Student Manual

Animal Behaviour
BIOS3011

Session 2, 2018

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Course Aims

Animal Behaviour provides one of the most fascinating and rewarding fields of biological study. In this course, we briefly introduce the study of animal behaviour and the levels at which it can be studied. We then spend the bulk of the course focussing on the adaptive evolution of animal behaviour and how ecological processes shape such behaviour. This course has a strong focus on contemporary research, both in lecture content and in a practical program that is heavily research—and student—centred. The course has the following explicit aims:

- To introduce the broad approaches used to study Animal Behaviour
- To consider the proximate genetic, neurobiological, hormonal, physiological and environmental influences on behaviour.
- To introduce the concepts and tools necessary to build a sophisticated understanding of the evolution of behaviour.
- To explore the important insights that an adaptive perspective on human behaviour can provide.
- To emphasise the importance of primary research in student learning by devoting a considerable portion of the course to case studies presented by practising scientists.
- To provide an introduction to the use of formal mathematical models to understand adaptive behaviour.
- To explicitly teach skills in research design, execution, analysis and communication by providing intensive collaborative research projects.
- To strengthen student skills in all aspects of collaborative work in these projects.

Learning Outcomes

By the end of this course you will be able to generate hypotheses regarding the adaptive basis for any given behaviour, and design, execute and interpret experimental, correlative or comparative studies to test these hypotheses. You will also be accomplished at presenting your results and interpretation in a way that is acceptable for peer-review and publication.

Through a range of case studies, you will get a feel for the process of conducting international-quality research in animal behaviour. You will learn to read, interpret and critically evaluate published research. You will also learn to critically read and evaluate popular science texts.

Through collaborative research exercises, you will develop new skills and strategies in working as part of a research team, and in research design, execution, analysis and communication.

Course Components

Lectures

There is a series of 14 ***lectures*** in which the course lecturers introduce important issues and topics in the study of animal behaviour, illustrated with examples from a broad range of taxa. Many of these lectures compliment material in the recommended textbook by John Alcock. Most lectures come with suggested additional reading (listed during lecture). Lecturers may provide outlines of or slides from these lectures on the Moodle site as an *aid* to your note-taking. Lectures are compulsory.

Case studies

As part of the research-focussed approach to this course, we have arranged a series of six ***case studies*** (in lecture time slots) each of which is presented by a scientist with a PhD in a topic in evolutionary ecology. These case studies focus on the presenting scientists' own research, and contain a mix of practical and theoretical insights. The class has access to a reading list and a series of questions and/or possible discussion points one week before the case study lecture. The objective is for the entire class to read independently and to think about the questions/discussion points in advance of the class. Each student will submit a short, individually written review of one of the published **research articles** (*not a review article or opinion piece*) that is either mentioned during the case-study lecture or is clearly related to the topic. **This review should be no more than 400 words and should be submitted at the lecture the week after the student's chosen case study.**

Book Review

Each student reads at least one recent popular science book that has some relevance to *Animal Behaviour.* It is designed to stimulate general reading and broad thinking about the relevance of animal behaviour to society, other aspects of biology and the human condition. We are hoping that this part of the course will show you that reading for pleasure can be an important part of your ongoing learning as a scientist.

Each reviewed book must be approved by Professor Brooks (who is responsible for this assignment), unless it appears on the list of recommended books on the following pages. It is best if you send a web-link to material describing the book (e.g. Amazon.com website listing for the book) so that we can assess the suitability of the book, and possibly add it to the list. There are likely to be hundreds of suitable books, many of which will be in the UNSW library. Some books have greater relevance to the course subject matter than others.

You are assessed on the basis of the review you should submit it through Moodle via the *turnitin* link. Your review needs to be targeted to answering the questions rather than providing a generic book review. Please remember that **you are always obliged to submit your own, original work (see plagiarism policy in this manual)**. You need to submit *at least one* review at any time before ***4 pm Wednesday 19 September (Week 9)***. Standard school policies on late submissions will apply. You may review up to three books in separate reviews, in which case you will be given the highest of the marks. Only reviews submitted before the deadline will be marked.

In marking your reviews, we will consider: the level of your comprehension of the subject matter, your demonstration of critical thinking, the clarity and quality of your writing and how well you have tailored your review to the questions.

Structure of Your Review

Answer the following 7 questions. Each answer should be preceded by the question – it should not be a single run-on piece of prose. Provide correct word counts for questions 4-7.

1. Book Title

2. Authors

3. Publisher, City, Year of Publication.

4. Provide a short (max 400 words) context to the book. Why was it written? What is the author trying to achieve? And what is the main argument?

5. Who do you think would benefit most from reading this book and why? (max 200 words)

6. What did you learn from reading this book? How does this book relate to what you have learned in the Animal Behaviour course and to your learning in areas outside of the course scope. (max 400 words)

7. Conclusion. Please give this book an overall rating between zero and ten, and a 200-word (maximum) encapsulation of why you gave the book this mark.

Please ensure your review also has your name and student number.

Some Recommended Books

Title	**Author**
The Handicap Principle	Zahavi, A. & Zahavi, A.
Journey To The Ants	Holldobler, B & Wilson, EO
Why Sex Matters	Bobbi Low
Magpie Alert	Darryl Jones
The Evolution of Desire	David Buss
The Mating Mind	Geoffrey Miller
Spent: Sex, Evolution and Consumer Behaviour	Geoffrey Miller
Mate	Geoffrey Miller & Tucker Max
Anatomy of Love	Helen Fisher
The Sex Contract: the Evolution of Human Behaviour	Helen Fisher
The Ant And The Peacock	Helena Cronin
Rise And Fall Of The Third Chimpanzee	Jared Diamond
The Triumph of Sociobiology	John Alcock
Evolution And The Theory Of Games	John Maynard-Smith
The Beak Of The Finch	Jonathan Weiner
Sense And Nonsense: Evolutionary Perspectives On Human Behaviour	Kevin Laland & Gillian Brown
Sexual Selections: What We Can and Can't Learn About Sex from Animals	Marlene Zuk
The Truth about Cinderella	Daly & Wilson
Homicide	Daly & Wilson
The Origins Of Virtue	Matt Ridley
The Red Queen	Matt Ridley
Genome	Matt Ridley
Nature via nurture	Matt Ridley

Some Recommended Books (Continued)

Title	Author
The Selfish Gene	Richard Dawkins
Unweaving the Rainbow	Richard Dawkins
The Pandas Thumb	Stephen Jay Gould
Eight Little Piggies	Stephen Jay Gould
Hen's Teeth And Horses Toes	Stephen Jay Gould
Ever Since Darwin	Stephen Jay Gould
Darwin's Dangerous Idea	Daniel Dennett
Breaking the Spell: Religion as a Natural	Daniel Dennett
The Stuff of Thought	Steven Pinker
The Blank Slate	Steven Pinker
The Language Instinct	Steven Pinker
How the Mind Works	Steven Pinker
Alpha God	Hector A. Garcia
DNA & Destiny: Nature & Nurture in Human Behaviour	R. Grant Steen
Human Instinct	Robert Winston
Defenders of the Truth	Ullica Segerstrale

Practical exercises

Most practicals run the full three hours, and students will not be excused from practical sessions (in full or in part) for non-medical reasons.

In weeks 2 – 6, the entire class will complete experiments and / or modelling exercises that have been set by the lecturers. In weeks 7-10, you will work independently in your student groups on a collaborative project (see below). In weeks 11 and 12, you will present the results of your collaborative work in class. This presentation will be assessed.

