Chapter 11: Conclusions

The progress through coming together, information transfer, decision-making, moving together, synchronisation, structures, regulation to complicated individuals is one of increasingly complex aspects of collective animal behaviour. Each chapter has attempted to unify group behaviour of different species in these different situations and explain similarities in the underlying function and mechanisms. I will close this book with a brief discussion of how I believe that we should think of the science of collective animal behaviour and suggest some future directions for research.

11.1 From toys to tools

This book grew from a review article I wrote three years ago on ‘principles of collective animal behaviour’ (Sumpter 2006). There I outlined several guiding principles such as ‘positive feedback’, ‘individual variation’ etc. which underlie many aspects of collective animal behaviour. These principles have again appeared at many points within this book.

Having a set of such principles is useful for grouping and categorising ideas and more quickly understanding new systems. Here, I have chosen a slightly different grouping of ideas under the different chapter headings, concentrating more on similarities between systems in spatial or temporal organisation. Again, these chapters provide a way of unifying our understanding of different systems.

Another way of unifying different systems is through mathematical modelling. One of the most remarkable features of the study of collective animal behaviour is the applicability of mathematical models. This is made all the more remarkable when we consider that animals are not as simple as physical particles. Individuals vary and experiments always involve intrinsic variation and noise. Despite, and sometimes because of this variation, it is possible to use one model to make predictions about very different types of groups.

Unifying principles are not however the be all and end all of science. In the 2006 article and now, I advocate a pragmatic view to unifying theories of collective behaviour. The study of collective animal behaviour should proceed on a case-by-case basis. For each particular system, we should classify how individuals interact with each other and build mathematical models based on observations. In many cases, models of one system may be applicable to other systems and this can help us understand the underlying mechanisms. This similarity between models should not in itself become the driving force in our research.

Instead, I see mathematical models and different theoretical approaches as a tool set for understanding a wide variety of systems. No single mathematical model provides a unique correct way of describing all aspects of a particular system. Neither can we expect to apply the same model to all systems. The art of understanding the world is not in mastery of particular models but in an ability to recognise and exploit connections where they exist.

It is for this reason that neither mechanistic nor functional approaches to group behaviour can claim precedence over the other. Both of these approaches have produced elegant models, which have been tested against experiments and suggest new ways in which systems can be viewed. In this book, I have emphasised the combination of functional and mechanistic approaches. Even if particular studies are likely to be more or less biased to either the functional or the mechanistic, it is important to bear in mind how the other approach can play a role in increasing understanding.

The idea that mathematical modelling has a role to play in understanding complex systems is not new. The last 30 years has seen the rapid growth of complexity science, the application of non-linear mathematics, statistical physics and the theory of networks to understanding biochemistry, biology and sociology. In many cases these models are ‘toy models’ of systems. The Kuramoto model, self-propelled particles, the logistic equation, self-organised criticality, small world networks, voter models, preferential attachment, to name just a few, are ideas which are less inspired by details of particular systems and more an attempt to abstract from details and make general predictions about a wide range of systems.

In my opinion, the aim of complexity science today should be to move from these toy models towards a set of tools that can be applied to specific complex systems. Without a clear relationship to biological or sociological systems the role of toy models is limited. Or to put it more bluntly, as a biologist colleague once told me as I was trying to explain one such model to him, “leave your toys at home, we’re trying to work here”.

The models applied in this book are not just toys used to train our intuition before we get to work on the real thing. They are the tools of a serious approach to understanding specific systems. From models of animal group size distributions; through cockroach, honey bee and ant emigration; to the collective motion of insects, birds and fish; to the structure of ant trails and termite nests, the interplay between experiment and model is clear. The models bring rigour to our assumptions about a system, make testable predictions and in many cases provide a quantitative as well as a qualitative match to the available data.

It is the combination of the relative sophistication of the individuals of which animal groups are composed and the empirical success in using mathematical models to predict and understand their behaviour, which makes the study of collective animal behaviour important. Despite the seeming complexity of the task of understanding social interactions, we do have tools that allow us to predict experimental outcomes. This should give hope to applications of similar methods in understanding ecosystems, brain function and other complex systems.

There is, of course, no clear cut distinction between toys and tools. Often a toy model based on very little experimental insight can serve as a basis for a more rigorous and detailed argument when fleshed out. Indeed, models of animal aggregations started as toy models of particle cohesion and self-propelled particle models of animal motion started as animations for computer games!

The important question is how to get the balance right between simplifying assumptions and biological detail. I believe the key to getting this balance right is as follows: one should concentrate on models that make predictions about a system which are both non-trivial and testable. Non-trivial means that the model is needed to make the prediction. We cannot simply arrive at the same conclusion by verbal argument alone. Here the rigour brought by mathematical modelling is important. Often the problem with verbal arguments is not that they cannot be used to make a particular prediction, but rather that verbal arguments can be made for all sorts of different predictions. It is determining which prediction follows from a set of well stated assumptions which is non-trivial and is the tool provided by mathematical modelling.

The work described in this book is testimony to the fact that ideas like self-organisation, emergence, complexity theory are not just fancy sounding names, but can be applied to make non-trivial and testable predictions about biological and sociological systems.

For this reason, scientists in all fields should be interested in collective animal behaviour and mathematical modelling of complex systems in general.

11.2 Some open questions

There are many open and interesting questions in collective animal behaviour. I have mentioned many of these during the course of the book, but it is worth listing some of them here for further consideration.

Linking mechanisms and function in group size distribution (section 2.9). While Niwa's model appears to provide a good empirical fit to data on fish schools and may be extendable to other animal groups, it does not include functional considerations. An interesting question is how individuals manipulate the average group size they experience, the key parameter in Niwa's model.

How humans integrate many wrongs (sections 3.5 & 4.4) The Milgram and Asch observations and experiments on humans reveal that humans use quorum-like rules to decide whether to copy the choices of others. It would be interesting to investigate these ideas in a context where there is a reward to be gained by making correct choices. Here, laboratory experiments, similar to those performed to investigate the prisoner's dilemma and other co-operative games in humans, could be used.

Modelling realistic motion of bird flocks and fish schools (**sections 5.2-5.4).** Many of the 'mesoscopic' features of moving animal groups are not reproduced by current self-propelled particle models. The main restriction here is the availability of empirical data on the structure and dynamics of moving animal groups. It is currently difficult to quantify why the models are not quite right. Recent empirical work on starlings is beginning to provide this data, but it remains an important challenge in an area where so much theoretical modelling has already been done.

Evolving self-propelled particles (section 5.7). The Wood et al. model of how predation avoidance evolves is just one example of how natural selection might influence collective motion. One possibility is that natural selection acts to increase the complexity of group motion, so that the group is highly sensitive to changes in the environment (Sumpter et al. 2008a).

Individual variation (sections 4.3 & 6.1). Many of the models of collective behaviour assume that individuals are identical units, but the many wrongs idea and Kuramoto's model of synchronisation instead make predictions on the basis of differences between individuals. There are consistent differences between animals in their behaviour and a research challenge is to understand how these differences are integrated at the level of the group. Instead of seeing individual differences as simply 'noise' we should investigate their role in producing collective patterns.

Modelling complex nest structures (section 7.3). Although several models have explained formation of pillars and chambers via templates and stigmergy, how the complex structures such as harvester ant nests (figure 7.5) are constructed remains an open problem.

Providing a useable formal framework for individual-based modelling (section 9.5). One of the weaknesses of the individual-based approach to modelling is that because they are not expressed in a formal framework individual-based model results can be difficult to reliably replicate. The problem is agreeing on a tool for individual-based modelling and designing one that is flexible enough to encompass different types of models.

Collective human behaviour (sections 3.5, 6.1 & 7.5 and chapter 8). While there is a growing application of mathematical models to understand the social behaviour of humans, I would continue to classify many of the models as toys rather than tools. The studies discussed throughout this book are notable exceptions and other recent studies using network analysis to look at social interaction on, for example, the internet are also beginning to use data to inform models. The possibility for rigorous application to data on human social interactions is clear. It will be interesting to see how types of techniques used in studying collective animal behaviour can be applied in studying humans.

References

Adams, E. S. & Tschinkel, W. R. 1995 Density-Dependent Competition in Fire Ants - Effects on Colony Survivorship and Size Variation. *Journal of Animal Ecology* **64**, 315-324.

Aleksiev, A. S., Sendova-Franks, A. B. & Franks, N. R. 2007 Nest 'moulting' in the ant Temnothorax albipennis. *Animal Behaviour* **74**, 567-575.

Ame, J. M., J., H., Rivault, C., Detrain, C. & Deneubourg, J. L. 2006 Collegial decision making based on social

amplification leads to optimal group formation. *PNAS* **103**, 5835-5840.

Ame, J. M., Rivault, C. & Deneubourg, J. L. 2004 Cockroach aggregation based on strain odour recognition. *Animal Behaviour* **68**, 793-801.

Anderson, C. & Jadin, J. L. V. 2001 The adaptive benefit of leaf transfer in Atta colombica. *Insectes Sociaux* **48**, 404-405.

Anderson, C. & McShea, D. W. 2001a Individual versus social complexity, with particular reference to ant colonies. *Biological Review* **76**, 211-237.

Anderson, C. & McShea, D. W. 2001b Intermediate-level parts in insect societies: adaptive structures that ants buid away from the nest. *Insectes Soc.* **48**, 291-301.

Anderson, C. & Ratnieks, F. L. W. 1999 Worker allocation in insect societies: coordination of nectar foragers and nectar receivers in honey bee (Apis mellifera) colonies. *Behavioral Ecology and Sociobiology* **46**, 73-81.

Anderson, C. & Ratnieks, F. L. W. 2000 Task partitioning in insect societies: novel situations. *Insectes Sociaux* **47**, 198-199.

Aoki, I. 1982 A Simulation Study on the Schooling Mechanism in Fish. *Bulletin of the Japanese Society of Scientific Fisheries* **48**, 1081-1088.

Arthur, W. B. 1994 Inductive Reasoning and Bounded Rationality. *American Economic Review* **84**, 406-411.

Arthur, W. B. 1999 Complexity and the economy. *Science* **284**, 107-109.

Asch, S. E. 1955 Opinions and social pressure. . *Scientific American* **193**, 31-25.

Ashby, W. R. 1947 Principles of the self-organizing dynamic system. *Journal of General Psychology* 125–128.

Avery, C. & Zemsky, P. 1998 Multidimensional uncertainty and herd behavior in financial markets. *American Economic Review* **88**, 724-748.

Aviles, L. & Tufino, P. 1998 Colony size and individual fitness in the social spider Anelosimus eximius. *American Naturalist* **152**, 403-418.

Avitabile, A., Morse, R. A. & Boch, R. 1975 Swarming honey bees guided by pheromones. . *Annals of the Entomological Society of America* **6**, 1079-1082.

Axelrod, R. & Hamilton, W. D. 1981 The Evolution of Cooperation. *Science* **211**, 1390-1396.

Azcarate, F. M. & Peco, B. 2003 Spatial patterns of seed predation by harvester ants (*Messor Forel*) in Mediterranean grassland and scrubland. *Insectes Soc.* **50**, 120-126.

Bak, P. 1996 *How Nature Works: The Science of Self-Organized Criticality*: Copernicus Books.

Ball, P. 2004 *Critical Mass: How one thing leads to another*: Heinemann/Farrar.

Ballerini, M., Cabibbo, N., Candelier, R., Cavagna, A., Cisbani, E., Giardina, I., Orlandi, A., Parisi, G., Procaccini, A., Viale, M. & Zdravkovic, V. 2008a Empirical investigation of starling flocks: a benchmark study in collective animal behaviour. *Animal Behaviour* **76**, 201-215.

Ballerini, M., Cabibbo, N., Candeleir, R., Cavagna, A., Cisbani, E., Giardina, I., Lecomte, V., Orlandi, A., Parisi, G., Procaccini, A., Viale, M. & Zdravkovic, V. 2008b Interaction ruling animal collective behavior depends on topological rather than metric distance: Evidence from a field study. *Proceedings of the National Academy of Sciences of the United States of America* **105**, 1232-1237.

Barabasi, A. L. 2003 *Linked*. London: Penguin Books.

Barabasi, A. L. & Albert, R. 1999 Emergence of scaling in random networks. *Science* **286**, 509-512.

Barabasi, A. L., Albert, R. & Jeong, H. 1999 Mean-field theory for scale-free random networks. *Physica A* **272**, 173-187.

Barber, J. C. E. 2001 Social Influences on the Motivation of Laying Hens. . In *Department of Zoology*, vol. DPhil. Oxford: University of Oxford.

Barnard, C. J. & Sibly, R. M. 1981 Producers And Scroungers - A General-Model And Its Application To Captive Flocks Of House Sparrows. *Animal Behaviour* **29**, 543-550.

Bartholdi, J. J., Seeley, T. D., Tovey, C. A. & Vande Vate, J. H. 1993 The pattern and effectiveness of forager allocation among flower patches by honey bee colonies. *Journal of Theoretical Biology* **160**, 23-40.

Batty, M. 2008 The size, scale, and shape of cities. *Science* **319**, 769-771.

Batty, M., Desyllas, J. & Duxbury, E. 2003a The discrete dynamics of small-scale spatial events: agent-based models of mobility in carnivals and street parades. *International Journal of Geographical Information Science* **17**, 673-697.

Batty, M., Desyllas, J. & Duxbury, E. 2003b Safety in numbers? Modelling crowds and designing control for the Notting Hill Carnival. *Urban Studies* **40**, 1573-1590.

Bays, P. M. & Wolpert, D. M. 2007 Computational principles of sensorimotor control that minimize uncertainty and variability. *Journal of Physiology-London* **578**, 387-396.

Beauchamp, G. & Fernandez-Juricic, E. 2005 The group-size paradox: effects of learning and patch departure rules. *Behavioral Ecology* **16**, 352-357.

Becco, C. V., N., Delcourt, J. & Poncin, P. 2006 Experimental evidences of a structural and dynamical transition in fish school. *Physica A* **367**, 487-493.

Beckers, R., Deneubourg, J. L. & Goss, S. 1992a Trail Laying Behavior During Food Recruitment in the Ant Lasius-Niger (L). *Insectes Sociaux* **39**, 59-72.

