, gorillas, and chimpanzees 183
   Peter D. Walsh, Magdalena Bermejo, and José Domingo Rodríguez-Teijeiro

9 Primate–parasitic zoonoses and anthropozoonoses: a literature review 199
   Taranjit Kaur and Jatinder Singh

10 Lice and other parasites as markers of primate evolutionary history 231
    David L. Reed, Melissa A. Toups, Jessica E. Light, Julie M. Allen, and Shelly Flannigan

11 Cryptic species and biodiversity of lice from primates 251
    Natalie P. Leo

12 Prevalence of Clostridium perfringens in intestinal microflora of non-human primates 271
    Shiho Fujita, Asami Ogasawara, and Takashi Kageyama

13 Intestinal bacteria of chimpanzees in the wild and in captivity: an application of molecular ecological methodologies 283
    Kazunari Ushida

14 Gastrointestinal parasites of bonobos in the Lomako Forest, Democratic Republic of Congo 297
    Jozef Dupain, Carlos Nell, Klára Judita Petrželková, Paola Garcia, David Modrý, and Francisco Ponce Gordo
Contents vii

15 Habitat disturbance and seasonal fluctuations of lemur parasites in the rain forest of Ranomafana National Park, Madagascar 311

16 Chimpanzee–parasite ecology at Budongo Forest (Uganda) and the Mahale Mountains (Tanzania): influence of climatic differences on self-medicative behavior 331
Michael A. Huffman, Paula Pebsworth, Chris Bakuneeta, Shunji Gotoh, and Massimo Bardi

Part III The ecology of primate–parasite interactions 351

17 Primate exposure and the emergence of novel retroviruses 353
Nathan D. Wolfe and William M. Switzer

18 Overview of parasites infecting howler monkeys, Alouatta sp., and potential consequences of human–howler interactions 371
Sylvia K. Vitazkova

19 Primate parasite ecology: patterns and predictions from an ongoing study of Japanese macaques 387
Alexander D. Hernandez, Andrew J. MacIntosh, and Michael A. Huffman

20 Crop raiding: the influence of behavioral and nutritional changes on primate–parasite relationships 403
Anna H. Weyher

21 Can parasite infections be a selective force influencing primate group size? A test with red colobus 423
Colin A. Chapman, Jessica M. Rothman, and Stacey A. M. Hodder

22 How does diet quality affect the parasite ecology of mountain gorillas? 441
Jessica M. Rothman, Alice N. Pell, and Dwight D. Bowman
viii  Contents

23  Host–parasite dynamics: connecting primate field data to theory 463
   Colin A. Chapman, Stacey A. M. Hodder, and Jessica M. Rothman

Part IV  Conclusions 485

24  Ways forward in the study of primate parasite ecology 487
   Colin A. Chapman, Michael A. Huffman, Sadie J. Ryan, Raja Sengupta, and Tony L. Goldberg

25  Useful diagnostic references and images of protozoans, helminths, and nematodes commonly found in wild primates 507
   Hideo Hasegawa, Colin A. Chapman, and Michael A. Huffman

Index 515
Contributors

JULIE M. ALLEN, Florida Museum of Natural History, and Department of Zoology, University of Florida, Gainesville, FL 32611, USA

SUMMER J. ARRIGO-NELSON, Centre ValBio, BP 33 – Ranomafana, 312 Ifanadiana Madagascar and Department of Anthropology, University of Notre Dame, Notre Dame, IN 46556, USA

FRANCISCO J. AYALA, Department of Ecology and Evolutionary Biology, University of California, Irvine, Irvine, CA 92697, USA

CHRISSBAKUNNETA, Department of Zoology, Makerere University, Kampala, Uganda

BRIAN BANNON, Department of Anthropology, Stony Brook University, Stony Brook, NY 11794, USA

MASSIMO BARDI, Department of Psychology, Marshall University, Huntington, WV, USA

MAGDALENA BERMEJO, Department of Animal Biology, Faculty of Biology, University of Barcelona, Av. Diagonal 645, ES-08028, Barcelona, Spain and Programme de conservation et utilisation rationnelle des Ecosystèmes Forestiers en Afrique Centrale (ECOFAC), BP 15115 Libreville, Gabon

DWIGHT D. BOWMAN, Department of Veterinary Microbiology and Immunology, College of Veterinary Medicine, Cornell University, Ithaca, NY 14853, USA