Collaborative independent group project

You will do a major independent research project in groups of 3 or 4 students. You will design the study, collect and analyse the data and write the project up as a paper formatted for the academic journal *Behavioral Ecology*. **Your group will give a seminar to the class during the practical time in week 11 or 12 and submit a written manuscript in week 13 (through Moodle via the *turnitin* link, any time before 4pm, Friday October 26).** You will be assessed as a group on the seminar and the final manuscript. In addition, your contribution to the project will be assessed by yourself, your group mates, and your project advisor.

We will post a list of possible projects on Moodle in week 3, which you will need to download and consider. During the practical of Week 3, you will form groups and shortlist the projects that you would most like to do. If you wish to design something that is not on the list, then you must present a brief outline/plan to your instructor in the practical of week 4. Once your project has been assigned, your group will then be assigned an advisor who will provide help throughout the course of the project.

Project Proposals: In week 7, you will need to hand in a proposal of your project to your advisor (emailed and no later than **4pm on Thursday Sept 6**), who will then provide critical feedback. This proposal must give a brief overview of the topic with reference to current literature, clear hypotheses to be tested and provide enough detail of the methods and analyses to allow your advisor to assess the practicality of your approach and to provide feedback. Proposals that do not meet these requirements will be returned to the group for revision. *Groups cannot proceed with their projects until they receive the go ahead from their advisors.*

Final Examination

The final exam will be devoted to testing your understanding of the principles covered in lectures and practicals (approximately 50% of questions) *and* case studies (remaining 50% of questions). The exam will consist of essay questions, so broad comprehension of the course material will be critical!

Breakdown of Marks

1. Case study	
a. Write-up	10
2. Book review	15
3. Collaborative independent research project	
a. Seminar – group mark	10
b. Written paper – group mark	20
c. Self and peer assessment	5
4. Final exam	40

Important Dates

Activity	**Date**	**Where**
Case study write up	Varied, starting wk 4 (1 week after 1st case study)	In lecture
List of group projects	6 Aug, wk 3	Moodle
Choose group projects	9 Aug, wk 3	In practical
Group project *proposal*	6 Sept, wk 7	Email to advisor
Book review	19 Sept, wk 9	Moodle
Group project seminars	11 Oct or 18 Oct, wks 11-12	In practical
Peer assessment form	22-26 Oct, wk 13	Email to advisor
Group project *final report*	26 Oct, wk 13	Moodle

Lecture & Case Study Schedule

Times: Monday, 9am, Matthews 310
Wednesday, 12noon, CLB 5

Week	Date	Lecture	Lecture or Case Study Topic	Lecturer
2	30-Jul	L1	**Introduction to the study of behaviour:** proximate and ultimate causes	Ord
	1-Aug	L2	**Neuroethology**	Ord
3	6-Aug	L3	**Mate choice**	Ord
	8-Aug	Cs1	*Case study 1: Animal personalities*	*A/Prof Shinichi Nakagawa*
4	13-Aug	L4	**Principles of animal communication**	Ord
	15-Aug	Cs2	*Case study 2: The role of the social environment in moderating development, behaviour and physiology*	*A/Prof Mike Kasumovic*
5	20-Aug	L5	**Conflict: intrasexual, inter-sexual, parent-offspring**	Ord
	22-Aug	Cs3	*Case study 3: Communication in flying lizards and land fish*	*Dr Terry Ord*
6	27-Aug	L6	**Beyond nature/nurture**: genes, development and the environment as "determinants" of behaviour.	Brooks
	29-Aug	Cs4	*Case study 4: Intrasexual competition in women*	*Dr Khandis Blake*
7	3-Sep	L7	**The evolution of behaviour:** natural selection, fitness, optimality theory, selfish genes, kin selection, game theory	Brooks
	5-Sep	Cs5	*Case study 5: Acoustic communication in mammals*	*Dr Kobe Martin*
8	10-Sep	L8	**Cooperation**	Brooks
	12-Sep	Cs6	*Case study 6: Maternal effects in reptiles: how maternal behaviour influences offspring traits*	*Dr Lisa Schwanz*
9	17-Sep	L9	**Social behaviour**	Brooks
	19-Sep	L10	**Food and foraging**	Schwanz
			22 - 30 September: Mid-semester break	
10	1-Oct		Public Holiday (1 October)	
	3-Oct	L11	**Predation**	Schwanz
11	8-Oct	L12	**Parental care**	Schwanz
	10-Oct	L13	**Learning**	Schwanz
12	15-Oct	L14	**Behaviour and the fossil record; tips for the exam**	Ord
			No lecture	
13			No lecture	
			No lecture	

Practical Schedule

Times: Thursday, 2-5pm, G007

Meet at 2 pm sharp at room G007 (Teaching Lab 6, Biosciences E26). Attendance for the full three hours is compulsory. **Lab coats and enclosed footwear must be worn**

Week	Date	Topic/description	Instructor
2	2-Aug	Display behaviour of fighting fish	Ord
3	9-Aug	Foraging and risk trade-off in fighting fish; Choosing research projects	Ord
4	16-Aug	Mate choice ('Blue Steal') Designing research projects	Ord / Kasumovic
5	23-Aug	Optimality models in animal behaviour; Designing research projects	Schwanz
6	30-Aug	Game theory; Finalising research projects	Brooks
7	6-Sep	Prepare project proposals	
8	13-Sep	Research projects	
9	20-Sep	Research projects	
		MID SESSION BREAK	
10	4-Oct	Research projects	
11	11-Oct	Research project seminar presentations	Ord
12	18-Oct	Research project seminar presentations	Ord
13	25-Oct	Finalise written group report	

Personnel

Course coordinator	Dr Terry Ord	t.ord@unsw.edu.au
Lecturers	Dr Terry Ord Prof Rob Brooks Dr Lisa Schwanz	t.ord@unsw.edu.au rob.brooks@unsw.edu.au l.schwanz@unsw.edu.au
Technical officer	Kobe Martin	kobe.martin@unsw.edu.au
Demonstrators	Gary Truong Claire Nelson Tom Summers	g.truong@unsw.edu.au claire.nelson@unsw.edu.au t.summers@unsw.edu.au

Reading

There is no course textbook, but some of the lectures will be based on:

ALCOCK, J. 2013. *Animal Behaviour.* 10th Edition. Sinauer, Sunderland Mass.

We do strongly recommend that you have at least access to a copy of the 9th or 10th edition because it provides a solid introduction to many of the concepts covered.

Other texts that you might find useful for components of the course are:

Danchin, E. Giraldeau, L-A. Cezilly, F. (2007). *Behavioural Ecology*. Oxford.

Davies, N.B., Krebs, J.R. & West S.A. (2012) *An Introduction to Behavioural Ecology*. 4th edition. Wiley-Blackwell.

Dugatkin, L.A. (2010). *Principles of Animal Behaviour*. 2nd Edition. W.W. Norton & Company.

Ryan, M.J. & Wilczynski, W. (2011). *An Introduction to Animal Behavior, An Integrative Approach*. Cold Springs Harbor Laboratory Press.

Sherman, P. W. & Alcock, J (2010). *Exploring Animal Behavior.* Sinauer

Westneat, D.F. & Fox, C. W. (eds) (2010) *Evolutionary Behavioral Ecology*. Oxford.

Important Points

Communication: Email and Moodle.

Electronic communication between academics/demonstrators and students, as well as from student to student, is required for this course. Students are requested to regularly logon to their UNSW student email accounts as well as the Animal Behaviour Moodle site (https://moodle.telt.unsw.edu.au/).