Beckers, R., Deneubourg, J. L. & Goss, S. 1992b Trails and U-Turns in the Selection of a Path by the Ant Lasius-Niger. *Journal of Theoretical Biology* **159**, 397-415.

Beckers, R., Deneubourg, J. L. & Goss, S. 1993 Modulation of Trail Laying in the Ant Lasius-Niger (Hymenoptera, Formicidae) and Its Role in the Collective Selection of a Food Source. *Journal of Insect Behavior* **6**, 751-759.

Beckers, R., Goss, S., Deneubourg, J. L. & Pasteels, J. M. 1989 Colony size, communication and ant foraging strategy. *Psyche* **96**, 239-256.

Bednekoff, P. A. 1997 Mutualism among safe, selfish sentinels: A dynamic game. *American Naturalist* **150**, 373-392.

Bednekoff, P. A. & Woolfenden, G. E. 2003 Florida scrub-jays (Aphelocoma coerulescens) are sentinels more when well-fed (even with no kin nearby). *Ethology* **109**, 895-903.

Bednekoff, P. A. & Woolfenden, G. E. 2006 Florida scrub-jays compensate for the sentinel behavior of flockmates. *Ethology* **112**, 796-800.

Beekman, M. & Bin Lew, J. 2008 Foraging in honeybees - when does it pay to dance? *Behavioral Ecology* **19**, 255-262.

Beekman, M., Fathke, R. L. & Seeley, T. D. 2006 How does an informed minority of scouts guide a honeybee swarm as it flies to its new home? *Animal Behaviour* **71**, 161-171.

Beekman, M., Gilchrist, A. L., Duncan, M. & Sumpter, D. J. T. 2007 What makes a honeybee scout? *Behavioral Ecology and Sociobiology*.

Beekman, M., Komdeur, J. & Ratnieks, F. L. W. 2003 Reproductive conflicts in social animals: who has power? *Trends in Ecology & Evolution* **18**, 277-282.

Beekman, M., Sumpter, D. J. T. & Ratnieks, F. L. W. 2001 Phase transition between disordered and ordered foraging in Pharaoh's ants. *Proceedings of the National Academy of Sciences of the United States of America* **98**, 9703-9706.

Bennett, M., Schatz, M. F., Rockwood, H. & Wiesenfeld, K. 2002 Huygens's clocks. *Proceedings of the Royal Society of London Series a-Mathematical Physical and Engineering Sciences* **458**, 563-579.

Bernasconi, G., Ratnieks, F. L. W. & Rand, E. 2000 Effect of "spraying" by fighting honey bee queens (Apis mellifera L.) on the temporal structure of fights. *Insectes Sociaux* **47**, 21-26.

Bernhardt, D., Campello, M. & Kutsoati, E. 2006 Who herds? *Journal of Financial Economics* **80**, 657-675.

Bernstein, C., Kacelnik, A. & Krebs, J. R. 1988 Individual Decisions And The Distribution Of Predators In A Patchy Environment. *Journal Of Animal Ecology* **57**, 1007-1026.

Berryman, A. A. 1999 *Principles of population dynamics*. London: Stanley Thornes.

Bertram, B. C. R. 1975 Social Factors Influencing Reproduction in Wild Lions. *Journal of Zoology* **177**, 463-482.

Bettencourt, L. M. A., Lobo, J., Helbing, D., Kuhnert, C. & West, G. B. 2007 Growth, innovation, scaling, and the pace of life in cities. *Proceedings of the National Academy of Sciences of the United States of America* **104**, 7301-7306.

Biesmeijer, J. C. & de Vries, H. 2001 Exploration and exploitation of food sources by social insect colonies: a revision of the scout-recruit concept. *Behavioral Ecology and Sociobiology* **49**, 89-99.

Biesmeijer, J. C. & Slaa, E. J. 2004 Information flow and organization of stingless bee foraging. *Apidologie* **35**, 143-157.

Biro, D., Sumpter, D. J. T., Meade, J. & Guilford, T. 2006 From compromise to leadership in pigeon homing. *Current Biology* **16**, 2123-2128.

Boi, S., Couzin, I. D., Del Buono, N., Franks, N. R. & Britton, N. F. 1999 Coupled oscillators and activity waves in ant colonies. *Proceedings Of The Royal Society Of London Series B-Biological Sciences* **266**, 371-378.

Bollazzi, M. & Roces, F. 2007 To build or not to build: circulating dry air organizes collective building for climate control in the leaf-cutting ant Acromyrmex ambiguus. *Animal Behaviour* **74**, 1349-1355.

Bonabeau, E. & Dagorn, L. 1995 Possible Universality In The Size Distribution Of Fish Schools. *Physical Review E* **51**, R5220-R5223.

Bonabeau, E., Dagorn, L. & Freon, P. 1999 Scaling in animal group-size distributions. *Proceedings Of The National Academy Of Sciences Of The United States Of America* **96**, 4472-4477.

Bonabeau, E., Theraulaz, G. & Deneubourg, J. L. 1998a Fixed response thresholds and the regulation of division of labor in insect societies. *Bulletin of Mathematical Biology* **60**, 753-807.

Bonabeau, E., Theraulaz, G., Deneubourg, J. L., Aron, S. & Camazine, S. 1997 Self-organization in social insects. *Trends in Ecology & Evolution* **12**, 188-193.

Bonabeau, E., Theraulaz, G., Deneubourg, J. L., Franks, N. R., Rafelsberger, O., Joly, J. L. & Blanco, S. 1998b A model for the emergence of pillars, walls and royal chambers in termite nests. *Philosophical Transactions of the Royal Society of London Series B-Mathematical Physical and Engineering Sciences* **353**, 1561-1576.

Bono, J. M. & Crespi, B. J. 2006 Costs and benefits of joint colony founding in Australian Acacia thrips. *Insectes Sociaux* **53**, 489-495.

Bono, J. M. & Crespi, B. J. 2008 Cofoundress relatedness and group productivity in colonies of social Dunatothrips (Insecta : Thysanoptera) on Australian Acacia. *Behavioral Ecology and Sociobiology* **62**, 1489-1498.

Bortkiewicz, L. J. 1898 *The Law of Small Numbers*.

Bourke, A. F. G. & Franks, N. R. 1995 *Social Evolution in Ants*. Princeton, New Jersey: Princeton University Press.

Brannstrom, A. & Sumpter, D. J. T. 2005 The role of competition and clustering in population dynamics. *Proceedings of the Royal Society B-Biological Sciences* **272**, 2065-2072.

Britton, N. F. 2005 *Essential Mathematical Biology*: Springer.

Britton, N. F., Franks, N. R., Pratt, S. C. & Seeley, T. D. 2002 Deciding on a new home: how do honeybees agree? *Proceedings of the Royal Society of London Series B-Biological Sciences* **269**, 1383-1388.

Brown, C. R. 1986 Cliff Swallow Colonies As Information-Centers. *Science* **234**, 83-85.

Brown, C. R. & Brown, M. B. 1986 Ectoparasitism as a cost of coloniality in cliff swallows (*Hirundo pyrrhonota*). *Ecology* **67**, 1206-1218.

Brown, C. R. & Brown, M. B. 1996 *Coloniality in the Cliff Swallow*. Chicago: The University of Chicago Press.

Brown, C. R., Brown, M. B. & Shaffer, M. L. 1991 Food-Sharing Signals Among Socially Foraging Cliff Swallows. *Animal Behaviour* **42**, 551-564.

Bruch, E. E. & Mare, R. D. 2006 Neighborhood choice and neighborhood change. *American Journal of Sociology* **112**, 667-709.

Bruns, G. 1997 *Distributed Systems Analysis with CCS*: Prentice Hall.

Buchanan, M. 2000 *Ubiquity: The New Science That Is Changing the World*. London: Phoenix.

Buck, J. 1988 Synchronous Rhythmic Flashing of Fireflies .2. *Quarterly Review of Biology* **63**, 265-289.

Buck, J. & Buck, E. 1976 Synchronous fireflies. *Scientific American* **234**, 74-85.

Buck, J., Buck, E., Case, J. F. & Hanson, F. E. 1981 Control of Flashing in Fireflies .5. Pacemaker Synchronization in Pteroptyx-Cribellata. *Journal of Comparative Physiology* **144**, 287-298.

Buhl, J., Deneubourg, J. L., Grimal, A. & Theraulaz, G. 2005 Self-organized digging activity in ant colonies. *Behavioral Ecology and Sociobiology* **58**, 9-17.

Buhl, J., Gautrais, J., Deneubourg, J. L. & Theraulaz, G. 2004 Nest excavation in ants: group size effects on the size and structure of tunneling networks. *Naturwissenschaften* **91**, 602-606.

Buhl, J., Hicks, K., Miller, E., Persey, S., Alinvi, O. & Sumpter, D. 2009 Shape and efficiency of wood ant foraging networks. *Behavioral Ecology and Sociobiology* **63**, 451-460.

Buhl, J., Sumpter, D. J. T., Couzin, I. D., Hale, J. J., Despland, E., Miller, E. R. & Simpson, S. J. 2006 From disorder to order in marching locusts. *Science* **312**, 1402-1406.

Burd, M. 2006 Ecological consequences of traffic organisation in ant societies. *Physica a-Statistical Mechanics and Its Applications* **372**, 124-131.

Burd, M. & Aranwela, N. 2003 Head-on encounter rates and walking speed of foragers in leaf-cutting ant traffic. *Insectes Sociaux* **50**, 3-8.

Burt, C. 1963 Is intelligence distributed normally? *British Journal of Mathematical & Statistical Psychology*, 170-190.

Calhim, S., Shi, J. B. & Dunbar, R. I. M. 2006 Sexual segregation among feral goats: testing between alternative hypotheses. *Animal Behaviour* **72**, 31-41.

Camazine, S., Deneubourg, J. L., Franks, N. R., Sneyd, J., Theraulaz, G. & Bonabeau, E. 2001 *Self-organization in biological systems*. Princeton studies in complexity. Princeton, N.J.: Princeton University Press.

Camazine, S. & Sneyd, J. 1991 A model of collective nectar source selection by honey bees: self-organisation through simple rules. *Journal of Theoretical Biology* **149**, 547-571.

Camazine, S., Visscher, P. K., Finley, J. & Vetter, R. S. 1999 House-hunting by honey bee swarms: collective decisions and individual behaviors. *Insectes Sociaux* **46**, 348-360.

Cammaerts, M. C. & Cammaerts, R. 1980 Food Recruitment Strategies of the Ants Myrmica-Sabuleti and Myrmica-Ruginodis. *Behavioural Processes* **5**, 251-270.

Caraco, T. 1979a Time Budgeting And Group-Size - Test Of Theory. *Ecology* **60**, 618-627.

Caraco, T. 1979b Time Budgeting And Group-Size - Theory. *Ecology* **60**, 611-617.

Caraco, T., Martindale, S. & Pulliam, H. R. 1980 Avian Flocking In The Presence Of A Predator. *Nature* **285**, 400-401.

Carlson, J. M. & Doyle, J. 2002 Complexity and robustness. *Proceedings of the National Academy of Sciences of the United States of America* **99**, 2538-2545.

Cavagna, A., Cimarelli, A., Giardina, I., Orlandi, A., Parisi, G., Procaccini, A., Santagati, R. & Stefanini, F. 2008a New statistical tools for analyzing the structure of animal groups. *Mathematical Biosciences* **214**, 32-37.

Cavagna, A., Giardina, I., Orlandi, A., Parisi, G., Procaccini, A., Viale, M. & Zdravkovic, V. 2008b The STARFLAG handbook on collective animal behaviour: 1. Empirical methods. *Animal Behaviour* **76**, 217-236.

Challet, D. & Zhang, Y. C. 1997 Emergence of cooperation and organization in an evolutionary game. *Physica A* **246**, 407-418.

Challet, D. & Zhang, Y. C. 1998 On the minority game: Analytical and numerical studies. *Physica A* **256**, 514-532.

Charles, C. Z. 2003 The dynamics of racial residential segregation. *Annual Review of Sociology* **29**, 167-207.

Chauvin, R. 1962 Observations sur les pistes de *Formica polyctena*. *Insectes Soc.* **9**, 311-321.

Chretien, L. 1996 Organisation spatiele du materiel provenant de l'excavation du nid chez *Messor barbarus* et des cadavres d'ouvrieres chez *Lasius niger* (Hymenoptera: Formicidae). In *Center for Nonlinear Phenomena and Complex Systems* vol. PhD. Brussles: Universite Libre de Bruxelles.

Clark, C. W. & Mangel, M. 1984 Foraging And Flocking Strategies - Information In An Uncertain Environment. *American Naturalist* **123**, 626-641.

Clark, C. W. & Mangel, M. 1986 The evolutionary advantages of group foraging. *Theoretical Population Biology*, 45-75.

Clark, W. A. V. 1991 Residential Preferences and Neighborhood Racial Segregation - a Test of the Schelling Segregation Model. *Demography* **28**, 1-19.

Clutton-Brock, T. 2002 Breeding together: Kin selection and Mutualism in Cooperative Vertebrates. *Science* **296**, 69-72.

Clutton-Brock, T. H., Brotherton, P. N. M., Russell, A. F., O'Riain, M. J., Gaynor, D., Kansky, R., Griffin, A., Manser, M., Sharpe, L., McIlrath, G. M., Small, T., Moss, A. & Monfort, S. 2001 Cooperation, control, and concession in meerkat groups. *Science* **291**, 478-481.

Clutton-Brock, T. H., O'Riain, M. J., Brotherton, P. N. M., Gaynor, D., Kansky, R., Griffin, A. S. & Manser, M. 1999 Selfish sentinels in cooperative mammals. *Science* **284**, 1640-1644.

Cole, B. J. 1991a Is Animal Behavior Chaotic - Evidence from the Activity of Ants. *Proceedings of the Royal Society of London Series B-Biological Sciences* **244**, 253-259.

Cole, B. J. 1991b Short-term activity cycles in ants: generation of periodicity through worker interaction. *American Naturalist* **137**, 244-259.

Cole, B. J. & Cheshire, D. 1996 Mobile cellular automata models of ant behavior: Movement activity of Leptothorax allardycei. *American Naturalist* **148**, 1-15.