COLIN A. CHAPMAN, Department of Anthropology and McGill School of Environment, McGill University, 855 Sherbrooke St. West, Montreal, Quebec, H3A 2T7, Canada and Wildlife Conservation Society, 2300 Southern Boulevard, Bronx, NY 10460, USA

ANTHONY DI FIORE, Center for the Study of Human Origins, Department of Anthropology, New York University, 25 Waverly Place, New York, NY 10003, USA
Contributors

TODD DISOTELL, Center for the Study of Human Origins, Department of Anthropology, New York University, 25 Waverly Place, New York, NY 10003, USA

JOZEF DUPAIN, African Wildlife Foundation, Boulevard du 30 juin n 2515, BP 2396, Kinshasa, Gombe, RDC.

SHELLY FLANNIGAN, Florida Museum of Natural History, University of Florida, Gainesville, FL 32611, USA

SHIHO FUJITA, Department of Veterinary Medicine, Faculty of Agriculture, Yamaguchi University, Yoshida1677–1, Yamaguchi-shi, Yamaguchi, 753–8515, Japan

PASCAL GAGNEUX, Glycobiology Research and Training Center, Cellular and Molecular Medicine East, University of California San Diego, 9500 Gilman Drive, La Jolla, CA 92093, USA

PAOLA GARCIA, Departamento de Parasitología, Facultad de Farmacia, Universidad Complutense de Madrid, Plaza Ramón y Cajal s/n, 28040 Madrid, Spain

ROBIN B. GASSER, Department of Veterinary Science, The University of Melbourne, 250 Princes Highway, Werribee, Victoria 3030, Australia

TONY L. GOLDBERG, University of Illinois Department of Pathobiology, 2001 South Lincoln Avenue, Urbana, IL 61802, USA

FRANCISCO PONCE GORDO, Departamento de Parasitología, Facultad de Farmacia, Universidad Complutense de Madrid, Plaza Ramón y Cajal s/n, 28040 Madrid, Spain

SHUNJI GOTOH, Wild Animal Research Clinic, Tatsugo, Amami, Japan

ELLIS C. GREINER, Department of Infectious Diseases and Pathology, College of Veterinary Medicine, University of Florida, Gainesville, FL 32610, USA

JOHANNA M. DE GRUIJTER, Department of Veterinary Science, The University of Melbourne, 250 Princes Highway, Werribee, Victoria 3030, Australia and Department of Parasitology, Leiden University Medical Center, Leiden, PO Box 9600, 2300 RC Leiden, The Netherlands

A. L. HARIVELO, Department of Paleontology and Biological Anthropology, University of Antananarivo, Antananarivo, Madagascar

HIDEO HASEGAWA, Department of Infectious Diseases (Biology), Faculty of Medicine, Oita University, Hasama, Yufu, Oita 879–5593, Japan
Contributors

ALEXANDER D. HERNANDEZ, Department of Ecology and Social Behavior, Primate Research Institute, Kyoto University, Inuyama, Aichi, 484–8506, Japan

STACEY A. M. HODDER, Department of Anthropology, McGill University, 855 Sherbrooke St. West, Montreal, Quebec, H3A 2T7, Canada

KRISTINA L. HOGG, College of Veterinary Medicine, Cornell University, Ithaca, NY 14853, USA

MICHAEL A. HUFFMAN, Department of Ecology and Social Behavior, Primate Research Institute, Kyoto University, 41–2 Kanrin, Inuyama, Aichi, 484–8506, Japan

TAKASHI KAGEYAMA, Center for Human Evolution Modeling Research, Primate Research Institute, Kyoto University, 41–2 Kanrin, Inuyama, Aichi 484–8506, Japan

TARANJIT KAUR, Department of Biomedical Sciences and Pathobiology, VA-MD Regional College of Veterinary Medicine, Virginia Tech, Duck Pond Drive (0442), Blacksburg, VA 24061, USA

NATALIE P. LEO, Center for Human Evolution Modeling Research, Primate Research Institute, Kyoto University, Inuyama, Aichi 484–8506, Japan

JESSICA E. LIGHT, Florida Museum of Natural History, University of Florida, Gainesville, FL 32611, USA

ANDREW J. MACINTOSH, Department of Ecology and Social Behavior, Primate Research Institute, Kyoto University, Inuyama, Aichi, 484–8506, Japan