Assessments

Assignments submitted after the due date will be penalised at the rate of 10% per day unless accompanied by a medical certificate. All outstanding assignments must be handed in by the end of Week 13. Work will only be accepted after this date if accompanied by a medical certificate.

Academic misconduct will not be tolerated in any form in this course and particular attention is drawn to the information about plagiarism included below.

Grievance Policy

In all cases you should first try to resolve any issues with the course convenor. If this is unsatisfactory, you should contact the School Student Ethics Officer (A/Prof Stephen Bonser, s.bonser@unsw.edu.au) or the Deputy Head of School (A/Prof Scott Mooney s.mooney@unsw.edu.au) who is the School's Grievance Officer and Designated Officer under the UNSW Plagiarism Procedure. UNSW has formal policies about the resolution of grievances that can be reviewed in MyUNSW A to Z Guide (see https://student.unsw.edu.au/complaints).

Plagiarism

Plagiarism is one of the most serious forms of academic misconduct, and it will not be tolerated in any form in this course. It is absolutely crucial that the work you or your group submit for assessment is yours alone, except where you have attributed full credit to sources such as references. You also need to acknowledge help that you receive. First offenders will receive zero (including the copied student in the case of copying). More serious penalties apply for repeat offenders, including those who have been caught previously in other courses.

What is Plagiarism?

Plagiarism is the presentation of the thoughts or work of another as one's own. Examples include:

- direct duplication of the thoughts or work of another, including by copying material, ideas or concepts from a book, article, report or other written document (whether published or unpublished), composition, artwork, design, drawing, circuitry, computer program or software, web site, Internet, other electronic resource, or another person's assignment without appropriate acknowledgement;
- paraphrasing another person's work with very minor changes keeping the meaning, form and/or progression of ideas of the original;
- piecing together sections of the work of others into a new whole;
- presenting an assessment item as independent work when it has been produced in whole or part in collusion with other people, for example, another student or a

tutor; and

- claiming credit for a proportion a work contributed to a group assessment item that is greater than that actually contributed.†

For the purposes of this policy, submitting an assessment item that has already been submitted for academic credit elsewhere may be considered plagiarism.

Knowingly permitting your work to be copied by another student may also be considered to be plagiarism.

Note that an assessment item produced in oral, not written, form, or involving live presentation, may similarly contain plagiarised material.

The inclusion of the thoughts or work of another with attribution appropriate to the academic discipline does *not* amount to plagiarism.

The UNSW Academic Study Skills is main repository for resources for staff and students on plagiarism and academic honesty. These resources can be located https://student.unsw.edu.au/plagiarism. The UNSW Plagiarism Procedure also has examples of what constitutes the various levels of plagiarism and is available at https://www.gs.unsw.edu.au/policy/documents/plagiarismprocedure.pdf.

The UNSW Learning Centre http://www.lc.unsw.edu.au/services-programs also provides substantial educational written materials, workshops, and tutorials to aid students, for example, in:

- correct referencing practices;
- paraphrasing, summarising, essay writing, and time management;
- appropriate use of, and attribution for, a range of materials including text, images, formulae and concepts.

Individual assistance is also available on request from The Learning Centre.

Students are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting, and the proper referencing of sources in preparing all assessment items.

* Based on that proposed to the University of Newcastle by the St James Ethics Centre. Used with kind permission from the University of Newcastle

† Adapted with kind permission from the University of Melbourne.

Ethics

Whether a study of animal behaviour is conducted in the field or under captive conditions, the welfare of the animal under observation must be considered. Every effort should be made to minimise the amount of distress caused to the animals studied, to avoid wastage or unnecessary repetition of experiments, and to maintain respect and a caring attitude towards animals. These criteria are especially important for studies of animal behaviour because it is rare that one can achieve significant results without some form of interaction with the animal. Mathematical models are an important part of our understanding of animal behaviour but they are based on data acquired by observation and must be tested with similar methods.

As a general principle, one should ensure that appropriate approvals are gained before undertaking a study. For example, in N.S.W. the project must be approved by an institution's Animal Care and Ethics Committee (ACEC), be conducted in accordance with the Animal Research Act 1985 and the Animal Research Regulation 1990 and the Code of Practice under that regulation, and for native species be conducted under a Scientific licence from N.S.W. National Parks and Wildlife Service. The relevant approvals have been granted by the UNSW ACEC for the experiments and observations you will be conducting. You may need to obtain clearance for your independent project research if it involves the use of a vertebrate. Regardless of the type of animal involved, you should ensure that you adopt an ethical attitude and one that does not imperil the welfare of the animals under study.

Further information specifically relating to the field of animal behaviour can be found in: Dawkins, M.S. & Gosling, M. (eds) (1991). Ethics in Research on Animal Behaviour. 4(Academic Press: London). See also: The Association for the Study of Animal Behaviour's *Guidelines for the Treatment of Animals in the Behavioural Research and Teaching* which is available at http://www.asab.org/ethics/

Special Consideration & Further Assessment

Students who believe that their performance, either during the session or in the end of session exams, may have been affected by illness or other circumstances may apply for special consideration. Applications can be made for compulsory class absences such as (laboratories and tutorials), in-session assessments tasks, and final examinations. **Students must make a formal application for Special Consideration** for the course/s affected as soon as practicable after the problem occurs and **within three working days of the assessment to which it refers**. Students should consult the "Special Consideration" section of the UNSW current students' website for further information https://student.unsw.edu.au/special-consideration.

How to apply for special consideration

Applications must be made via Online Services in myUNSW. You must obtain and attach Third Party documentation before submitting the application. **Failure to do so will result in the application being rejected.** Log into myUNSW and go to My Student Profile tab > My Student Services channel > Online Services > Special Consideration. After applying online, students must also verify supporting their documentation by submitting to UNSW Student Central:

- Originals or certified copies of your supporting documentation (Student Central can certify your original documents), and
- A completed Professional Authority form (pdf - download here).

The supporting documentation must be submitted to Student Central for verification **within three working days** of the assessment or the period covered by the supporting documentation. Applications which are not verified will be rejected.

Students will be contacted via the online special consideration system as to the outcome of their application. Students will be notified via their official university email once an outcome has been recorded.

Supplementary Examinations

The University does not give deferred examinations. However, further assessment exams may be given to those students who were absent from the final exams through illness or misadventure. Special Consideration applications for final examinations and in-session tests will only be considered after the final examination period when lists of students sitting supplementary exams/tests for each course are determined at School Assessment Review Group Meetings. Students will be notified via the online special consideration system as to the outcome of their application. It is the responsibility of all students to regularly consult their official student email accounts and myUNSW in order to ascertain whether or not they have been granted further assessment.

Further assessment exams will be offered on this day ONLY and failure to sit for the appropriate exam may result in an overall failure for the course. Further assessment will NOT be offered on any alternative dates.

Occupational Health & Safety Obligations

The School of BEES recognises its obligations to provide a safe working environment for all persons involved in School-related activities. To achieve this goal with regards to teaching and learning, the School adopts the UNSW Occupational Health and Safety Policy (2001) and the UNSW OH&S Responsibility and Accountability Document (2001). These documents stipulate that everyone attending a UNSW workplace must ensure their actions do not adversely affect the health and safety of others. This outcome is achieved through the establishment of a documented chain of responsibility and accountability for all persons in the workplace, extending from the Head of School through to the students undertaking courses offered by the School of BEES.