Collett, M., Despland, E., Simpson, S. J. & Krakauer, D. C. 1998 Spatial scales of desert locust gregarization. *Proceedings Of The National Academy Of Sciences Of The United States Of America* **95**, 13052-13055.

Collins, L. M. & Sumpter, D. J. T. 2007 The feeding dynamics of broiler chickens. *Journal of the Royal Society Interface* **4**, 65-72.

Conlisk, J. 1996 Why bounded rationality? *Journal of Economic Literature* **34**, 669-700.

Conradt, L. 1998 Could asynchrony in activity between the sexes cause intersexual social segregation in ruminants? *Proceedings of the Royal Society of London Series B-Biological Sciences* **265**, 1359-1363.

Conradt, L. & Roper, T. J. 2000 Activity synchrony and social cohesion: a fission-fusion model. *Proceedings of the Royal Society of London Series B-Biological Sciences* **267**, 2213-2218.

Conradt, L. & Roper, T. J. 2003 Group decision-making in animals. *Nature* **421**, 155-158.

Conradt, L. & Roper, T. J. 2005 Consensus decision making in animals. *Trends In Ecology & Evolution* **20**, 449-456.

Conradt, L. & Roper, T. J. 2007 Democracy in animals: the evolution of shared group decisions. *Proceedings of the Royal Society B-Biological Sciences* **274**, 2317-2326.

Coolen, I., Giraldeau, L. A. & Lavoie, M. 2001 Head position as an indicator of producer and scrounger tactics in a ground-feeding bird. *Animal Behaviour* **61**, 895-903.

Costa, J. T. 2006 *The other insect societies*. Cmbridge, Massachusetts: Harvard University Press.

Couzin, I. D. & Franks, N. R. 2003 Self-organized lane formation and optimized traffic flow in army ants. *Proceedings Of The Royal Society Of London Series B-Biological Sciences* **270**, 139-146.

Couzin, I. D. & Krause, J. 2003 Self-organization and collective behavior in vertebrates. *Advances in the Study of Behavior* **32**, 1-75.

Couzin, I. D., Krause, J., Franks, N. R. & Levin, S. A. 2005 Effective leadership and decision-making in animal groups on the move. *Nature (London)* **433**, 513-516.

Couzin, I. D., Krause, J., James, R., Ruxton, G. D. & Franks, N. R. 2002 Collective memory and spatial sorting in animal groups. *Journal Of Theoretical Biology* **218**, 1-11.

Croft, D. P., Arrowsmith, B. J., Bielby, J., Skinner, K., White, E., Couzin, I. D., Magurran, A. E., Ramnarine, I. & Krause, J. 2003 Mechanisms underlying shoal composition in the Trinidadian guppy, Poecilia reticulata. *Oikos* **100**, 429-438.

Croft, D. P., James, R., Thomas, P. O. R., Hathaway, C., Mawdsley, D., Laland, K. N. & Krause, J. 2006 Social structure and co-operative interactions in a wild population of guppies (Poecilia reticulata). *Behavioral Ecology and Sociobiology* **59**, 644-650.

Croft, D. P., James, R., Ward, A. J. W., Botham, M. S., Mawdsley, D. & Krause, J. 2005 Assortative interactions and social networks in fish. *Oecologia* **143**, 211-219.

Cully, S. M. & Seeley, T. D. 2004 Self-assemblage formation in a social insect: the protective curtain of a honey bee swarm. *Insectes Sociaux* **51**, 317-324.

Czirok, A., Barabasi, A. L. & Vicsek, T. 1999 Collective motion of self-propelled particles: Kinetic phase transition in one dimension. *Physical Review Letters* **82**, 209-212.

Czirok, A., Stanley, H. E. & Vicsek, T. 1997 Spontaneously ordered motion of self-propelled particles. *Journal Of Physics A-Mathematical And General* **30**, 1375-1385.

Czirok, A. & Vicsek, T. 2000 Collective behavior of interacting self-propelled particles. *Physica A* **281**, 17-29.

Dall, S. R. X., Giraldeau, L. A., Olsson, O., McNamara, J. M. & Stephens, D. W. 2005 Information and its use by animals in evolutionary ecology. *Trends In Ecology & Evolution* **20**, 187-193.

Dambach, M. & Goehlen, B. 1999 Aggregation density and longevity correlate with humidity in first-instar nymphs of the cockroach Blattella germanica. . *Journal of Insect Physiology* **45**, 423–429.

Danchin, E., Giraldeau, L. A., Valone, T. J. & Wagner, R. H. 2004 Public information: From nosy neighbors to cultural evolution. *Science* **305**, 487-491.

Dawkins, R. 1976 *The Selfish Gene*. Oxford: Oxford University Press.

Dawkins, R. 1982 *The extended phenotype*. Oxford: W.H. Freeman and Company.

de Vries, H. & Biesmeijer, J. C. 1998 Modelling collective foraging by means of individual behaviour rules in honey-bees. *Behavioral Ecology and Sociobiology* **44**, 109-124.

de Vries, H. & Biesmeijer, J. C. 2002 Self-organization in collective honeybee foraging: emergence of symmetry breaking, cross inhibition and equal harvest-rate distribution. *Behavioral Ecology and Sociobiology* **51**, 557-569.

Deneubourg, J. L., Aron, S., Goss, S. & Pasteels, J. M. 1990a The self-organizing exploratory pattern of the Argentine ant. *Journal of Insect Behavior* **3**, 159-168.

Deneubourg, J. L. & Goss, S. 1989 Collective Patterns and Decision-Making. *Ethology Ecology & Evolution* **1**, 295-311.

Deneubourg, J. L., Goss, S., Franks, N. & Pasteels, J. M. 1989 The blind leading the blind: Modeling chemically mediated army ant raid patterns. *Journal of Insect Behavior* **2**, 719-725.

Deneubourg, J. L., Grégoire, J. C. & Le Fort, E. 1990b Kinetics of larval gregarious behavior in the bark beetle *Dendroctonus micans* (Coleoptera: Scolytidae). *Journal of Insect Behavior* **3**, 169-182.

Deneubourg, J. L., Lioni, A. & Detrain, C. 2002 Dynamics of aggregation and emergence of cooperation. *Biological Bulletin* **202**, 262-267.

Despland, E., Rosenberg, J. & Simpson, S. J. 2004 Landscape structure and locust swarming: a satellite's eye view. *Ecography* **27**, 381-391.

Detrain, C. & Deneubourg, J. L. 2006 Self-organized structures in a superorganism: do ants “behave” like molecules? *Physics of Life Reviews* **3**, 162-187.

Detrain, C., Tasse, O., Versaen, M. & Pasteels, J. M. 2000 A field assessment of optimal foraging in ants: Trail patterns and seed retrieval by the European harvester ant *Messor barbarus*. *Insectes Soc.* **47**, 56-62.

Devenow, A. & Welch, I. 1996 Rational herding in financial economics. *European Economic Review* **40**, 603-615.

Devigne, C. & Detrain, C. 2002 Collective exploration and area marking in the ant Lasius niger. *Insectes Sociaux* **49**, 357-362.

Doebeli, M. & Hauert, C. 2005 Models of cooperation based on the Prisoner's Dilemma and the Snowdrift game. *Ecology Letters* **8**, 748-766.

Doebeli, M., Hauert, C. & Killingback, T. 2004 The evolutionary origin of cooperators and defectors. *Science* **306**, 859-862.

Dornhaus, A. & Chittka, L. 2004 Why do honey bees dance? *Behavioral Ecology And Sociobiology* **55**, 395-401.

Dornhaus, A. & Franks, N. R. 2006 Colony size affects collective decision-making in the ant Temnothorax albipennis. *Insectes Sociaux* **53**, 420-427.

Dornhaus, A., Franks, N. R., Hawkins, R. M. & Shere, H. N. S. 2004 Ants move to improve: colonies of Leptothorax albipennis emigrate whenever they find a superior nest site. *Animal Behaviour* **67**, 959-963.

Dornhaus, A., Klugl, F., Oechslein, C., Puppe, F. & Chittka, L. 2006 Benefits of recruitment in honey bees: effects of ecology and colony size in an individual-based model. *Behavioral Ecology* **17**, 336-344.

Downs, S. G. & Ratnieks, F. L. W. 1999 Recognition of conspecifics by honeybee guards uses nonheritable cues acquired in the adult stage. *Animal Behaviour* **58**, 643-648.

Doyle, J. & Carlson, J. M. 2000 Power laws, highly optimized tolerance, and generalized source coding. *Physical Review Letters* **84**, 5656-5659.

Drent, R. & Swierstra, P. 1977 Goose flocks and food finging: field experiments with barnacle geese in winter. *Wildfowl* **28**, 15-20.

Dugatkin, L. A. & Reeve, H. K. 1994 Behavioral ecology and levels of selection: dissolving the group selection controversy. *Advances in the Study of Behavior* **23**, 101-133.

Dugatkin, L. A. & Reeve, H. K. 1998 *Game theory and Animal Behaviour*. Oxford: Oxford University Press.

Dunn, T. & Richards, M. H. 2003 When to bee social: interactions among environmental constraints, incentives, guarding, and relatedness in a facultatively social carpenter bee. *Behavioral Ecology* **14**, 417-424.

Durier, V. & Rivault, C. 1999 Path integration in cockroach larvae, Blattella germanica (L.) (insect : Dictyoptera): Direction and distance estimation. *Animal Learning & Behavior* **27**, 108-118.

Dussutour, A., Deneubourg, J. L. & Fourcassie, V. 2005a Amplification of individual preferences in a social context: the case of wall-following in ants. *Proceedings Of The Royal Society B-Biological Sciences* **272**, 705-714.

Dussutour, A., Deneubourg, J. L. & Fourcassie, V. 2005b Temporal organization of bi-directional traffic in the ant Lasius niger (L.). *Journal Of Experimental Biology* **208**, 2903-2912.

Dussutour, A., Fourcassie, V., Helbing, D. & Deneubourg, J. L. 2004 Optimal traffic organization in ants under crowded conditions. *Nature* **428**, 70-73.

Dussutour, A., Nicolis, S. C., Despland, E. & Simpson, S. J. 2008 Individual differences influence collective behaviour in social caterpillars. *Animal Behaviour* **76**, 5-16.

Dussutour, A., Simpson, S. J., Despland, E. & Colasurdo, N. 2007 When the group denies individual nutritional wisdom. *Animal Behaviour* **74**, 931-939.

Edmonds, B., Hernandez, C. & Troitzsch, K. G. (ed.) 2008 *Social simulation Technologies, advances and new discoveries*: IGI Global.

Ehrlich, P. R. & Levin, S. A. 2005 The evolution of norms. *Plos Biology* **3**, 943-948.

Emery, N. J. & Clayton, N. S. 2001 Effects of experience and social context on prospective caching strategies by scrub jays. *Nature* **414**, 443-446.

Emlen, S. T. 1997 Predicting family dynamics in social vertebrates. In *Behavioural Ecology Fourth Edition* (ed. J. D. Krebs, N. B.). Oxford: Blackwell's Science.

Fama, E. F. 1970 Efficient Capital Markets - Review of Theory and Empirical Work. *Journal of Finance* **25**, 383-423.

Fama, E. F. 1991 Efficient Capital-Markets .2. *Journal of Finance* **46**, 1575-1617.

Farley, R. 1978 Chocolate City, Vanilla Suburbs. Will the Trend toward Racially Separate Communities Continue? *Social Science Research* 319-44.

Farley, R. & Frey, W. H. 1994 Changes in the Segregation of Whites from Blacks During the 1980s - Small Steps toward a More Integrated Society. *American Sociological Review* **59**, 23-45.

Farley, R., Steeh, C., Krysan, M., Jackson, T. & Reeves, K. 1994 Stereotypes and Segregation - Neighborhoods in the Detroit Area. *American Journal of Sociology* **100**, 750-780.

Fehr, E. & Fischbacher, U. 2003 The nature of human altruism. *Nature* **425**, 785-791.

Fehr, E. & Fischbacher, U. 2004 Social norms and human cooperation. *Trends in Cognitive Sciences* **8**, 185-190.

Fernandez-Juricic, E., Erichsen, J. T. & Kacelnik, A. 2004a Visual perception and social foraging in birds. *Trends In Ecology & Evolution* **19**, 25-31.

Fernandez-Juricic, E., Siller, S. & Kacelnik, A. 2004b Flock density, social foraging, and scanning: an experiment with starlings. *Behavioural ecology* **15**, 371–379.

Ferrer, J., Prats, C. & Lopez, D. 2008 Individual-based Modelling: An Essential Tool for Microbiology. *Journal of Biological Physics* **34**, 19-37.

Fewell, J. H. 1988 Energetic and time costs of foraging in harvester ants, Pogonomyrmex occidentalis. *Behav. Ecol. Sociobiol.* **22**, 401-408.

Fewell, J. H. 2003 Social insect networks. *Science* **301**, 1867-1870.

Fewell, J. H. & Winston, M. L. 1992 Colony state and regulation of pollen foraging in the honey bee, *Apis mellifera* L. *Behavioral Ecology and Sociobiology* **30**, 387-393.

Feynman, R. P. 1965 *The character of physical law*. London: Penguin books.

Fitzgerald, T. D. & Peterson, S. C. 1983 Elective Recruitment by the Eastern Tent Caterpillar (Malacosoma-Americanum). *Animal Behaviour* **31**, 417-423.

Fitzgerald, T. D. & Willer, D. E. 1983 Tent-Building Behavior of the Eastern Tent Caterpillar Malacosoma-Americanum (Lepidoptera, Lasiocampidae). *Journal of the Kansas Entomological Society* **56**, 20-31.

Fletcher, J. A. & Doebeli, M. 2006 How altruism evolves: assortment and synergy. *Journal of Evolutionary Biology* **19**, 1389-1393.

Fletcher, J. A., Zwick, M., Doebeli, M. & Wilson, D. S. 2006 What's wrong with inclusive fitness? *Trends in Ecology & Evolution* **21**, 597-598.

Focardi, S. & Pecchioli, E. 2005 Social cohesion and foraging decrease with group size in fallow deer (Dama dama). *Behavioral Ecology and Sociobiology* **59**, 84-91.