ANTOINETTE MCIINTOSH, Department of Infectious Diseases and Pathology, College of Veterinary Medicine, University of Florida, Gainesville, FL 32610, USA

DAVID MODRÝ, Department of Parasitology, University of Veterinary and Pharmaceutical Sciences, Palackého 1–3, 612 42 Brno, Czech Republic and Institute of Parasitology, Biological Centre, Academy of Sciences of the Czech Republic, Branišovská 31, 370 05 České Budějovice, Czech Republic

TONI LYN MORELLI, Centre ValBio, BP 33 – Ranomafana, 312 Ifanadiana Madagascar and Department of Ecology and Evolution, Stony Brook University, Stony Brook, NY 11794 USA

MICHAEL P. MUEHLENBEIN, Department of Anthropology, Evolutionary Physiology and Ecology Laboratory, Indiana University, 701 E. Kirkwood Ave., Student Building 130, Bloomington, IN 47405, USA
xii  Contributors

CARLOS NELL,  Departamento de Parasitología, Facultad de Farmacia, Universidad Complutense de Madrid, Plaza Ramón y Cajal s/n, 28040 Madrid, Spain

CHARLES L. NUNN,  Max Planck Institute for Evolutionary Anthropology, D-04103 Leipzig, Germany, and University of California, Department of Integrative Biology, Berkeley, CA 94720–3140, USA

ASAMI OGASAWARA,  Center for Human Evolution Modeling Research, Primate Research Institute, Kyoto University, Inuyama, Aichi 484–8506, Japan

PAULA PEBSWORTH,  Roots & Shoots, The Jane Goodall Institute, 4245 N. Fairfax Drive, Suite 600, Arlington, VA 22203, USA

ALICE N. PELL,  Department of Animal Science, Cornell University, Ithaca, NY, 14853, USA

KLÁRA JUDITA PETRŽELKOVÁ,  Institute of Vertebrate Biology, Academy of Sciences of the Czech Republic, Květná 8, 603 00 Brno, Czech Republic and Zoo Liberec, Masarykova 1347/31, 460 01 Liberec, Czech Republic

ANTON M. POLDERMAN,  Department of Parasitology, Leiden University Medical Center, Leiden, PO Box 9600, 2300 RC Leiden, The Netherlands

FELIX RATELOLAY,  Department of Paleontology and Biological Anthropology, University of Antananarivo, Antananarivo, Madagascar

DAVID L. REED,  Florida Museum of Natural History, University of Florida, Gainesville, FL 32611, USA

JOSÉ DOMINGO RODRÍGUEZ-TEJEIRO,  Department of Animal Biology, Faculty of Biology, University of Barcelona, Av. Diagonal 645, ES-08028, Barcelona, Spain

JESSICA M. ROTHMAN,  Department of Biology and McGill School of Environment, McGill University, 3534 University Avenue, Montreal, Quebec, H3A 2A7, Canada

SADIE J. RYAN,  Department of Anthropology and McGill School of Environment, McGill University, Montreal, Quebec, Canada H3A 2T7 and Department of Anthropological Sciences, Building 360, Stanford University, Stanford, CA 94305, USA

RAJA SENGUPTA,  Department of Geography, McGill University, Montreal, Quebec, H3A 2K6, Canada
 Contributors

JATINDER SINGH, Department of Biomedical Sciences and Pathobiology, VA-MD Regional College of Veterinary Medicine, Virginia Tech, Duck Pond Drive (0442), Blacksburg, VA 24061, USA

MICHAEL V. K. SUKHDEO, Department of Ecology, Evolution and Natural Resources, Rutgers University, NJ 088903, USA

SUZANNE C. SUKHDEO, Department of Ecology, Evolution and Natural Resources, Rutgers University, NJ 088903, USA

WILLIAM M. SWITZER, Laboratory Branch, Division of HIV/AIDS Prevention, National Center for HIV, Hepatitis, STD, and TB Prevention, Centers for Disease Control and Prevention MS G-45, Atlanta, GA 30333, USA

MELISSA A. TOUPS, Florida Museum of Natural History and Department of Zoology, University of Florida, Gainesville, FL 32611, USA

KAZUNARI USHIDA, Laboratory of Animal Science, Kyoto Prefectural University, Shimogamo, Kyoto 606–8522, Japan