As part of this chain of responsibility and accountability, the Course Authority* is responsible for ensuring all activities associated with this course are safe. The Course Authority has undertaken detailed risk assessments of all course activities and identified all associated potential hazards. These hazards have been minimised and appropriate steps taken to ensure your health and safety. For each activity, clear written instructions are given and appropriate hazard warnings or risk minimisation procedures included for your protection.

It is the student's responsibility to prepare for all practical work. Students should be familiar with the written procedures scheduled for the practical class and identify all personal protection requirements needed to complete the exercise in a safe manner. Students must comply with all safety instructions given by the Course Authority and/or Laboratory / Field Demonstrator, and observe the Safety Information located outside or within teaching rooms. If you are unsure of any safe operating procedures or written instruction regarding safety, you should seek further information from the Course Authority and/or Laboratory / Field Demonstrator before attempting the task. Failure to comply with safety instructions may, in the first instance, be considered as a form of academic misconduct. If the outcome of a student's failure to comply with safety instructions results in personal injury, or endangers the health and safety of others, then the matter may be dealt with by WorkCover as a breach of the NSW OH&S Act (2000).

For the purposes of this course the practicals in weeks 2 – 6 require that you **wear closed shoes and bring a lab coat**. Failure to do either of these will result in your exclusion from the lab and a mark of absent.

PRACTICAL INSTRUCTIONS

Aims of the Practical Course

The practical course has been designed to serve a number of purposes. The first weeks are intended to train you in methods for observing, measuring and analysing animal behaviour. In weeks 5 – 6 you will explore the value of theoretical models in understanding behaviour and its adaptive significance. Last, the collaborative group research projects will allow you to put what you have learned in the earlier components of the practical course and in the lecture course into practice in order to find out something new and original about how and why animals behave the way they do.

For the first two weeks of the practical course, we will practice the skills of observation and description and the techniques of scoring behaviour. Practice in your spare time watching people or any animals you see. Observe closely what they do, the movements they make, their posture, etc.; and try to describe them. The more you look, the more you will see.

There will also be an opportunity for everyone to form into their project groups and begin figuring out the design of their research projects. For more information on this important practical component of the course see Page 34.

Preparation

1. Read notes on *Observation, Description, Measurement and Analysis of Behaviour* at the end of this manual.

Week 2: Display Behaviour of Siamese Fighting Fish (*Betta splendens*)

Introduction

The Siamese fighting fish, *Betta splendens*, is a very useful subject for laboratory behaviour work. It is attractive, easily kept in aquariums, and its display behaviour in particular is dramatic and easily observed.

The wild form of *B. splendens* is distributed widely in Singapore, Malaysia and Southeast Asia in standing or slow-moving fresh water over a swampy bottom. These fish are anabantids, a group characterised by the possession of a labyrinth or accessory breathing organ. Oxygen is taken in by gulping air at the surface.

Males are extremely aggressive, and in Thailand, wagers are lodged on the outcome of male fights. The attractive long-finned and highly coloured variants seen in the aquarist's shop have been selected and bred from wild stock. The fact that the fish have been carefully selected for colour and fin size must be kept in mind when interpreting the results of your experiments. Nonetheless, the ornamental variant shows the same display behaviour as the wild type.

Probably the most obvious feature of male Siamese fighting fish is the enormous size and bright colour of the fins. In male-male encounters, these fins, the operculum and its associated branchiostegal membrane (gill cover) may all be raised. This is accompanied by an enhancement of the fin and body colour. As these displays are conspicuous, easy to elicit and composed of fairly distinct components, this forms a suitable exercise to look at the exaggerated ritualised nature of display behaviour. In addition, describing display behaviour requires accurate observation. You will also be introduced to social behaviour in which not only the behaviour of each actor is important but also the nature and patterning of each actor's behaviour in relation to the other actor must be considered.

Aims

The aims of the practical are:

1. To describe the display behaviour of the male Siamese fighting fish.
2. To look at the contexts in which display behaviour may be elicited.

Preparation

Two males have been housed in separate tanks for at least 24 hours prior to this practical class, while a female has been housed in a communal tank with other females. No food has been given to the male fish in this period.

Materials

Each group with have:

1. Two aquaria, each housing an isolated male.
2. Plastic containers in which to transport female fish removed from a communal tank.
3. A small hand net for removing/transferring fish.
4. A stop-watch.
5. Bloodworms.
6. A mirror.
7. Cardboard and masking tape, which will be used to set up aquaria for next week's prac.

Methods

**Try to keep all fish visually isolated from each other.*

Description of threat display:

Before commencing any experimental observations make sure that you can identify the various fins of the Siamese fighting fish (Fig. 1), and become familiar with the types of display behaviours you're likely to see once you start your experiment.

Fins: The pectoral and pelvic fins are most likely to be confused, because the latter are almost as forward as the former. The pelvic fins, which are elongated and dark, are also more conspicuous than the pectoral fins, which are unpigmented and transparent.

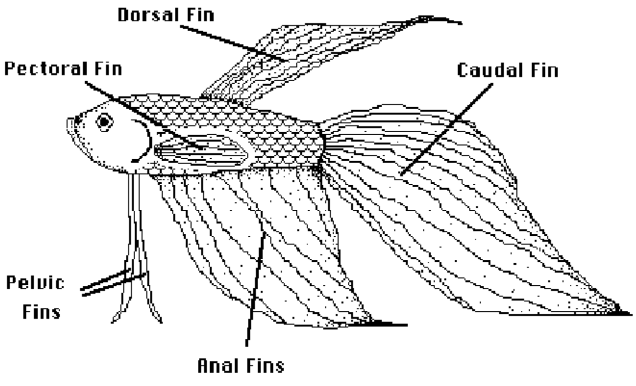

Figure 1. Fins of a Siamese fighting fish.

<u>Behaviour:</u> The names given here to describe the behavioural elements observed in this and other situations described are based on those outlined in Simpson (1968). The elements most likely to be seen in male displays are:

(a) *Fins spread*: Spreading of vertical fins.
(b) *Gill cover erection*: Erection of gill covers and protrusion of the branchiostegal membrane (Fig. 2).
(c) *Bite*: Striking with the mouth and closing the jaws.
(d) *Tail beating*: the two fish swimming parallel and directing tail beats towards their opponent.
(e) *Colour change*: The red or blue colour of the males will be seen to darken and take an additional brilliance.

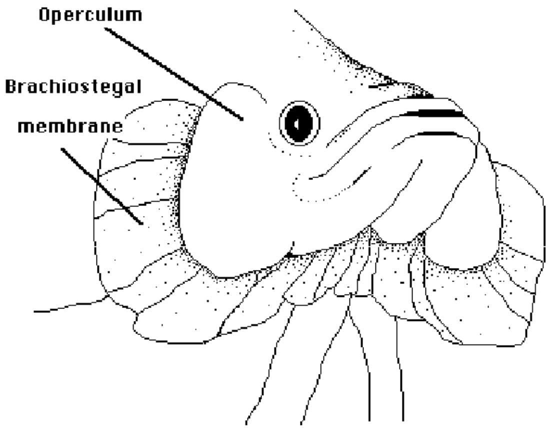

Figure 2. Head of male fighting fish with opercula raised and branchiostegal membranes extended.

Make sure you can identify the display behaviour patterns before proceeding. Now create a repertoire of these and any other behaviour you observe on you male fish.

Before starting the experiments, you'll need to create a behavioural repertoire:

(i). Label each tank using the masking tape with "Male A" and "Male B", with a unique name for your group (you'll be using the same fish in the practical next week, so you'll need to know which tanks were yours).