Foster, K. R. 2004 Diminishing returns in social evolution: the not-so-tragic commons. *Journal of Evolutionary Biology* **17**, 1058-1072.

Foster, K. R., Wenseleers, T. & Ratnieks, F. L. W. 2006 Kin selection is the key to altruism. *Trends In Ecology & Evolution* **21**, 57-60.

Fourcassie, V. & Deneubourg, J. L. 1994 The Dynamics of Collective Exploration and Trail-Formation in Monomorium-Pharaonis - Experiments and Model. *Physiological Entomology* **19**, 291-300.

Franks, N., Gomez, N, Goss, S and Deneubourg, JL. 1991 The blind leading the blind in army ant raid patterns: testing a model of self-organization (Hymenoptera : Formicidae). *J. Insect Behav.* **4**.

Franks, N. R. 1989 Army ants: a collective intelligence. *Am. Sci.* **77**, 139-145.

Franks, N. R., Bryant, S., Griffiths, R. & Hemerik, L. 1990 Synchronization of the behaviour within nests of the ant *Lepothorax acervorum* (Fabricius): I. Discovering the phenomenon and its relation to the level of starvation. *Bulletin of Mathematical Biology* **52**, 597-612.

Franks, N. R. & Deneubourg, J.-L. 1997 Self-organizing nest construction in ants: Individual worker behaviour and the nest's dynamics. *Animal Behaviour* **54**, 779-796.

Franks, N. R., Dornhaus, A., Best, C. S. & Jones, E. L. 2006 Decision making by small and large house-hunting ant colonies: one size fits all. *Animal Behaviour* **72**, 611-616.

Franks, N. R., Dornhaus, A., Fitzsimmons, J. P. & Stevens, M. 2003a Speed versus accuracy in collective decision making. *Proceedings of the Royal Society of London Series B-Biological Sciences* **270**, 2457-2463.

Franks, N. R., Gomez, N., Goss, S. & Deneubourg, J. L. 1991 The blind leading the blind in army ant raid patterns: Testing a model of self-organization (Hymenoptera: Formicidae). *Journal of Insect Behavior* **4**, 583-607.

Franks, N. R., Hardcastle, K. A., Collins, S., Smith, F. D., Sullivan, K. M. E., Robinson, E. J. H. & Sendova-Franks, A. B. 2008 Can ant colonies choose a far-and-away better nest over an in-the-way poor one? *Animal Behaviour* **76**, 323-334.

Franks, N. R., Hooper, J. W., Gunn, M., Bridger, T. H., Marshall, J. A. R., Gross, R. & Dornhaus, A. R. 2007 Moving targets: collective decisions and flexible choices in house-hunting ants *Swarm Intelligence* **1**, 81-94.

Franks, N. R., Mallon, E. B., Bray, H. E., Hamilton, M. J. & Mischler, T. C. 2003b Strategies for choosing between alternatives with different attributes: exemplified by house-hunting ants. *Animal Behaviour* **65**, 215-223.

Franks, N. R. & Richardson, T. 2006 Teaching in tandem-running ants. *Nature (London)*, 153.

Franks, N. R., Wilby, A., Silverman, B. W. & Tofts, C. 1992 Self-organizing nest constuction in ants: sophisticated building by blind bulldozing. *Animal Behaviour* **44**, 357-375.

Franks, N. R. T., C. & Sendova-Franks, A. 1997 Studies of the division of labour: neither physics nor stamp collecting. *Animal Behaviour* **53**, 219-224.

Galef, B. G. & Buckley, L. L. 1996 Use of foraging trails by Norway rats. *Animal Behaviour* **51**, 765-771.

Galef, B. G. & White, D. J. 1997 Socially acquired information reduces Norway rats' latencies to find food. *Animal Behaviour* **54**, 705-714.

Galton, F. 1907 Vox Populi. *Nature (London)* **75**, 450-451.

Ganeshaiah, K. N. & Veena, T. 1991 Topology of the foraging trails of *Leptogenys processionalis* - why are they branched? *Behav. Ecol. Sociobiol.* **29**, 263-270.

Gastner, M. T. & Newman, M. E. J. 2006 Shape and efficiency in spatial distribution networks. *Journal of Statistical Mechanics-Theory and Experiment*.

Gautrais, J., Michelena, P., Sibbald, A., Bon, R. & Deneubourg, J. L. 2007 Allelomimetic synchronization in Merino sheep. *Animal Behaviour* **74**, 1443-1454.

George, A. J. T., Stark, J. & Chan, C. 2005 Understanding specificity and sensitivity of T-cell recognition. *Trends in Immunology* **26**, 653-659.

Gerard, J. F., Bideau, E., Maublanc, M. L., Loisel, P. & Marchal, C. 2002 Herd size in large herbivores: Encoded in the individual or emergent? *Biological Bulletin* **202**, 275-282.

Geritz, S. A. H., Kisdi, E., Meszena, G. & Metz, J. A. J. 1998 Evolutionarily singular strategies and the adaptive growth and branching of the evolutionary tree. *Evolutionary Ecology* **12**, 35-57.

Gierer, A. & Meinhard, H. 1972 Theory of Biological Pattern Formation. *Kybernetik* **12**, 30-39.

Giraldeau, J. L. & Livoreil, B. 1996 Game theory and social foraging. In *Game theory and animal behaviour* (ed. L. A. R. Dugatkin, K.): Oxford University Press.

Giraldeau, L. A. 1988 The stable group and determinants of foraging group size In *The ecology of social beahviour* (ed. C. N. Slobodchikoff). New York: Academeic press.

Giraldeau, L. A. 2000 *Social foraging theory*. Monographs in Behaviour and Ecology. Princeton, New Jersey: Princeton University Press.

Giraldeau, L. A. & Beauchamp, G. 1999 Food exploitation: searching for the optimal joining policy. *Trends In Ecology & Evolution* **14**, 102-106.

Giraldeau, L. A. & Gillis, D. 1985 Optimal group size can be stable: A reply to Sibly. *Animal Behaviour*, 666-667.

Giraldeau, L. A. & Livoreil, B. 1998 Game theory and social foraging. In *Game theory and animal behaviour* (ed. L. A. Dugatkin & H. K. Reeve). Oxford: Oxford University Press.

Goldenfeld, N. & Kadanoff, L. P. 1999 Simple Lessons from Complexity. *Science* **284**, 87-89.

Gordon, D. M. 1996 The organization of work in social insect colonies. *Nature* **380**, 121-124.

Gordon, D. M. 2002 The regulation of foraging activity in red harvester ant colonies. *American Naturalist* **159**, 509-518.

Gordon, D. M. 2007 Control without hierarchy. *Nature* **446**, 143-143.

Gordon, D. M., Holmes, S. & Nacu, S. 2008 The short-term regulation of foraging in harvester ants. *Behavioral Ecology* **19**, 217-222.

Gordon, D. M. & Mehdiabadi, N. J. 1999 Encounter rate and task allocation in harvester ants. *Behavioral Ecology and Sociobiology* **45**, 370-377.

Gordon, D. M., Paul, R. E. & Thorpe, K. 1993 What Is the Function of Encounter Patterns in Ant Colonies. *Animal Behaviour* **45**, 1083-1100.

Gordon, D. M., Rosengren, R. & Sundstrom, L. 1992 The Allocation of Foragers in Red Wood Ants. *Ecological Entomology* **17**, 114-120.

Goss, S., Aron, S., Deneubourg, J. L. & Pasteels, J. M. 1989 Self-Organized Shortcuts in the Argentine Ant. *Naturwissenschaften* **76**, 579-581.

Goss, S. & Deneubourg, J. L. 1988 Auto-Catalysis as a Source of Synchronized Rhythmical Activity in Social Insects. *Insectes Sociaux* **35**, 310-315.

Grafen, A. 1984 Natural selection, kin selection and group selection In *Behavioural Ecology, An evolutionary approach, 2nd edition* (ed. J. Krebs & N. Davies), pp. 62-84: Blackwell Science.

Grafen, A. 1985 A geometric view of relatedness. In *Oxford Surveys in Evolutionary Biology*, vol. 2 (ed. R. Dawkins & M. Ridley), pp. 28-89. Oxford: Oxford University Press.

Graham, S., Myerscough, M. R., Jones, J. C. & Oldroyd, B. P. 2006 Modelling the role of intracolonial genetic diversity on regulation of brood temperature in honey bee (Apis mellifera L.) colonies. *Insectes Sociaux* **53**, 226-232.

Granovetter, M. 1978 Threshold models of collective behaviour. *The American Journal of Sociology* **83**, 1420-1443.

Grassé, P. P. 1959 La reconstruction du nid et les coordinations interindividuelles chez *Bellicositermes natalensis* et *Cubitermes* sp. La theorie de la stigmergie: essai d'interpretation du comportement des termites constructeurs. *Insectes Sociaux* **6**, 41-83.

Greene, M. J. & Gordon, D. M. 2007a How patrollers set foraging direction in harvester ants. *American Naturalist* **170**, 943-948.

Greene, M. J. & Gordon, D. M. 2007b Interaction rate informs harvester ant task decisions. *Behavioral Ecology* **18**, 451-455.

Gregoire, G., Chate, H. & Tu, Y. H. 2003 Moving and staying together without a leader. *Physica D-Nonlinear Phenomena* **181**, 157-170.

Griffin, A. S. & West, S. A. 2002 Kin selection: fact and fiction. *Trends in Ecology & Evolution* **17**, 15-21.

Griffin, A. S. & West, S. A. 2003 Kin Discrimination and the Benefit of Helping in Cooperatively Breeding Vertebrates. *Science* **302**, 634-636.

Grimm, V. & Railsback, S. F. 2005 *Individual-based Modeling and Ecology*. Princeton: Princeton University Press.

Grunbaum, D. & Veit, R. R. 2003 Black-browed albatrosses foraging on Antarctic krill: Density-dependence through local enhancement? *Ecology* **84**, 3265-3275.

Gueron, S. 1998 The steady-state distributions of coagulation-fragmentation processes. *Journal Of Mathematical Biology* **37**, 1-27.

Gueron, S. & Levin, S. A. 1995 The Dynamics Of Group Formation. *Mathematical Biosciences* **128**, 243-264.

Gueron, S., Levin, S. A. & Rubenstein, D. I. 1996 The dynamics of herds: From individuals to aggregations. *Journal Of Theoretical Biology* **182**, 85-98.

Guilford, T. & Dawkins, M. S. 1991 Receiver psychology and the evolution of animal signals. *Animal Behaviour* **42**, 1-14.

Hale, J. J. 2008 Automated tracking and collective behaviour in locusts and humans. In *Zoology Department*, vol. DPhil: University of Oxford.

Hall, S. J., Wardle, C. S. & MacLennan, D. N. 1986 Predator evasion in a fish school: test of a model for the fountain effect. *Marine biology*, 143-148.

Halley, J. D. & Burd, M. 2004 Nonequilibrium dynamics of social groups: insights from foraging Argentine ants. *Insectes Sociaux* **51**, 226-231.

Halley, J. D., Burd, M. & Wells, P. 2005 Excavation and architecture of Argentine ant nests. *Insectes Sociaux* **52**, 350-356.

Hamilton, W. D. 1964 The genetical evolution of social behaviour. I, II. *Journal of Theoretical Biology* **7**, 1-52.

Hamilton, W. D. 1971 Geometry for the selfish herd. *Journal of Theoretical Biology* **31**, 295-311.

Hardin, G. 1968 The Tragedy of the Commons. *Science* **162**, 1243-1248.

Hart, A. G. & Ratnieks, F. L. W. 2001 Task partitioning, division of labour and nest compartmentalisation collectively isolate hazardous waste in the leafcutting ant Atta cephalotes. *Behavioral Ecology and Sociobiology* **49**, 387-392.

Hart, A. G. & Ratnieks, F. L. W. 2002 Waste management in the leaf-cutting ant Atta colombica. *Behavioral Ecology* **13**, 224-231.

Hauert, C. 2002 Effects of space in 2 x 2 games. *International Journal of Bifurcation and Chaos* **12**, 1531-1548.

Hedstrom, P. 2005 *Dissecting the Social*. Cambridge: Cambridge University Press.

Heinze, J., Trunzer, B., Holldobler, B. & Delabie, J. H. C. 2001 Reproductive skew and queen relatedness in an ant with primary polygyny. *Insectes Sociaux* **48**, 149-153.

Helbing, D. 2001 Traffic and related self-driven many-particle systems. *Reviews of Modern Physics* **73**, 1067-1141.

Helbing, D., Buzna, L., Johansson, A. & Werner, T. 2005 Self-organized pedestrian crowd dynamics: Experiments, simulations, and design solutions. *Transportation Science* **39**, 1-24.

Helbing, D., Farkas, I. & Vicsek, T. 2000 Simulating dynamical features of escape panic. *Nature* **407**, 487-490.

Helbing, D., Johansson, A. & Al-Abideen, H. Z. 2007 Dynamics of crowd disasters: An empirical study. *Physical Review E* **75**.

Helbing, D., Keltsch, J. & Molnar, P. 1997a Modelling the evolution of human trail systems. *Nature* **388**, 47-50.

Helbing, D. & Molnar, P. 1995 Social Force Model for Pedestrian Dynamics. *Physical Review E* **51**, 4282-4286.

Helbing, D., Molnar, P., Farkas, I. J. & Bolay, K. 2001 Self-organizing pedestrian movement. *Environment and Planning B-Planning & Design* **28**, 361-383.

Helbing, D., Schweitzer, F., Keltsch, J. & Molnar, P. 1997b Active walker model for the formation of human and animal trail systems. *Physical Review E* **56**, 2527-2539.

Hemelrijk, C. K. 2000 Towards the integration of social dominance and spatial structure. *Animal Behaviour* **59**, 1035-1048.

Hensor, E., Couzin, I. D., James, R. & Krause, J. 2005 Modelling density-dependent fish shoal distributions in the laboratory and field. *Oikos* **110**, 344-352.

Hoare, D. J., Couzin, I. D., Godin, J. G. J. & Krause, J. 2004 Context-dependent group size choice in fish. *Animal Behaviour* **67**, 155-164.