SYLVIA K. VITAZKOVA, University of the Virgin Islands, VI-EPSCoR, Division of Science and Mathematics, and Center for Marine and Environmental Studies, #2 John Brewer’s Bay, St. Thomas, US Virgin Islands 00802

PETER D. WALSH, Max Planck Institute for Evolutionary Anthropology, Deutscher Platz 6, 01203 Leipzig, Germany

ANNA H. WEYHER, Department of Anthropology, Washington University in St. Louis, St. Louis, MO 63130, USA

NATHAN D. WOLFE, Department of Epidemiology, School of Public Health, University of California Los Angeles, 650 Charles E. Young Drive South, CHS 71–279B, Box 177220, Los Angeles, CA 90095–1772, USA

PATRICIA C. WRIGHT, Department of Anthropology, Stony Brook University, Stony Brook, NY 11794 USA and Centre ValBio, BP 33 – Ranomafana, 312 Ifanadiana, Madagascar, and Institute of Biotechnology, and Department of Ecology and Systematics, University of Helsinki, FIN-00014, Finland

JEFFREY WYATT, Centre ValBio, BP 33 – Ranomafana, 312 Ifanadiana Madagascar and Department of Comparative Medicine, University of Rochester Medical Center, Rochester, NY 14627 USA
Anyone who has spent any extended period living and researching in the tropics has an idea, whether by second-hand experience caring for others or by being infected themselves with malaria, amebic dysentery, sand fleas, or some of the other local milieu of parasites, just what it is like to be a primate parasite host. The effects of parasitism can be serious or even deadly, warranting that all precautionary measures be taken. However, for some like ourselves who have had the experience more than once, it can lead to an interest to understanding the nature of host–parasite relationships and the effect parasites can have on the host. For both of us, the study of primate parasite ecology is truly infectious, and it is our wish that this enthusiasm is transmitted to you the reader!

The sudden appearance of diseases like SARS (Severe Acute Respiratory Syndrome) and bird flu or the devastating impacts that diseases like Ebola have had on both human and wildlife communities, and the immense social and economic costs created by viruses like HIV underscore our need to understand the ecology of infectious diseases. Given that monkeys and apes often share parasites with humans, understanding the ecology of infectious diseases in non-human primates is of paramount importance. This is well illustrated by the HIV viruses, the causative agents of human AIDS, which evolved recently from related viruses of chimpanzees (Pan troglodytes) and sooty mangabeys (Lophocebus aytis) and the outbreaks of Ebola virus, which trace their origins to zoonotic transmissions from local apes. A consideration of how environmental change may promote contact between humans and non-human primates and increase the possibility of sharing infectious disease detrimental to humans or non-human primates is now critical to both conservation and human health planning.

Such emerging diseases and the impact that they have had on humans and wildlife has stimulated a considerable amount of recent research and it is clear that the field of primate disease ecology has recently been gaining momentum. The study of disease adds a new and important dimension to primatology, as most previous research has focused on predation and resource competition, with almost no research on infectious disease as an ecological force. The relevance of issues of disease ecology is wide with an expected impact on a diverse set of
Preface

researchers including the veterinary sciences, conservation, zoonotic diseases, zoology, and evolutionary biology. This is a very young field, but the time is right to gather together what information has recently become available on primate disease ecology to clearly illustrate the “state of the art” and to also point the way forward.

This book covers a diversity of aspects of host–parasite relationships integrating laboratory methodology, field research, and theory. In general, the chapters fall into three broad categories: (1) Methods to study primate–parasite interactions, (2) The natural history of primate–parasite interactions, and (3) The ecology of primate–parasite interactions. Within this general framework chapters in the section on field research cover a variety of primate species ranging from tropical to temperate habitats. They cover host–parasite, pathogen interactions of both internal and external parasites. Authors address the dynamic nature of host–parasite relationships and look at such aspects as host behavioral counter-measures in response to infection, inter- and intra-species difference in parasite prevalence as a consequence of climatic and environmental variation, habitat fragmentation, and seasonality. Chapters include original research papers, reviews, methodology, theory on various aspects of host–parasite ecology research, and resources for species identification.

This book would not have come to fruition had it not been for the enthusiasm and efforts of all the authors and colleagues who offered their time and assistance in preparing and reviewing the manuscripts. To all of you we give our hearty appreciation.