(ii). Start with Male A, give him a couple of minutes to settle down, then carefully introduce the mirror at one end of his tank.

(iii). Note down all the behaviours you see, which may include behaviours not described on the previous page, for a period of about 3 minutes.

(iv). After gently removing the mirror from the male's tank, create a table of the behaviours you noted down. In one column, list the behaviours from most common to the least frequent down – this will be your *behavioural repertoire*. Create another four other columns wide enough that you can tally the number of times you see these behaviours in during the experiments described below.

EXPERIMENT 1: Threat displays to a mirror stimulus.

1. Using Male B (or whichever male that you did not use in your initial observations to create the behavioural repertoire) slowly introduce the mirror at end of his tank.

2. For the next 10 minutes, tally the number of times you see the behaviours in your repertoire in the second column of your table. Label this second column something like “Male B, Experiment 1”.

3. Once you have finished your observations, slowly remove the mirror.

4. Now that Male A has had a chance to settle down, repeat steps 1 to 3 and tally Male A’s behaviours in the third column entitled “Male A, Experiment 1”.

The tally of behaviours you’ve listed here will provide the baseline or *control* to compare the frequency of behaviours you will observe in Experiment 2.

EXPERIMENT 2: Threat displays to a mirror stimulus, in the presence of a female.

5. Introduce the female into the tank of Male A.

> The male alone with the female can be persuaded to display to her by putting some worms in the tank; this induces feeding and also results in a general increase in activity and display behaviour. *What are the behaviours in the male elicited by the female?*
> [Note these down and give a general description of how the male interacts with the female. These observations will be used to answer several questions made available to you after the prac that you will answer for handing in the following week.]

6. For the time being, leave the male and female together in their tank. Move back over to the isolated male and repeat steps 1 through 3 under the previous experiment, tallying behaviours in a fourth column entitled “Male B, Experiment 2”.

7. Now ago back to your male-female pair and carefully introduce the mirror into one end of the tank, and repeat steps 1 through 3 above, tallying behaviours in a fifth column entitled “Male A/Female, Experiment 2”.

> *Did you notice any differences in the level of the male’s responses evoked by the mirror in the presence of the female, compared to the level of responses when the male was alone?* [Again, note these down for reference]

Each group should hand in their completed – and **legible** – repertoire table at the end of the practical. Results from all groups will be compiled and made available to the class the following day. Each of you will then need to complete a series of exercises based on this data set, which will then be handed in next week.

Prep for next week’s practical

(i). If you haven’t already done so, remove the female from the tank of Male A.

(ii). You will now create a 'shelter' out of one half of the tank for both males. Tape some of the cardboard around the outside of part of the tank and across the top, such that half of the tank is covered along the sides and top, while the other half is left open. Make sure your tank labels are left visible, otherwise you won't know which fish are yours next week.

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Robertson, C.M. & Sale, P.F. (1975). Sexual discrimination in the Siamese fighting fish (*Betta splendens* Regan). *Behaviour* **54**, 1-25. [W9003]

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Week 3: Foraging and Risk Trade-offs in Siamese Fighting Fish (*Betta splendens*)

Introduction

Animals are often faced with a variety of conflicting decisions in day-to-day life. In particular, spending time looking for food while avoiding being eaten can be a challenge. On one hand, an individual needs to devote enough time to feeding otherwise they'll starve. On the other hand, foraging often means venturing out into the open and paying more attention on finding food rather than avoiding predators.

In this practical, you will explore how animals balance this trade-off between foraging and predation risk. Specifically, you will investigate under what circumstances your fish will 'risk' foraging out in the open when a potential predator might be nearby.

Aims

The aims of the practical are:

1. To examine the trade-off between obtaining food and the potential risk of predation.
2. To explore how risk assessments are influenced by context.

Preparation

The two males you studied in Experiments 1 and 2 last week have continued to be housed separately in their respective tanks. One of the males has been kept on an ample diet of bloodworms, while the other has been fed only enough to sustain him over the course of the week. You do not know which male has been 'well fed' and which male has been 'under fed'. In today's practical you will play detective and use the behavioural data collected in the following experiments to make a conclusion on who has and who has not been fed amply.

Materials

Each group with have:

1. The same two aquaria and males they used in last week's practical.
2. Plastic containers in which to transport female fish removed from a communal tank.
3. A small hand net for removing/transferring fish.
4. A stop-watch.
5. Bloodworms.

Methods

**As in last week's practical, try to keep all fish visually isolated from each other.*

EXPERIMENT 3: Boldness in the face of risk.

1. Start with Male A.

2. One member of the group should rest their hand gently on the edge of the open half of the tank (i.e., on the open side opposite to your cardboard 'shelter'). At this stage, keep your fingers out of contact of the water.

3. Get comfortable and wait quietly for about 10 minutes to allow the male to become settled.

4. After this period, and with another member of the group holding the stopwatch at the ready, flick the surface of the water twice in rapid succession to elicit a startle response from the male. In nature, a similar disturbance could signal the rapid approach of a predatory fish or some other potential threat.

5. As soon as the surface of the water is disturbed, start the stopwatch while another group member drops in a small piece of food at the farthest end of the tank from the shelter.

6. Note down the exact time that: (i) the male first emerges from the sheltered of the tank; and (ii) finds and eats the food.

7. Repeat the exercise for Male B.

Repeat this experiment on both males at least twice. *Based on the time it took for each male to emerge and eat the food after startling, which do you think might be the male that was feed more or less during week?*

EXPERIMENT 4: Social context and boldness in the face of risk.

8. Decide on which male you consider to be more weary or skittish, and introduce the female into his tank.

9. Leave the pair to become acquainted for a few minutes, and perform steps 2 through 6 above. It's possible the female grabs the food before the male, but you should still be able to time how long it took the male to emerge from the shelter. <u>Do this experiment at least twice</u>, with at least 10 minutes between each test.

    Was there a noticeable difference in the behaviour of the male following the startle response compared to before the female was introduced?

    Did the behaviour of the female affect the male's behaviour in any way?

10. Transfer the female into the other male's tank, let the pair become acquainted as before, and conduct the experiment on the second male (i.e., perform steps 8 and 9). Again, run the experiment at least twice on the second male, separated by at least 10 minutes.

    Were there any noticeable differences between the two males in how long it took them to emerge from the shelter?

Are the results in this experiment consistent with which male you thought might have been feed more or less in Experiment 3?

Each group should hand in their time sheet, with each time labelled clearly by male ID (A and B) and experiment number. Data will be compiled and made available in lecture the following day, and you will complete a series of exercises based on this data for handing in the following week.

Week 3: Choosing research projects

In the second half of this week's practical everyone will form into their project groups and select their research project. For more information on this important practical component of the course see Page 34.

Week 4: Mate Choice

Details on the series of exercises in this practical will be provided during class.

Week 4: Designing research projects

In the second half of this week's practical everyone will form into their project groups and start to design their research project. For more information on this important practical component of the course see Page 34.

Week 5: Optimality models in animal behaviour

Simulation and analytical models are important tools that enable us to generate and test behavioural theory. Of course models and their underlying theory are derived from observations of one or many species and their validity must also be tested in the field. The advantage of using models is that they make it possible to perform many simplified 'experiments' to sort out the probable from the improbable before the field test is applied. This is a good idea for both practical and ethical reasons.