Hoelzer, G. A., Smith, E. & Pepper, J. W. 2006 On the logical relationship between natural selection and self-organization. *Journal of Evolutionary Biology* **19**, 1785-1794.

Hofbauer, J. & Sigmund, K. 1998 *Evolutionary games and population dynamics*. Cambridge: Cambridge University Press.

Hogendoorn, K. & Velthuis, H. H. W. 1999 Task allocation and reproductive skew in social mass provisioning carpenter bees in relation to age and size. *Insectes Sociaux* **46**, 198-207.

Holland, J. H. 1998 *Emergence from Chaos to Order*. Oxford: Oxford University Press.

Hölldobler, B. 1976 Recruitment behavior, home range orientation and territoriality in harvester ants, *Pogonomyrmex*. *Behav. Ecol. Sociobiol.* **1**, 3-44.

Hölldobler, B. & Möglich, M. 1980 The foraging system of *Pheidole militicida* (Hymenoptera: Formicidae). *Insectes Soc.* **27**, 237-264.

Hölldobler, B. & Wilson, E. O. 1990 *The ants*. Cambridge, Massachusetts: Belknap Press of Harvard University Press.

Hughes, B. 1971 Allelometric feeding in the domestic fowl. . *British Poultry Science* **12**, 359-366.

Inada, Y. & Kawachi, K. 2002 Order and flexibility in the motion of fish schools. *Journal of Theoretical Biology* **214**, 371-387.

Irwin, A. J. & Taylor, P. D. 2000 Evolution of dispersal in a stepping-stone population with overlapping generations. *Theoretical Population Biology* **58**, 321-328.

Irwin, A. J. & Taylor, P. D. 2001 Evolution of altruism in stepping-stone populations with overlapping generations. *Theoretical Population Biology* **60**, 315-325.

Ishii, S. & Kuwahara, Y. 1968 Aggregation of German cockroach Blattella germanica nymphs. *Experientia* **24**, 88—89.

Jackson, D. E. & Chaline, N. 2007 Modulation of pheromone trail strength with food quality in Pharaoh's ant, Monomorium pharaonis. *Animal Behaviour* **74**, 463-470.

Jackson, D. E., Martin, S. J., Holcombe, M. & Ratnieks, F. L. W. 2006 Longevity and detection of persistent foraging trails in Pharaoh's ants, Monomorium pharaonis (L.). *Animal Behaviour* **71**, 351-359.

Janis, I. L. 1972 *Victims of Groupthink*. New York: Houghton Mifflin.

Janis, I. L. 1982 *Groupthink: Psychological Studies of Policy Decisions and Fiascoes. Second Edition.* . New York: Houghton Mifflin.

Janson, S., Middendorf, M. & Beekman, M. 2005 Honeybee swarms: how do scouts guide a swarm of uninformed bees? *Animal Behaviour* **70**, 349-358.

Janson, S., Middendorf, M. & Beekman, M. 2007 Searching for a new home - scouting behavior of honeybee swarms. *Behavioral Ecology* **18**, 384-392.

Jeanne, R. L. (ed.) 1988 *Interindividual Behavioral Variability in Social Insects*. Boulder, Colorado: Westview Press.

Jeanson, R., Deneubourg, J. L., Grimal, A. & Theraulaz, G. 2004a Modulation of individual behavior and collective decision-making during aggregation site selection by the ant Messor barbarus. *Behavioral Ecology And Sociobiology* **55**, 388-394.

Jeanson, R., Deneubourg, J. L. & Theraulaz, G. 2004b Discrete dragline attachment induces aggregation in spiderlings of a solitary species. *Animal Behaviour* **67**, 531-537.

Jeanson, R., Ratnieks, F. L. W. & Deneubourg, J. L. 2003 Pheromone trail decay rates on different substrates in the Pharaoh's ant, Monomorium pharaonis. *Physiological Entomology* **28**, 192-198.

Jeanson, R., Rivault, C., Deneubourg, J. L., Blanco, S., Jost, C. & Theraulaz, G. 2005 Self-organized aggregation in cockroaches. *Animal Behaviour* **69**, 167-180.

Jerome, C. A., McInnes, D. A. & Adams, E. S. 1998 Group defense by colony-founding queens in the fire ant Solenopsis invicta. *Behavioral Ecology* **9**, 301-308.

Jones, J. C., Myerscough, M. R., Graham, S. & Oldroyd, B. P. 2004 Honey bee nest thermoregulation: Diversity promotes stability. *Science* **305**, 402-404.

Jones, J. C., Nanork, P. & Oldroyd, B. P. 2007 The role of genetic diversity in nest cooling in a wild honey bee, Apis florea. *Journal of Comparative Physiology a-Neuroethology Sensory Neural and Behavioral Physiology* **193**, 159-165.

Jost, C., Verret, J., Casellas, E., Gautrais, J., Challet, M., Lluc, J., Blanco, S., Clifton, M. J. & Theraulaz, G. 2007 The interplay between a self-organized process and an environmental template: corpse clustering under the influence of air currents in ants. *Journal of the Royal Society Interface* **4**, 107-116.

Judd, T. M. & Sherman, P. W. 1996 Naked mole-rats recruit colony mates to food sources. *Animal Behaviour* **52**, 957-969.

Kamler, J. F., Jedrzejewska, B. & Jedrzejewski, W. 2007 Activity patterns of red deer in Bialowieza National Park, Poland. *Journal of Mammalogy* **88**, 508-514.

Kauffman, S. A. 1993 *The Origins of Order*. Oxford: Oxford University Press.

Keeling, M. J. & Ross, J. V. 2008 On methods for studying stochastic disease dynamics. *Journal of the Royal Society Interface* **5**, 171-181.

Keller, L. (ed.) 1999 *Levels of selection in evolution*. Princeton: Princeton University Press.

Kelley, S. 1991 The regulation of comb building in honey bee colonies: Cornell University.

Kenne, M. & Dejean, A. 1999 Spatial distribution, size and density of nests of *Myrmicaria opaciventris* Emery (Formicidae, Myrmicinae). *Insectes Soc.* **46**, 179-185.

Kevrekidis, I. G., Gear, C. W. & Hummer, G. 2004 Equation-free: The computer-aided analysis of comptex multiscale systems. *Aiche Journal* **50**, 1346-1355.

Killingback, T. & Doebeli, M. 2002 The continuous prisoner's dilemma and the evolution of cooperation through reciprocal altruism with variable investment. *American Naturalist* **160**, 421-438.

Kimura, M. & Weiss, G. H. 1964 The stepping stone model of population structure and the decrease of the genetic correlation with distance. *Genetics* **49**, 561-576.

King, A. J. & Cowlishaw, G. 2007 When to use social information: the advantage of large group size in individual decision making. *Biology Letters* **3**, 137-139.

Kirman, A. 1993 Ants, Rationality, and Recruitment. *Quarterly Journal of Economics* **108**, 137-156.

Kitano, H. 2002 Computational systems biology. *Nature (London)* **420**.

Kokko, H., Johnstone, R. A. & Clutton-Brock, T. H. 2001 The evolution of cooperative breeding through group augmentation. *Proceedings of the Royal Society of London Series B-Biological Sciences* **268**, 187-196.

Kokko, H., Johnstone, R. A. & Wright, J. 2002 The evolution of parental and alloparental effort in cooperatively breeding groups: when should helpers pay to stay? *Behavioral Ecology* **13**, 291-300.

Komdeur, J. & Hatchwell, B. J. 1999 Kin recognition: function and mechanism in avian societies. *Trends in Ecology & Evolution* **14**, 237-241.

Korb, J. 2003 Thermoregulation and ventilation of termite mounds. *Naturwissenschaften* **90**, 212-219.

Korb, J. & Heinze, J. 2004 Multilevel selection and social evolution of insect societies. *Naturwissenschaften* **91**, 291-304.

Korb, J. & Linsenmair, K. E. 1998a The effects of temperature on the architecture and distribution of Macrotermes bellicosus (Isoptera, Macrotermitinae) mounds in different habitats of a West African Guinea savanna. *Insectes Sociaux* **45**, 51-65.

Korb, J. & Linsenmair, K. E. 1998b Experimental heating of Macrotermes bellicosus (Isoptera, Macrotermitinae) mounds: what role does microclimate play in influencing mound architecture? *Insectes Sociaux* **45**, 335-342.

Korb, J. & Linsenmair, K. E. 2000 Thermoregulation of termite mounds: what role does ambient temperature and metabolism of the colony play? *Insectes Sociaux* **47**, 357-363.

Krause, J. 1993 The Effect of Schreckstoff on the Shoaling Behavior of the Minnow - a Test of Hamiltons Selfish Herd Theory. *Animal Behaviour* **45**, 1019-1024.

Krause, J. 1994 Differential Fitness Returns in Relation to Spatial Position in Groups. *Biological Reviews of the Cambridge Philosophical Society* **69**, 187-206.

Krause, J. & Ruxton, G. D. 2002 *Living in groups*. Oxford series in ecology and evolution. Oxford ; New York: Oxford University Press.

Krebs, J. R. & Davies, N. B. 1997 *Behavioural Ecology: An evolutionary approach*. Oxford, UK: Blackwells Science.

Krebs, J. R. & Davis, N. B. 1993 *An introduction to behavioural ecology*. Oxford: Blackwell Science.

Kretz, T., Grunebohm, A., Kaufman, M., Mazur, F. & Schreckenberg, M. 2006a Experimental study of pedestrian counterflow in a corridor. *Journal of Statistical Mechanics-Theory and Experiment*.

Kretz, T., Grunebohm, A. & Schreckenberg, M. 2006b Experimental study of pedestrian flow through a bottleneck. *Journal of Statistical Mechanics-Theory and Experiment*.

Kretz, T., Wolki, M. & Schreckenberg, M. 2006c Characterizing correlations of flow oscillations at bottlenecks. *Journal of Statistical Mechanics-Theory and Experiment*.

Krugman, P. & Wells, R. 2004 *Microeconomics*: Worth publishers.

Krugman, P. W., R. 2005 *Macroeconomics*: Worth publishers.

Kuhnert, C., Helbing, D. & West, G. B. 2006 Scaling laws in urban supply networks. *Physica a-Statistical Mechanics and Its Applications* **363**, 96-103.

Kuhnholz, S. & Seeley, T. D. 1997 The control of water collection in honey bee colonies. *Behavioral Ecology and Sociobiology* **41**, 407-422.

Kuramoto, Y. 1975 Self-entrainment of a population of coupled oscillators. In *International Symposium on mathematical problems in theoretical physics*, vol. 39 (ed. H. Araki): Springer-Verlag.

Kuramoto, Y. 1984 *Chemical Oscillations, Waves and Turbulence*: Springer-Verlag, Berlin.

Kydland, F. E. & Prescott, E. C. 1982 Time to Build and Aggregate Fluctuations. *Econometrica* **50**, 1345-1370.

Laland, K. N. W., K. . 1998 Social transmission of maladaptive information in the guppy. . *Behavioral Ecology* **9** 493-499.

LeBaron, B. 2006 Agent-based Computational Finance. In *Handbook of Computational Economics* (ed. L. Tesfatsion & K. Judd), pp. 1187-1232: North-Holland.

Lee, S. H. 2006 Predator's attack-induced phase-like transition in prey flock. *Physics Letters A* **357**, 270-274.

Lee, S. H., Pak, H. K. & Chon, T. S. 2006 Dynamics of prey-flock escaping behavior in response to predator's attack. *Journal of Theoretical Biology* **240**, 250-259.

Lehmann, L. 2007 The evolution of trans-generational altruism: kin selection meets niche construction. *Journal of Evolutionary Biology* **20**, 181-189.

Lehmann, L. & Keller, L. 2006a The evolution of cooperation and altruism - a general framework and a classification of models. *Journal of Evolutionary Biology* **19**, 1365-1376.

Lehmann, L. & Keller, L. 2006b Synergy, partner choice and frequency dependence: their integration into inclusive fitness theory and their interpretation in terms of direct and indirect fitness effects. *Journal of Evolutionary Biology* **19**, 1426-1436.

Leoncini, I. & Rivault, C. 2005 Could species segregation be a consequence of aggregation processes? Example of Periplaneta americana (L.) and P-fuliginosa (Serville). *Ethology* **111**, 527-540.

Levin, S. A. 1992 The Problem of Pattern and Scale in Ecology. *Ecology* **73**, 1943-1967.

Levin, S. A. 2000 *Fragile Dominion: Complexity and the Commons*: Helix books.

Lieberman, E., Hauert, C. & Nowak, M. A. 2005 Evolutionary dynamics on graphs. *Nature* **433**, 312-316.

Lindauer, M. 1952 Ein Beitrag zur Frage der Arbeitsteilung im Bienenstaat. *Zeitschrift für vergleichende Physiologie* **34**, 299-345.

Lindauer, M. 1954 Temperaturregulierung und Wasserhaushalt im Bienenstaat. *Zeitschrift für vergleichende Physiologie* **36**, 391-432.

Lindauer, M. 1955 Schwarmbienen auf Wohnungssuche. *Zeitschrift für vergleichende Physiologie* **37**, 263-324.

Lindauer, M. 1961 *Communication among social bees*. New York: Atheneum.

Lioni, A. & Deneubourg, J. L. 2004 Collective decision through self-assembling. *Naturwissenschaften* **91**, 237-241.

List, C. 2004 Democracy in animal groups: a political science perspective. *Trends in Ecology & Evolution* **19**, 168-169.

Loe, L. E., Irvine, R. J., Bonenfant, C., Stien, A., Langvatn, R., Albon, S. D., Mysterud, A. & Stenseth, N. C. 2006 Testing five hypotheses of sexual segregation in an arctic ungulate. *Journal of Animal Ecology* **75**, 485-496.

Lopez, F., Acosta, F. J. & Serrano, J. M. 1994 Guerilla vs phalanx strategies of resource capture: Growth and structural plasticity in the trunk trail system of the harvester ant *Messor barbarus*. *J. Anim. Ecol.* **63**, 127-138.

Lucas, R. E. 1975 Equilibrium Model of Business Cycle. *Journal of Political Economy* **83**, 1113-1144.

Lux, T. 1995 Herd Behavior, Bubbles and Crashes. *Economic Journal* **105**, 881-896.

MacFarlane, A. M. 2006 Can the activity budget hypothesis explain sexual segregation in western grey kangaroos? *Behaviour* **143**, 1123-1143.

Mailleux, A. C., Deneubourg, J. L. & Detrain, C. 2000 How do ants assess food volume? *Animal Behaviour* **59**, 1061-1069.

Mailleux, A. C., Deneubourg, J. L. & Detrain, C. 2003a How does colony growth influence communication in ants? *Insectes Sociaux* **50**, 24-31.

Mailleux, A. C., Deneubourg, J. L. & Detrain, C. 2003b Regulation of ants' foraging to resource productivity. *Proceedings of the Royal Society of London Series B-Biological Sciences* **270**, 1609-1616.

Mailleux, A. C., Detrain, C. & Deneubourg, J. L. 2006 Starvation drives a threshold triggering communication. *Journal of Experimental Biology* **209**, 4224-4229.

Makse, H. A., Havlin, S. & Stanley, H. E. 1995 Modeling Urban-Growth Patterns. *Nature* **377**, 608-612.

Mallon, E. B., Pratt, S. C. & Franks, N. R. 2001 Individual and collective decision-making during nest site selection by the ant *Leptothorax albipennis*. *Behavioral Ecology and Sociobiology* **50**, 352-359.

Mantegna, R. N. & Stanley, H. E. 1995 Scaling Behavior in the Dynamics of an Economic Index. *Nature* **376**, 46-49.

Marzluff, J. M., Heinrich, B. & Marzluff, C. S. 1996 Raven roosts are mobile information centres. *Animal Behaviour* **51**, 89-103.

Mattila, H. R. & Seeley, T. D. 2007 Genetic diversity in honey bee colonies enhances productivity and fitness. *Science* **317**, 362-364.

May, R. M. 1976 Simple mathematical models with very complicated dynamics. *Nature* **261**, 459-467.

Maynard Keynes, J. 1936 *The General Theory of Employment, Interest and Money!*: Harcourt.

Maynard Smith, J. 1982 *Evolution and the Theory of Games*. Cambridge: Cambridge University Press.

Maynard Smith, J. & Harper, D. 2005 *Animal Signals*. Oxford: Oxford University Press.

Maynard Smith, J. & Szathmáry, E. 1995 *The Major Transitions of Evolution*: W.H. Freeman Spektrum.

McGowan, K. J. & Woolfenden, G. E. 1989 A sentinel system in the Florida scrub jay. *Animal Behaviour* **37**, 1000-1006.

Milgram, S. 1992 *The individual in the social world*: McGraw-Hill.

Milgram, S., Bickman, L. & Berkowitz, L. 1969 Note on the drawing power of crowds of different size. . *Journal of Personality & Social Psychology* **13**, 79-82.

Miller, J. H. & Page, S. E. 2007 *Complex Adaptive Systems*: Princeton University Press.

Millor, J., Ame, J. M., Halloy, J. & Deneubourg, J. L. 2006 Individual discrimination capability and collective decision-making. *Journal of Theoretical Biology* **239**, 313-323.

Milner, R. 1989 *Communication and concurrency*. Prentice Hall international series in computer science. New York: Prentice Hall.

Mirollo, R. E. & Strogatz, S. H. 1990 Synchronization of Pulse-Coupled Biological Oscillators. *Siam Journal on Applied Mathematics* **50**, 1645-1662.

Moffett, M. W. 1988 Foraging dynamics in the group-hunting myrmicine ant, *Pheidologeton diversus*. *J. Insect Behav.* **1**, 309-331.

Möglich, M. 1978 Social organization of nest emigration in *Leptothorax* (Hym., Form.). *Insectes Sociaux* **25**, 205-225.

Moody, A. L., Houston, A. I. & McNamara, J. M. 1996 Ideal free distributions under predation risk. *Behavioral Ecology and Sociobiology* **38**, 131-143.

Mottley, K. & Giraldeau, L. A. 2000 Experimental evidence that group foragers can converge on predicted producer–scrounger equilibria. *Animal Behaviour*, 341-350.

Murray, J. D. 1993 *Mathematical Biology*. Biomathematics. Berlin: Springer-Verlag.

Myerscough, M. R. 2003 Dancing for a decision: a matrix model for nest-site choice by honeybees. *Proceedings of the Royal Society of London Series B-Biological Sciences* **270**, 577-582.

Neda, Z., Ravasz, E., Brechet, Y., Vicsek, T. & Barabasi, A. L. 2000a The sound of many hands clapping. *Nature (London)* **403**, 849.

Neda, Z., Ravasz, E., Vicsek, T., Brechet, Y. & Barabasi, A. L. 2000b Physics of the rhythmic applause. *Physical Review E* **61**, 6987-6992.

Nee, S., Colegrave, N., West, S. A. & Grafen, A. 2005 The illusion of invariant quantities in life histories. *Science* **309**, 1236-1239.

Newman, M. E. J. 2003 The structure and function of complex networks. *Siam Review* **45**, 167-256.

Newman, M. E. J. 2005 Power laws, Pareto distributions and Zipf's law. *Contemporary Physics* **46**, 323-351.

Nicolis, G. & Prigogine, I. 1977 *Self-organization in nonequilibrium systems*: John Wiley & sons, New York.

Nicolis, S. C. & Deneubourg, J. L. 1999 Emerging patterns and food recruitment in ants: an analytical study. *Journal of Theoretical Biology* **198**, 575-592.

Nieh, J. C. 2004 Recruitment communication in stingless bees (Hymenoptera, Apidae, Meliponini). *Apidologie* **35**, 159-182.

Nielsen B, L., Lawrence A, B. & Whittmore C, T. 1996 Feeding behaviour of growing pigs using single or multi-space feeders. . *Applied Animal Behaviour Science* **47**, 235-246.

Niwa, H. S. 1998 School size statistics of fish. *Journal of Theoretical Biology* **195**, 351-361.

Niwa, H. S. 2003 Power-law versus exponential distributions of animal group sizes. *Journal of Theoretical Biology* **224**, 451-457.

Niwa, H. S. 2004 Space-irrelevant scaling law for fish school sizes. *Journal of Theoretical Biology* **228**, 347-357.

Nowak, M. A. & May, R. M. 1992 Evolutionary Games And Spatial Chaos. *Nature* **359**, 826-829.

Nowak, M. A. & Sigmund, K. 1998 Evolution of indirect reciprocity by image scoring. *Nature* **393**, 573-577.

Nunney, L. 1985 Group selection, alturism, and structured-deme models. *American Naturalist* **126**, 212-230.

Ohtsuki, H., Hauert, C., Lieberman, E. & Nowak, M. A. 2006 A simple rule for the evolution of cooperation on graphs and social networks. *Nature* **441**, 502-505.

Okubo, A. 1986 Dynamical aspects of animal grouping. . *Advances in Biophysics* **22**, 1-94.

Okubo, A. & Chiang, H. C. 1974 An analysis of the kinematics of swarming ofAnarete pritchardi kim (Diptera: Cecidomyiidae). *Population Ecology*, 1-42.

Oldroyd, B. P., Gloag, R. S., Even, N., Wattanachaiyingcharoen, W. & Beekman, M. 2008 Nest site selection in the open-nesting honeybee Apis florea. *Behavioral Ecology and Sociobiology* **62**, 1643-1653.

Ormerod, P. 1998 *Butterfly economics*: Pantheon books.

Ormerod, P., Mounfield, C. & Smith, L. 2001 Non-linear modelling of burglary and violent crime in the UK. Volterra Consulting Ltd.

Packer, C. & Pusey, A. E. 1983 Male Takeovers and Female Reproductive Parameters - a Simulation of Estrous Synchrony in Lions (Panthera-Leo). *Animal Behaviour* **31**, 334-340.

Pankiw, T. & Page, R. E. 2000 Response thresholds to sucrose predict foraging division of labor in honeybees. *Behavioral Ecology and Sociobiology* **47**, 265-267.

Parrish, J. K. 1989 Reexamining The Selfish Herd - Are Central Fish Safer. *Animal Behaviour* **38**, 1048-1053.

Parrish, J. K., Viscido, S. V. & Grunbaum, D. 2002 Self-organized fish schools: An examination of emergent properties. *Biological Bulletin* **202**, 296-305.

Partridge, B. L. 1981 Internal Dynamics and the Interrelations of Fish in Schools. *Journal of Comparative Physiology* **144**, 313-325.

Partridge, B. L. & Pitcher, T. J. 1980 The sensory basis of fish schools: relative roles of lateral line and vision. *Journal of Comparative Physiology* **135**, 315-325.

Partridge, B. L., Pitcher, T. J., Cullen, M. J. & Wilson, J. 1980 The three-dimensional structure of fish schools. *Behavioral Ecology and Sociobiology* **6**.

Partridge, B. L. J. 1982 The structure and function of fish schools. *Scientific American* **246**.

Partridge, B. L. J., Johansson, J. & Kalisk, J. 1983 Structure of schools of giant bluefin tuna in Cape Cod Bay. *Environmental Biology of Fishes* **9**, 253-262.

Passino, K. M. & Seeley, T. D. 2006 Modeling and analysis of nest-site selection by honeybee swarms: the speed and accuracy trade-off. *Behavioral Ecology and Sociobiology* **59**, 427-442.

Passino, K. M., Seeley, T. D. & Visscher, P. K. 2008 Swarm cognition in honey bees. *Behavioral Ecology and Sociobiology* **62**, 401-414.

Pasteels, J. M., Deneubourg, J. L. & Goss, S. 1987 Self-organisation mechanisms in ant societies (I): trail recruitment to newly discovered food sources. In *From individual to collective behavior in social insects* (ed. J. M. Pasteels & J. L. Deneubourg), pp. 155-175. Basel: Birkhauser Verlag.

Pedersen, J. S., Krieger, M. J. B., Vogel, V., Giraud, T. & Keller, L. 2006 Native supercolonies of unrelated individuals in the invasive Argentine ant. *Evolution* **60**, 782-791.

Pepper, J. W. & Hoelzer, G. 2001 Self-organization in biological systems. *Science* **294**, 1466-1467.

Perloff, J. M. 2007 *Microeconomics*. Boston: Pearson Education.

Perna, A., Jost, C., Couturier, E., Valverde, S., Douady, S. & Theraulaz, G. 2008a The structure of gallery networks in the nests of termite Cubitermes spp. revealed by X-ray tomography. *Naturwissenschaften* **95**, 877-884.

Perna, A., Valverde, S., Gautrais, J., Jost, C., Solé, R., Kuntz, P. & Theraulaz, G. 2008b Topological efficiency in three-dimensional gallery networks of termite nests. *Physica A: Statistical Mechanics and its Applications* **387**, 6235-6244.

Pitcher, T. J., Magurran, A. E. & Winfield, I. J. 1982 Fish in Larger Shoals Find Food Faster. *Behavioral Ecology and Sociobiology* **10**, 149-151.

Portha, S., Deneubourg, J. L. & Detrain, C. 2002 Self-organized asymmetries in ant foraging: a functional response to food type and colony needs. *Behavioral Ecology* **13**, 776-781.

Portha, S., Deneubourg, J. L. & Detrain, C. 2004 How food type and brood influence foraging decisions of Lasius niger scouts. *Animal Behaviour* **68**, 115-122.

Potters, M., Cont, R. & Bouchaud, J. P. 1998 Financial markets as adaptive systems. *Europhysics Letters* **41**, 239-244.

Pratt, S. C. 1998a Condition-dependent timing of comb construction by honeybee colonies: how do workers know when to start building? *Animal Behaviour* **56**, 603-610.

Pratt, S. C. 1998b Decentralized control of drone comb construction in honey bee colonies. *Behavioral Ecology and Sociobiology* **42**, 193-205.

Pratt, S. C. 1999 Optimal timing of comb construction by honeybee (*Apis mellifera*) colonies: a dynamic programming model and experimental tests. *Behavioral Ecology and Sociobiology* **46**, 30-42.

Pratt, S. C. 2004 Collective control of the timing and type of comb construction by honey bees (Apis mellifera). *Apidologie* **35**, 193-205.

Pratt, S. C. 2005a Behavioral mechanisms of collective nest-site choice by the ant Temnothorax curvispinosus. *Insectes Sociaux* **52**, 383-392.

Pratt, S. C. 2005b Detection of a nestmate quorum by encounter rates in the ant Leptothorax albipennis. *Behavioral Ecology* **in press**.

Pratt, S. C. 2005c Quorum sensing by encounter rates in the ant Temnothorax albipennis. *Behavioral Ecology* **16**, 488-496.

Pratt, S. C. 2008 Efficiency and regulation of recruitment during colony emigration by the ant Temnothorax curvispinosus. *Behavioral Ecology and Sociobiology* **62**, 1369-1376.

Pratt, S. C., Mallon, E. B., Sumpter, D. J. T. & Franks, N. R. 2002 Quorum sensing, recruitment, and collective decision-making during colony emigration by the ant *Leptothorax albipennis*. *Behavioral Ecology and Sociobiology* **52**, 117-127.

Pratt, S. C. & Pierce, N. E. 2001 The cavity-dwelling ant Leptothorax curvispinosus uses nest geometry to discriminate between potential homes. *Animal Behaviour* **62**, 281-287.

Pratt, S. C. & Sumpter, D. J. T. 2006 A tunable algorithm for collective decision-making. *Proceedings of the National Academy of Sciences of the United States of America* **103**, 15906-15910.

Pratt, S. C., Sumpter, D. J. T., Mallon, E. B. & Franks, N. R. 2005 An agent-based model of collective nest choice by the ant Temnothorax albipennis. *Animal Behaviour* **70**, 1023-1036.

Price, D. J. D. 1976 General Theory of Bibliometric and Other Cumulative Advantage Processes. *Journal of the American Society for Information Science* **27**, 292-306.

Pride, E. 2005 Optimal group size and seasonal stress in ring-tailed lemurs (Lemur catta). *Behavioral Ecology* **16**, 550-560.

Prokopy, R. J. & Roitberg, B. D. 2001 Joining and avoidance behaviour in nonsocial insects. *Annual Review of Entomology*, 631-665.