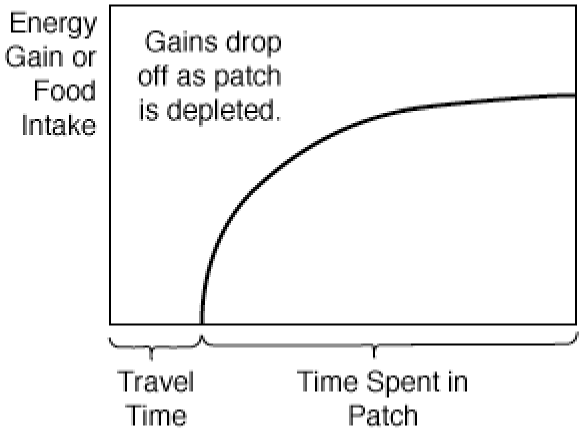
This practical examines a category of behaviour that is commonly modelled; namely, foraging. Foraging behaviour is an example of behaviour where there are a multitude of strategies that could be applied to a variable environment. Modelling enables us to sort out probable strategies given known constraints or behaviour.

The modelling approach we will be exploring today is called “optimality modelling”. It involves deriving a prediction of the optimal way in which an animal should behave under a given set of circumstances. It is then possible to test the accuracy of the model by comparing the predicted optimal behaviour with the actual behaviour displayed by real animals.

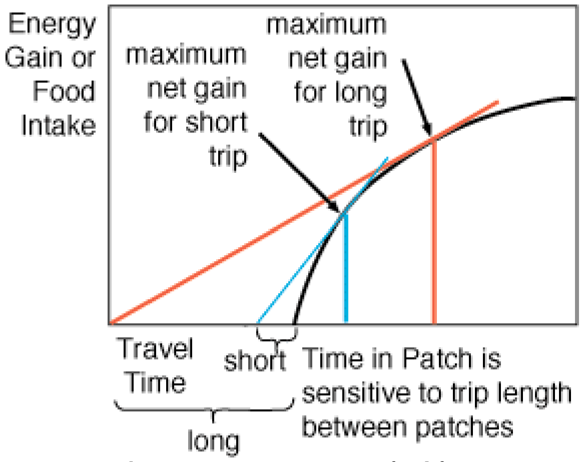
Question: Do we expect animals to always behave in a way that is optimal? Give reasons for your answer?

Part 1: The marginal value theorem

One important optimality model is the marginal value theorem with which we calculate the optimum behaviour when the returns from that behaviour follow what is known as a diminishing returns curve such as the one below.



The optimum (in this case the time a forager stays in a patch) depends on the travel time and the shape of the curve. In fact the optimum is calculated as the time spent in the patch corresponding with the tangent from the origin to the curve. Thus longer travel times will have higher optimum staying times if the returns curve is the same, as below.



Exercise:
You will calculate the optimum staying time in a patch of food by plotting the diminishing returns curve, and the relationship between distance and travel time. You will also each have a chance to predict the optimal behaviour in a new situation.

The predator is YOU, and the prey are plastic balls in a "patch" on the lawns in front of Bioscience. The rate at which you are able to pick up and hold a number of balls should show a diminishing returns curve because it becomes incrementally harder to hold each new ball.

You must conform strictly to the instructions for how to pick up and hold the balls – the "predatory action". The slower and more deliberately and consistently you do this, the better your results will be.

I. Find a ball and stand so it is between your feet.
II. Bend at the knees, keeping your back straight and pick up a ball with your non-writing hand (for most of you this is your left hand).
III. Straighten up.
IV. Pass the ball to your writing hand / arm and hold it there.
V. Walk to the next ball in the patch and stand so it is between your feet.
VI. If you drop one or more balls, pick them up using the same motion.

Step 1:
Once you have practiced the "predatory action" several times each, you should construct a diminishing returns curve for each group member. To do this start the timer as the person steps into the "patch", and record the number of seconds until the predator has passed the 2nd, 4th, 6th etc ball (stopping when the person can consistently hold no more balls) to their writing arm. Plot the curve.

Step 2:
Pace out how long the return travel time to and from patches 5m, 10m, 15m, 20m and 30m from the starting area takes. The data from step 1 and 2 will allow you to build a model of the optimum number of balls to carry on a trip of given distance.

Step 3:
Each student should choose at least two distances and should go on a foraging trip to each in turn with the aim of bringing back the greatest number of balls *per unit time*. It

is important that both walking and picking up balls occur at exactly the same speeds as in steps 1 and 2. Time the entire round trip.

Step 4:
Calculate the optimum for each distance calculated by drawing the tangent from the return travel time for that distance (step 2) to the diminishing returns curve (step 1).

Step 5:
Use linear regression to compare your measured performance in step 3 (dependent variable) with the predicted optimum from Step 4 (independent variable) in units of balls per minute.

References:

Belovsky, G.E. (1986). Optimal foraging and community structure: implications for a guild of generalist grassland herbivores. *Oecologia* **70**, 35-52.

Grier, J.W. & Burk, T. (1992). *Biology of Animal Behaviour.* Chapter 9, pp. 247-267 (Mosby Year Book, Sydney). [MBQ591.51/44A, B, C]

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Krebs, J.R. (1984). Optimal foraging: Decision rules for predators. In J.R. Krebs & N.B. Davies (eds.), *Behavioural Ecology: an evolutionary approach*, 1st Edition, pp. 23-63. (Blackwell Scientific, Oxford). [MB591/78B, C]

Mangel, M & Clark, C.W. (1986). *Dynamic Modelling in Behavioural Ecology*. (Princeton University Press, Princeton). [MB591.51011/1].

McFarland, D. (1993). *Animal Behaviour 2nd Ed*. Pp. 152-155. (Longman Scientific & Technical, Harlow).

Ritchie, M.E. (1990). Optimal foraging and fitness in Columbian ground squirrels. *Oecologia* **82**, 56-67.

Kacelnik, A, Bernstein, C & Krebs JR. (1992) The ideal free distribution and predator-prey interactions. TREE 7(2), 50-55.

Week 5: Designing research projects

In the second half of this week's practical everyone will form into their project groups and design their research project. For more information on this important practical component of the course see Page 34.

Week 6: Evolutionary Game Theory

In these practical classes we will explore evolutionary game theory. This is an approach to finding the optimal strategy for an individual to "play" in the context of what others in the population are doing. Much of the development of game theory was done in the context of economics, including the key contributions of John Nash (as portrayed in *A Beautiful Mind*). For more on the history of Game Theory, visit http://www.econ.canterbury.ac.nz/personal_pages/paul_walker/gt/hist.htm .

Game theory makes it possible to mathematically calculate the best strategy for individuals to adopt in a situation (i.e. "play" in a "game"), based not only on the costs and benefits of the strategy per se, but also on what others ("opponents") in the population are doing. In evolutionary biology, such a strategy is called an "Evolutionarily Stable Strategy" (ESS), because it is the strategy that cannot be "invaded" by other strategies.

In this practical class we will:

- Explore a simple evolutionary game of conflict and fighting (the Hawk-Dove game)
- Examine how the costs and benefits influence the Evolutionarily Stable Strategy.
- Expand Hawk-Dove to incorporate a third strategy
- Be introduced to a classic problem in game theory, the "Prisoner's dilemma", which has direct relevance to the evolution of cooperation.
- Each develop your own strategies to play in the Prisoner's dilemma game, and play them in a tournament to find the best strategy.

The Hawk-Dove Game

This game explores why not all conflicts escalate into serious fights. We know that in the animal world, conflicts are often settled by conventions such as displays, and only rarely do they escalate to full-scale fights.

Fights cause major damage and thus reduce combatant's probability of survival. If evolution maximised benefit to the species, there would be no such fights. However, an individual that was always aggressive would be favoured by natural selection in a population of non-aggressive individuals. In game theory terms, we say an aggressive **strategy** can **invade** a population playing a non-aggressive strategy.

In the Hawk-Dove game, we model the success of two strategies.

Hawks: always fight at full intensity.
Doves: never fight. If they are not attacked, they display (at small cost), and have a 50/50 chance of winning the "display contest".

The payoffs of the various outcomes are given as follows:

w = the payoff of winning the contest
i = the cost of losing a fight (i.e. the cost of injury)
d = the cost of displaying

Question: In a contest between Hawks and Doves, who do you think would win? Why?

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Payoff matrix

An important tool for exploring the outcome of a game is the payoff matrix. It documents the payoffs to an individual playing a certain strategy against each possible type of opponent. The payoff matrix in our Hawk-Dove game is as follows:

	Opponent	
Payoff to ...	Hawk	Dove
Hawk	$\frac{w}{2}+\frac{i}{2}$	w
Dove	0	$\frac{w+d}{2}+\frac{d}{2}$

Task: Use the payoff matrix to calculate the net fitness outcomes from all four types of contest when w=50, i= -100 and d = -10.

	Opponent	
Payoff to ...	Hawk	Dove
Hawk		
Dove		

Question: At these payoffs, are either Hawk or Dove pure Evolutionarily Stable Strategies?

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Calculating the frequencies in a mixed ESS

In a situation where neither strategy is a pure ESS, the frequencies with which the different strategies should exist in a mixed ESS can be calculated.

Let h be the proportion of "hawks" in the population.

H = average payoff for a hawk
$= -25h + 50\,(1-h)$

and
D = average payoff for a dove
$= 0h + 15\,(1 - h)$

At ESS H and D are in equilibrium, thus

H = D
-25*h* + 50 (1-*h*) = 0*h* + 15 (1 – *h*)
-60 *h* = -35
∴ *h* = 35/60 = 7/12 = 0.5833333

The mixed ESS will be reached if 7/12 of the individuals are hawks OR if individuals play hawk 7/12 of the time and dove the remaining 5/12.

Exercise: Exploring the ESS

1. Work together to derive the general solution for *h* (that is an equation that will give you the frequency of hawks (or doves) at equilibrium if you plug in the values of *w*, *i* and *d*). (hint: the final version should take the form *h = …………..,* and the symbols *w*, *i* and *d* should appear in the right hand side of the equation*)*

2. What is the equilibrium frequency of hawks, h, if :

   - the value of winning a contest doubles? ………..
   - the value of winning the contest halves? ………..
   - The cost of display equals – 2 units? ………….
   - The cost of losing a fight shrinks to -60? ………

A Third Strategy: Bourgeois

Hawk and Dove are inflexible strategies. Could a more flexible strategy invade a population of hawks and/or doves? One possible such strategy is called *bourgeois* (def: conventionally middle class; upholding the values of the capitalist class). This strategy depends on who occupied or owned the resource prior to the conflict. Bourgeois players concede when they are intruders and fight when they are resident.

Try to derive the payoff matrix, assuming that a bourgeoisie is resident half the time and intruder the other half:

	Opponent		
Payoff to ..	Hawk	Dove	Bourgeois
Hawk	$\frac{w}{2}+\frac{i}{2}$	w	
Dove	0	$\frac{w+d}{2}+\frac{d}{2}$	
Bourgeois			

Questions:

Assuming the same costs and benefits as in the Hawk-Dove game above, can Bourgeois invade a population of hawks?

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Can Bourgeois invade a population of doves?

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Can Hawk or Dove invade a Bourgeois population?

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What are the implications for animal contests?

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The Repeated Prisoner's Dilemma

This is a game about cooperation, and whether it is in one's self interest to be cooperative.

Before the lab, check out this video about the Prisoner's Dilemma
http://www.youtube.com/watch?feature=player_embedded&v=jUTWcYXVR5w

What if two prisoners had the chance to cooperate to escape from prison? If they cooperate and both escape, they both benefit, but (e.g. due to increased chances of capture) not as much as the prisoner who cheats his cooperating partner (we call the absence of cooperation "defection"). In this case, the cheated partner does not benefit at all. The classic payoff matrix for the Prisoner's dilemma is:

	Opponent	
Payoff to …	Cooperator	Defector
Cooperator	3	0
Defector	5	1

In a one-off game, it is easy to see that a defector will always do as well as, or better than it's opponent.

But what happens if (as with many interactions in animals and humans) there are repeated interactions. It is easy to see that if all individuals defect, they average a payoff of only 1 per round, yet if they all cooperate they average 3.

You are now going to play in a Prisoner's dilemma tournament. As preparation you need to come up with a strategy. It may be as simple or as complex as you like, but it must be based on rules – you cannot simply go on a "hunch". And it must be written down.

The winner will bask in glory and possibly Guinness.

Some example strategies are

- Always cooperate
- Always defect
- Cooperate if a coin says heads / defect if tails
- Cooperate every second go, else defect

It pays to apply some thought to your strategy. You will hand in your strategy "rules" for assessment.

How the tournament is played and won

You will play 20 repeated games in a round. You will play several rounds in a tournament.

The group phase:
You will be divided into four "groups". Each person will play all the others in his/her group. The player with the highest total score in each group will win the group. It is overall scores that matter, not number of games "won".

Each player should begin by playing their own strategy against itself. The total score is written down on the appropriate grey square on the diagonal of the "round robin playoff matrix". E.g. the strategy "always defect" scores a total of 20 points against itself in a given round.

Then each player should play their strategy against every other player in the group. Write the total score of each player in the **row** for the player under the **column** for his/her opponent.

Add up the row totals to find out who wins the group.

The FINALS:
The four group winners play one another AND themselves in another round-robin. The player with the highest score wins the tournament.

<u>You must play the strategy that you have written down at all times and throughout the tournament! Departure from your written strategy will result in disqualification.</u>

Week 6: Finalise research projects

In the second half of this week's practical everyone will form into their project groups and put the finishing touches to the design of their research project. For more information on this important practical component of the course see Page 34.

Weeks 7-10: Collaborative Research Project.

Aim: The aim of this practical is to give you an opportunity to conduct a complete investigation from design to execution, analysis and writing. You need to join up with other students into a group of either three or four. If you do not do so by the beginning of week 3, we will assign you to a group.

Topic choice

The topic of your group's research project may be arrived at in either of two ways:

1. In week 3, a list of potential project titles will be posted on Moodle. In the practical class of that week, you will be asked to rank your top four projects from this list. We will then allocate groups to projects in such a way as to try to ensure that each group gets one of their four favoured projects.

2. You may design a project of your own. If you plan to do this you must identify the species you wish to study, how you will get access to enough individuals of this species, and the hypotheses you wish to test. It may do to choose some topics from the list of projects that you might wish to do as fall-back projects.

Supervision

You will be allocated one of the demonstrators as an advisor. Your advisor will help to guide your group through the process of design, and will act as a source of advice throughout the execution, analysis and writing up of the experiment. Most of you will have access to your supervisor during practical classes, and may send emails if urgent queries arise during the week. If your advisor is one of the lecturers and is not present during the practical, you should email and schedule a meeting; they will be expecting you and will set side aside time to meet with your group. The demonstrators are paid for 30 minutes a week outside of labs in which they have to deal with queries from all of their groups. In all cases, <u>*do not expect your advisor to come to you*</u>! If you don't ask for feedback and guidance, you won't receive it, and your project will suffer for it.