Queller, D. C. 1985 Kinship, Reciprocity and Synergism in the Evolution of Social-Behavior. *Nature* **318**, 366-367.

Queller, D. C. & Strassmann, J. E. 1998 Kin selection and social insects. *Bioscience* **48**, 165-175.

Queller, D. C. & Strassmann, J. E. 2006 Models of cooperation. *Journal Of Evolutionary Biology* **19**, 1410-1412.

Quinn, J. L. & Cresswell, W. 2006 Testing domains of danger in the selfish herd: sparrowhawks target widely spaced redshanks in flocks. *Proceedings of the Royal Society B-Biological Sciences* **273**, 2521-2526.

Radakov, D. V. 1973 *Schooling in the ecology of fish*. New York: John Wiley & Sons.

Rands, S. A., Cowlishaw, G., Pettifor, R. A., Rowcliffe, J. M. & Johnstone, R. A. 2003 Spontaneous emergence of leaders and followers in foraging pairs. *Nature* **423**, 432-434.

Rangel, J. & Seeley, T. D. 2008 The signals initiating the mass exodus of a honeybee swarm from its nest. *Animal Behaviour* **76**, 1943-1952.

Ranta, E., Peuhkuri, N., Laurila, A., Rita, H. & Metcalfe, N. B. 1996 Producers, scroungers and foraging group structure. *Animal Behaviour* **51**, 171-175.

Ratcliffe, J. M. & ter Hofstede, H. M. 2005 Roosts as information centres: social learning of food preferences in bats. *Biology Letters* **1**, 72-74.

Ratnieks, F. L. W. 2006 The evolution of cooperation and altruism: the basic conditions are simple and well known. *Journal of Evolutionary Biology* **19**, 1413-1414.

Ratnieks, F. L. W., Foster, K. R. & Wenseleers, T. 2006 Conflict resolution in insect societies. *Annual Review of Entomology* **51**, 581-608.

Rayor, L. S. & Uetz, G. W. 1990 Trade-Offs in Foraging Success and Predation Risk with Spatial Position in Colonial Spiders. *Behavioral Ecology and Sociobiology* **27**, 77-85.

Reed, W. J. 2001 The Pareto, Zipf and other power laws. *Economics Letters* **74**, 15-19.

Reeve, H. K. & Keller, L. 2001 Tests of reproductive-skew models in social insects. *Annual Review of Entomology* **46**, 347-385.

Reeve, H. K., Westneat, D. F., Noon, W. A., Sherman, P. W. & Aquadro, C. F. 1990 Dna Fingerprinting Reveals High-Levels Of Inbreeding In Colonies Of The Eusocial Naked Mole-Rat. *Proceedings of the National Academy of Sciences of the United States of America* **87**, 2496-2500.

Reynolds, C. W. 1987 Flocks, herds and schools: A distributed behavioural model. *Computer Graphics* **21**, 25-33.

Richmond, P. 2001 Power law distributions and dynamic behaviour of stock markets. *European Physical Journal B* **20**, 523-526.

Richner, H. & Heeb, P. 1996 Communal life: Honest signaling and the recruitment center hypothesis. *Behavioral Ecology* **7**, 115-118.

Riley, J. R., Greggers, U., Smith, A. D., Reynolds, D. R. & Menzel, R. 2005 The flight paths of honeybees recruited by the waggle dance. *Nature* **435**, 205-207.

Rittschof, C. C. & Seeley, T. D. 2008 The buzz-run: how honeybees signal 'Time to go!' *Animal Behaviour* **75**, 189-197.

Rivault, C. 1989 Spatial distribution of the cockroach, Blattella germanica, in a swimming-bath facility *Entomologia Experimentalis Et Applicata* **53**, 247-255.

Rivault, C. & Cloarec, A. 1998 Cockroach aggregation: discrimination between strain odours in Blattella germanica. . *Animal Behaviour*, 177–184.

Rivault, C., Cloarec, A. & Sreng, L. 1998 Cuticular extracts inducing aggregation in the German cockroach, Blattella germanica (L.). *Journal of Insect Physiology* **44**, 909–918.

Robinson, E. J. H., Jackson, D. E., Holcombe, M. & Ratnieks, F. L. W. 2005 Insect communication - 'No entry' signal in ant foraging. *Nature* **438**, 442-442.

Rook A, J. & Penning P, D. 1991 Synchronization of eating, ruminating and idling activity by grazing sheep. . *Applied Animal Behaviour Science* **32**, 157-166.

Rosengren, R. & Sundström, L. 1987 The foraging system of a red wood ant colony (Formica s. str.) - collecting and defending food through an extended phenotype. In *From individual to collective behavior in social insects : les Treilles Workshop. Experientia Supplementum*, vol. 54 (ed. J. M. Pasteels & J. L. Deneubourg), pp. 117-137. Basel: Birkhauser.

Rousset, F. 2004 *Genetic structure and selection in subdivided populations*. Princeton: Princeton University Press.

Ruckstuhl, K. E. 1999 To synchronise or not to synchronise: a dilemma for young bighorn males? *Behaviour* **136**, 805-818.

Ruckstuhl, K. E. & Neuhaus, P. 2001 Behavioral synchrony in ibex groups: Effects of age, sex and habitat. *Behaviour* **138**, 1033-1046.

Ruckstuhl, K. E. & Neuhaus, P. 2002 Sexual segregation in ungulates: a comparative test of three hypotheses. *Biological Reviews* **77**, 77-96.

Ruxton, G. D., Fraser, C. & Broom, M. 2005 An evolutionarily stable joining policy for group foragers. *Behavioral Ecology* **16**, 856-864.

Saam, N. J. & Sumpter, D. 2008 EU institutional reforms - How do member states reach a decision? *Journal of Policy Modeling* **30**, 71-86.

Saffre, F., Mailleux, A. C. & Deneubourg, J. L. 2000 Exploratory recruitment plasticity in a social spider (Anelosimus eximius). *Journal Of Theoretical Biology* **205**, 37-46.

Santos, F. C. & Pacheco, J. M. 2006 A new route to the evolution of cooperation. *Journal of Evolutionary Biology* **19**, 726-733.

Savit, R., Manuca, R. & Riolo, R. 1999 Adaptive competition, market efficiency, and phase transitions. *Physical Review Letters* **82**, 2203-2206.

Schelling, T. C. 1969 Models of Segregation. *American Economic Review* **59**, 488-493.

Schelling, T. C. 1971 Dynamic Models of Segregation. *Journal of Mathematical Sociology* **1**, 143-186.

Schelling, T. C. 1978 *Micromotives and macrobehaviour*. New York: W W Norton and Company.

Schmickl, T. & Crailsheim, K. 2002 How honeybees (Apis mellifera L.) change their broodcare behavior in response to non-foraging conditions and poor pollen conditions. . *Behavioral Ecology Sociobiology* **51**, 415–425.

Schmickl, T. & Crailsheim, K. 2008a An individual-based model of task selection in honeybees. *From Animals to Animats 10, Proceedings* **5040**, 383-392.

Schmickl, T. & Crailsheim, K. 2008b TaskSelSim: a model of the self-organization of the division of labour in honeybees. *Mathematical and Computer Modelling of Dynamical Systems* **14**, 101-125.

Schneirla, T. C. 1971 *Army ants. A study in social organization*. San Francisco: W. H. Freeman & Co.

Schuessler, R. 1989 Exit Threats and Cooperation under Anonymity. *Journal of Conflict Resolution* **33**, 728-749.

Schultz, K. M., Passino, K. M. & Seeley, T. D. 2008 The mechanism of flight guidance in honeybee swarms: subtle guides or streaker bees? *Journal of Experimental Biology* **211**, 3287-3295.

Seeley, T. D. 1977 Measurement of nest cavity volume by the honey bee (Apis mellifera). *Behavioral Ecology and Sociobiology* **2**, 201-227.

Seeley, T. D. 1983 Division of labour between scouts and recruits in honeybee foraging. *Behavioral Ecology and Sociobiology* **12**, 253-259.

Seeley, T. D. 1992 The tremble dance of the honey bee: message and meanings. *Behavioral Ecology and Sociobiology* **31**, 375-383.

Seeley, T. D. 1995 *The wisdom of the hive*. Cambridge, Massachusetts: Belknap Press of Harvard University Press.

Seeley, T. D. 1997 Honey bee colonies are group-level adaptive units. *American Naturalist* **150**, S22-S41.

Seeley, T. D. 1998 Thoughts on information and integration in honey bee colonies. *Apidologie* **29**, 67-80.

Seeley, T. D. 2002 When is self-organization used in biological systems? *Biological Bulletin* **202**, 314-318.

Seeley, T. D. 2003 Consensus building during nest-site selection in honey bee swarms: the expiration of dissent. *Behavioral Ecology and Sociobiology* **53**, 417-424.

Seeley, T. D. & Buhrman, S. C. 1999 Group decision making in swarms of honey bees. *Behavioral Ecology and Sociobiology* **45**, 19-31.

Seeley, T. D. & Buhrman, S. C. 2001 Nest-site selection in honey bees: how well do swarms implement the "best-of-N" decision rule? *Behavioral Ecology and Sociobiology* **49**, 416-427.

Seeley, T. D., Camazine, S. & Sneyd, J. 1991 Collective decision-making in honey bees: how colonies choose among nectar sources. *Behavioral Ecology and Sociobiology* **28**, 277-290.

Seeley, T. D., Kleinhenz, M., Bujok, B. & Tautz, J. 2003 Thorough warm-up before take-off in honey bee swarms. *Naturwissenschaften* **90**, 256-260.

Seeley, T. D., Morse, R. A. & Visscher, P. K. 1979 The natural history of the flight of honey bee swarms. *Psyche* **86**, 103-113.

Seeley, T. D. & Tautz, J. 2001 Worker piping in honey bee swarms and its role in preparing for liftoff. *Journal of Comparative Physiology a-Sensory Neural and Behavioral Physiology* **187**, 667-676.

Seeley, T. D. & Towne, W. F. 1992 Tactics of dance choice in honey bees: do foragers compare dances? *Behavioral Ecology and Sociobiology* **30**, 59-69.

Seeley, T. D. & Visscher, P. K. 2003 Choosing a home: how the scouts in a honey bee swarm perceive the completion of their group decision making. *Behavioral Ecology and Sociobiology* **54**, 511-520.

Seeley, T. D. & Visscher, P. K. 2004a Group decision making in nest-site selection by honey bees. *Apidologie* **35**, 101-116.

Seeley, T. D. & Visscher, P. K. 2004b Quorum sensing during nest-site selection by honeybee swarms. *Behavioral Ecology and Sociobiology* **56**, 594-601.

Seeley, T. D. & Visscher, P. K. 2008 Sensory coding of nest-site value in honeybee swarms. *Journal of Experimental Biology* **211**, 3691-3697.

Seeley, T. D., Weidenmuller, A. & Kuhnholz, S. 1998 The shaking signal of the honey bee informs workers to prepare for greater activity. *Ethology* **104**, 10-26.

Sethna, J. P. 2006 *Entropy, order parameters and complexioty*: Oxford Univeristy Press.

Sharp, S. P., McGowan, A., Wood, M. J. & Hatchwell, B. J. 2005 Learned kin recognition cues in a social bird. *Nature* **434**, 1127-1130.

Shepherd, J. D. 1982 Trunk trails and the searching strategy of a leaf-cutter ant, *Atta colombica*. *Behav. Ecol. Sociobiol.* **11**, 77-84.

Sherman, P. W. V., P. K. 2002 Honeybee colonies gain fitness through dancing. *Nature (London)* **419**, 920-922.

Shiller, R. J. 2000 *Irrational exuberance*. Princeton: Princeton University Press.

Shiller, R. J. 2003 From efficient markets theory to behavioral finance. *Journal of Economic Perspectives* **17**, 83-104.

Sibly, R. M. 1983 Optimal group size is unstable. *Animal Behaviour* **31**, 947-948.

Simon, H. A. 1955 On a Class of Skew Distribution Functions. *Biometrika* **42**, 425-440.

Simons, A. M. 2004 Many wrongs: the advantage of group navigation. *Trends in Ecology & Evolution* **19**, 453-455.

Sinclair, A. R. E. 1977 *The American Buffalo*. Chicago: University of Chicago Press.

Sjoberg, M., Albrectsen, B. & Hjalten, J. 2000 Truncated power laws: a tool for understanding aggregation patterns in animals? *Ecology Letters* **3**, 90-94.

Skog, O.-J. 1986 The long waves of alchohol consumption: a social network perspective of cultural change. *Social networks* **8**, 1-32.

Skryms, B. 2004 *The Stag Hunt and the Evolution of Social Structure*. Cambridge: Cambridge University Press.

Sole, R. V. & Miramontes, O. 1995 Information at the Edge of Chaos in Fluid Neural Networks. *Physica D* **80**, 171-180.

Sole, R. V., Miramontes, O. & Goodwin, B. C. 1993 Oscillations and Chaos in Ant Societies. *Journal of Theoretical Biology* **161**, 343-357.

Sonerud, G. A., Smedshaug, C. A. & Brathen, O. 2001 Ignorant hooded crows follow knowledgeable roost-mates to food: support for the information centre hypothesis. *Proceedings of the Royal Society of London Series B-Biological Sciences* **268**, 827-831.

Sornette, D. 2003a Critical market crashes. *Physics Reports-Review Section of Physics Letters* **378**, 1-98.

Sornette, D. 2003b *Why stock markets crash*. Princeton: Princeton University Press.

Sornette, D. 2004 *Critical Phenomena in Natural Sciences*: Springer Verlag.

Stainforth, D. A., Aina, T., Christensen, C., Collins, M., Faull, N., Frame, D. J., Kettleborough, J. A., Knight, S., Martin, A., Murphy, J. M., Piani, C., Sexton, D., Smith, L. A., Spicer, R. A., Thorpe, A. J. & Allen, M. R. 2005 Uncertainty in predictions of the climate response to rising levels of greenhouse gases. *Nature* **433**, 403-406.

Stanley, H. E., Amaral, L. A. N., Gabaix, X., Gopikrishnan, P. & Plerou, V. 2001 Quantifying economic fluctuations. *Physica a-Statistical Mechanics and Its Applications* **302**, 126-137.

Stern, K. & McClintock, M. K. 1998 Regulation of oculation by human pheromones. *Nature (London)* **392**, 177-179.

Strogatz, S. 2003 Sync: the emerging science of spontaneous order.

Strogatz, S. H. 1994 *Nonlinear Dynamics and Chaos*. Reading, Massachusetts: Addison-Wesley Publishing Company.

Strogatz, S. H. 2000 From Kuramoto to Crawford: exploring the onset of synchronization in populations of coupled oscillators. *Physica D* **143**, 1-20.

Strogatz, S. H. 2001 Exploring complex networks. *Nature* **410**, 268-276.

Strogatz, S. H. & Stewart, I. 1993 Coupled Oscillators and Biological Synchronization. *Scientific American* **269**, 102-109.

Sumpter, D. J. T. 2006 The principles of collective animal behaviour. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences* **361**, 5-22.

Sumpter, D. J. T. & Beekman, M. 2003 From nonlinearity to optimality: pheromone trail foraging by ants. *Animal Behaviour* **66**, 273-280.

Sumpter, D. J. T., Blanchard, G. B. & Broomhead, D. S. 2001 Ants and agents: a process algebra approach to modelling ant colony behaviour. *Bulletin of Mathematical Biology* **63**, 951-980.

Sumpter, D. J. T. & Brännström, Å. 2008 Synergy in social communication. In *Sociobiology of Communication* (ed. P. D'Ettorre & D. Hughes). Oxford: Oxford Univeristy Press.

Sumpter, D. J. T. & Broomhead, D. S. 2000 Shape and dynamics of thermoregulating honey bee clusters. *Journal of Theoretical Biology* **204**, 1-14.

Sumpter, D. J. T. & Broomhead, D. S. 2001 Relating individual behaviour to population dynamics. *Proceedings of the Royal Society of London Series B-Biological Sciences* **268**, 925-932.

Sumpter, D. J. T., Buhl, J., Biro, D. & Couzin, I. D. 2008a Information transfer in moving animal groups *Theory of Biosciences*.

Sumpter, D. J. T., Krause, J., James, R., Couzin, I. D. & Ward, A. J. W. 2008b Consesus decision-making by fish. *Current Biology* **18**, 1773-1777.

Sumpter, D. J. T. & Pratt, S. C. 2003 A modelling framework for understanding social insect foraging. *Behavioral Ecology and Sociobiology* **53**, 131-144.

Sumpter, D. J. T. & Pratt, S. C. 2008 Quorum responses and consensus decision-making *Philosophical Transactions of the Royal Society of London: Series B* **in press**.

Surowiecki, J. 2004 *The wisdom of crowds*: Little, Brown.

Szabo, B., Szollosi, G. J., Gonci, B., Juranyi, Z., Selmeczi, D. & Vicsek, T. 2006 Phase transition in the collective migration of tissue cells: Experiment and model. *Physical Review E* **74**.

Takayasu, H. 1989 Steady-State Distribution Of Generalized Aggregation System With Injection. *Physical Review Letters* **63**, 2563-2565.

Takayasu, H., Nishikawa, I. & Tasaki, H. 1988 Power-Law Mass-Distribution Of Aggregation Systems With Injection. *Physical Review A* **37**, 3110-3117.

Takayasu, H., Takayasu, M., Provata, A. & Huber, G. 1991 Statistical Properties Of Aggregation With Injection. *Journal Of Statistical Physics* **65**, 725-745.

Tamm, S. 1980 Bird Orientation - Single Homing Pigeons Compared with Small Flocks. *Behavioral Ecology and Sociobiology* **7**, 319-322.

Taylor, P. D. 1992a Altruism in Viscous Populations - an Inclusive Fitness Model. *Evolutionary Ecology* **6**, 352-356.

Taylor, P. D. 1992b Inclusive Fitness in a Homogeneous Environment. *Proceedings of the Royal Society of London Series B-Biological Sciences* **249**, 299-302.

Taylor, P. D. & Irwin, A. J. 2000 Overlapping generations can promote altruistic behavior. *Evolution* **54**, 1135-1141.

Templeton, J. J. & Giraldeau, L.-A. 1996 Vicarious sampling: the use of personal and public information by starlings foraging in a simple patch environment. *Behavioral Ecology and Sociobiology* **38**, 105-114.

Templeton, J. J. & Giraldeau, L. A. 1995 Public Information Cues Affect The Scrounging Decisions Of Starlings. *Animal Behaviour* **49**, 1617-1626.

Theraulaz, G., Bonabeau, E., Nicolis, S. C., Sole, R. V., Fourcassie, V., Blanco, S., Fournier, R., Joly, J. L., Fernandez, P., Grimal, A., Dalle, P. & Deneubourg, J. L. 2002 Spatial patterns in ant colonies. *Proceedings of the National Academy of Sciences of the United States of America* **99**, 9645-9649.

Theraulaz, G., Gautrais, J., Camazine, S. & Deneubourg, J. L. 2003 The formation of spatial patterns in social insects: from simple behaviours to complex structures. *Philosophical Transactions of the Royal Society of London Series a-Mathematical Physical and Engineering Sciences* **361**, 1263-1282.

Thom, C., Gilley, D. C., Hooper, J. & Esch, H. E. 2007 The scent of the waggle dance. *Plos Biology* **5**, 1862-1867.

Tibbetts, E. A. & Reeve, H. K. 2003 Benefits of foundress associations in the paper wasp Polistes dominulus: increased productivity and survival, but no assurance of fitness returns. *Behavioral Ecology* **14**, 510-514.

Tien, J. H., Levin, S. A. & Rubenstein, D. I. 2004 Dynamics of fish shoals: identifying key decision rules. *Evolutionary Ecology Research* **6**, 555-565.

Tofts, C. 1991 Describing social insect behaviour using process algebra. *Transactions of the Society for Computer Simulation* **December**, 227-283.

Tofts, C. 1993 Algorithms for task allocation in ants. (A study of temporal polyethism: Theory). *Bulletin of Mathematical Biology* **55**, 891-918.

Tofts, C. M. 1994 Processes with probabilities, priorities and time. *Formal Aspects of Computer Science* **6**, 536-564.

Topoff, H. 1984 Social organization of raiding and emigrations in army ants. *Advances in the Study of Behavior* **14**, 81-126.

Treherne, J. E. & Foster, W. A. 1981 Group transmissin of predator avoidance behaviour ina marine insect: the Trafalgar effect. *Animal Behaviour* **28**.

Trivers, R. L. 1971 Evolution of Reciprocal Altruism. *Quarterly Review of Biology* **46**, 35-&.

Tschinkel, W. R. 2004 The nest architecture of the Florida harvester ant, Pogonomyrmex badius. *Journal of Insect Science* **4**.

Uvarov, B. P. 1977 Grasshoppers and Locusts. Vol. 2. .

Vasconcellos, H. L. 1990 Foraging activity of two species of leaf-cutting ants (*Atta*) in a primary forest of the central Amazon. *Insectes Soc.* **37**, 131-145.

Vercelli, A. 1991 *Methodological Foundations of Macroeconomics: Keynes and Lucas*. Cambridge: Cambridge University Press.

Vickery, W. L., Giraldeau, L. A., Templeton, J. J., Kramer, D. L. & Chapman, C. A. 1991 Producers, Scroungers, and Group Foraging. *American Naturalist* **137**, 847-863.

Vicsek, T., Czirok, A., Benjacob, E., Cohen, I. & Shochet, O. 1995 Novel Type Of Phase-Transition In A System Of Self-Driven Particles. *Physical Review Letters* **75**, 1226-1229.

Vincent, T. L. & Brown, J. S. 1984 Stability in an evolutionary game. *Theoretical Population Biology*, 408-427.

Vine, I. 1971 Risk of visual detection and pursuit by a predator and the selective advantage of flocking behaviour. *Journal of Theoretical Biology* **30**, 405-422.

Visscher, P. K. 2007 Nest-site selection and group decision-making in social insects. . *Annual Review of Entomology* **52**, in press.

Visscher, P. K. & Camazine, S. 1999 Collective decisions and cognition in bees. *Nature* **397**, 400.

Visscher, P. K. & Seeley, T. D. 2007 Coordinating a group departure: who produces the piping signals on honeybee swarms? *Behavioral Ecology and Sociobiology* **61**, 1615-1621.

Vittori, K., Talbot, G., Gautrais, J., Fourcassie, V., Araujo, A. F. R. & Theraulaz, G. 2006 Path efficiency of ant foraging trails in an artificial network. . *Journal of Theoretical Biology* **239**, 507-515

von Bertalanffy, L. 1968 *General system theory*: Georgr Braziller, New York.

von Dassow, G., Meir, E., Munro, E. & Odell, G. 2000 The segment polarity network is a robust development module. *Nature (London)* **406**.

von Frisch, K. 1967 *The Dance Language and Orientation of Bees*. Cambridge, Massachusetts: The Belknap Press of Harvard University Press.

Wagner, R. H. & Danchin, E. 2003 Conspecific copying: a general mechanism of social aggregation. *Animal Behaviour* **65**, 405-408.

Wahl, L. M. & Nowak, M. A. 1999 The continuous prisoner's dilemma: I. Linear reactive strategies. *Journal of Theoretical Biology* **200**, 307-321.

Wallin, K. F. & Raffa, K. F. 2004 Feedback between individual host selection behavior and population dynamics in an eruptive herbivore. *Ecological Monographs* **74**, 101-116.

Wallraff, H. G. 1978 Social Interrelations Involved in Migratory Orientation of Birds - Possible Contribution of Field Studies. *Oikos* **30**, 401-404.

Walter, A. & Weber, F. M. 2006 Herding in the German mutual fund industry. *European Financial Management* **12**, 375-406.

Ward, A., Sumpter, D. J. T., Couzin, I. D., Hart & Krause, J. 2008 Quorum decision-making facilitates information transfer in fish schools. *Proceedings of the National Academy of Sciences of the United States of America*, 6948-6953.

Watts, D. J. & Strogatz, S. H. 1998 Collective dynamics of 'small-world' networks. *Nature* **393**, 440-442.

Weber, N. A. 1972 The fungus-culturing behavior of ants. *Am. Zool.* **12**, 577-587.

Weeks, C. A. D., Davies, H. C. , Hunt, P. & Kestin, S. C. 2000 The behaviour of broiler chickens and its modification by lameness. *Applied Animal Behaviour Science* **67**, 111-125

Weidenmuller, A. 2004 The control of nest climate in bumblebee (*Bombus terrestris*) colonies: interindividual variability and self reinforcement in fanning response. *Behavioural Ecology* **15**, 120-128.

Weimerskirch, H., Martin, J., Clerquin, Y., Alexandre, P. & Jiraskova, S. 2001 Energy saving in flight formation - Pelicans flying in a 'V' can glide for extended periods using the other birds' air streams. *Nature* **413**, 697-698.

Welch, I. 2000 Herding among security analysts. *Journal of Financial Economics* **58**, 369-396.

Wertheim, B., van Baalen, E. J. A., Dicke, M. & Vet, L. E. M. 2005 Pheromone-mediated aggregation in nonsocial arthropods: An evolutionary ecological perspective. *Annual Review of Entomology* **50**, 321-346.

West, S. A., Gardner, A. & Griffin, A. S. 2006 Altruism. *Current Biology* **16**, R482-R483.

West, S. A., Griffin, A. S. & Gardner, A. 2007 Social semantics: altruism, cooperation, mutualism, strong reciprocity and group selection. *Journal of Evolutionary Biology* **20**, 415-432.

West, S. A., Murray, M. G., Machado, C. A., Griffin, A. S. & Herre, E. A. 2001 Testing Hamilton's rule with competition between relatives. *Nature* **409**, 510-513.

White, D. J. & Galef, B. G. 1999a Affiliative preferences are stable and predict mate choices in both sexes of Japanese quail, Coturnix japonica. *Animal Behaviour* **58**, 865-871.

White, D. J. & Galef, B. G. 1999b Social effects on mate choices of male Japanese quail, Coturnix japonica. *Animal Behaviour* **57**, 1005-1012.

White, D. J. & Galef, B. G. 2000 'Culture' in quail: social influences on mate choices of female Coturnix japonica. *Animal Behaviour* **59**, 975-979.

Wiener, N. 1948 *Cybernetics*: John Wiley & Sons, New York.

Wilson, D. S. 1983 The group selection controversy: history and current status. *Annual Review of Ecology and Systematics* **14**, 159-187.

Wilson, D. S. & Dugatkin, L. A. 1997 Group selection and assortative interactions. *American Naturalist* **149**, 336-351.

Wilson, E. O. 1971 *The Insect Societies*. Cambridge, Massachusetts: Belknap Press of Harvard University Press.

Wilson, E. O. & Holldobler, B. 2005 Eusociality: Origin and consequences. *Proceedings of the National Academy of Sciences of the United States of America* **102**, 13367-13371.

Winston, M. L. 1987 *The Biology of the Honey Bee*. Cambridge, Massachusetts: Harvard University Press.

Wolfram, S. 2002 *A new kind of science*: Wolfram Media.

Wood, A. J. & Ackland, G. J. 2007 Evolving the selfish herd: emergence of distinct aggregating strategies in an individual-based model. *Proceedings of the Royal Society B-Biological Sciences* **274**, 1637-1642.

Wright, J., Stone, R. E. & Brown, N. 2003 Communal roosts as structured information centres in the raven, Corvus corax. *Journal of Animal Ecology* **72**, 1003-1014.

Wright, S. 1943 Isolation by distance. *Genetics* **28**, 114-138.

Wyatt, T. D. 2003 *Pheromones and Animal Behaviour*. Cambridge: Cambridge University Press.

Zahavi, A. 1971 The function of pre-roost gatherings and communal roosts. . *Ibis* **113**, 106–109.

Zeeman, E. C. 1981 Dynamics of the Evolution of Animal Conflicts. *Journal of Theoretical Biology* **89**, 249-270.

Zheng, M., Kashimori, Y., Hoshino, O., Fujita, K. & Kambara, T. 2005 Behavior pattern (innate action) of individuals in fish schools generating efficient collective evasion from predation. *Journal of Theoretical Biology* **235**, 153-167.