You may not ask your advisor to: design the study for you, collect any data, and provide you with computer facilities, software or references or to read through drafts of your work.

A GENERAL RULE: Every group should seek out their advisor and discuss with them in detail their project at least once *before* the submission of their proposal, and *again* after the submission of their proposal.

Timelines and assessable work

You will begin working on the formal design of your project in week 4-5, once you've been assigned a project. You may begin pilot studies collecting data at any time after this date, but it is advisable that you have your research plan clearly written out and agreed to before you start data collection for your main study (see Proposal below).

Proposal

This research plan will form the basis of the research proposal your group will **email to your group's assigned advisor** by no later than *Thursday 4pm in Week 7 (6 September)*. This proposal should comprise **no more than four printed pages**, double-spaced, including references and diagrams. It should include an introduction with appropriate references from the literature, a brief rationale for the study, a full description of the experimental design, methods and proposed analyses. Your advisor will read the proposal and you will receive feedback on it by the following week. *No group should start on their project until their supervisor has given the go ahead.*

Seminar

In either week 11 or 12, your group will have 10 minutes to give a seminar and a further 5 minutes to answer questions on your study. In the seminar you will have a chance to discuss and interpret your findings. If you are well prepared, and you use the question time well, you will be able to receive valuable feedback on your study that you can incorporate into the **manuscript you must submit in week 13** (see below). This seminar is marked, and you should pay attention to the section "Notes on giving a good seminar" in order to understand the basis for these marks. The best seminars are those in which all group members have practiced their respective parts, have memorized their delivery and fine-tuned their deliveries for clarity and for keeping to time. Groups will be marked down for going excessively over time, so be careful!

Final manuscript

Your group needs to submit a final manuscript as if you were submitting a paper to the journal *Behavioral Ecology* (http://academic.oup.com/beheco). Pay attention to the notes on writing a manuscript, the instructions for authors on the journal's webpage (http://www.oxfordjournals.org/our_journals/beheco/for_authors/general.html), and the other resources on writing that are provided on the Moodle site for the course. Part of your mark will depend on whether you have followed this formatting guide. There is no word limit *per se*, but you should aim for something between 3000-5000 words. Manuscripts over 5000 words will be marked down. The manuscript receives a group mark and should be submitted through Moodle by **4pm Friday 26 October**.

Self, peer and advisor assessment

In order to ensure that mark allocations for group work are consistent with individual contributions, you have an opportunity to **confidentially** appraise the contributions you and your group mates made to the project as a whole. These comments will be used, together with comments from your advisor, to assign each individual student a mark for their overall contribution to the project. Each member of the group should email their assessment form (available on Moodle) confidentially (i.e., individually) to your group's advisor at some point between 9am Monday 22 October and 4pm Friday 26 October.

Materials and resources available for project use

The following materials are available for your use:

1. Binoculars (5 pairs).
2. Stop-watches.
3. 1 x 35mm SLR camera with 50mm, or 200-500mm zoom lenses and a tripod (these must be booked in advance).

4. Access to computer statistics and analysis packages when needed as well as advice on computer graphics (eg. graphing, drawing, painting programs) for use in G007.
5. Experimental apparatus used in practical classes.
6. Advice when needed.

You may book and obtain these materials from the course technical officer. Please provide a list of the materials you need for your project as well as some time for these items to be obtained. Remember there will be a number of different project groups who will all need equipment so do not leave asking for materials until the day your experiments start as you may be disappointed.

7. The Library. The journal and book collections in the library are probably the most useful resource to any researcher. Use them, and read, read, read.

Useful references:

Altmann, J. (1974). Observational study of behaviour: sampling methods. *Behaviour* **49**, 227-267.

Altmann, S. & Altmann, J. (1977). On the analysis of rates of behaviour. *Animal Behaviour* **25**, 364-372.

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Key journals: *Animal Behaviour, Behaviour, Behavioral Ecology, Behavioral Ecology and Sociobiology, Ethology, Evolution, Ecology Letters, Proceedings of the Royal Society of London Series B, Trends in Ecology and Evolution.*

Notes on giving a good seminar

A few notes are given here about the presentation of a seminar.

- You have ten minutes in which to make your presentation and the remaining five minutes for questions. You will be warned at nine minutes and stopped by the chair at ten minutes.
- Your job is to connect with your audience by speaking to them in a comfortable, relaxed, entertaining yet respectful way.
- To this end you should stand up in clear view of the audience and speak directly to them. Do not be tempted to sit or to read.
- Remember that your audience want to see you succeed. They are genuinely interested and will forgive signs of nervousness and minor errors.

- Illustrate your points with visual aids. Sparing text can be useful, tables are better, but pictures are by far the most powerful type of visual aid. Visuals break the talk into sections and give people a chance to assimilate what you say. Summary tables are often useful but should not contain too much data. Tables and diagrams should be fully explained - this gives people a chance to catch up with you and take in what you are saying.
- Practice your talk at least five times – practice your own contribution several times and practice as a group to get your transitions right and ensure you are not wasting time by repeating yourselves.
- We expect every group member to contribute. Group members that do not speak in the formal talk will have to field the questions. **Contribution *will* effect your mark.**

PREPARATION OF POWERPOINT SLIDES FOR SEMINARS

Listed below are suggestions which should improve the quality of your presentation.

- Facilities are available to project PowerPoint presentations, and this is or recommended medium.
- Slides should be clear, legible and in letters large enough to be easily and quickly read by the audience.
- Do not include more than 5 or 6 lines of data, results, or methods per figure or table. The audience will be trying to read and will not hear your discussion if it cannot be read and absorbed quickly.
- In general, limit the amount of data presented, and do so as figures rather than in tables.
- Pay attention to colour and contrast. Always use a light font on a dark background or vice versa – do not mix middle tones.
- Take care in the preparation and presentation of slides. They are an extension of you and your work and an indication of your respect for the audience.
- Is the slide really necessary? Limit your slides to the minimum and carefully choose what you are going to say. One slide per minute is usually the maximum.
- Remember you should know your own story better than anyone else. Others will be a bit slower in appreciating the story's significance, may not understand it as well as you, and may become more easily confused than you expect.
- Ensure your file fits on a PC-readable USB drive. ***<u>You will not be able to use your personal laptop or link to a dropbox/cloud.</u>***

Observation, Description, Measurement and Analysis of Behaviour

If we are to apply the scientific method and test formal hypotheses about behaviour, we need to be able to analyse quantitative measures. Before we can analyse or even measure behaviour, we need robust descriptions of the behaviours and their sub-components so that any observer may obtain the same results from a given protocol. These descriptions are arrived at after substantial observation of behaviour, which is the necessary first part of any behavioural study.

Observation

Behaviour is most explicitly defined as all the observable activities of an animal and hence refers not only to movements of component parts of the animal but also to such events as colour change through chromatophore expansion and contraction, glandular secretions, vocalisations, etc. In most circumstances behaviour consists of responses to internal and external environmental factors. Usually it is what we can perceive of an animal's reaction to a change in environmental circumstances. The key to successful behavioural studies, however, lies in accurate observation. You must both be perceptive and discriminating in what you choose to record and what you ignore from the continuum of an animal's activities, and this judgement improves with experience.

The first task then, is simply to observe the behaviour in general, in as many contexts as possible. The surroundings can distort and modify behaviour, so the study should be made under conditions which are as natural as possible. Ideally, one would follow the animal around on its daily routines in the wild state. The observer must be inconspicuous and not interfere in any way with the animal's normal activities. In many cases this requires a period of habituation to the observer's presence so that the animal essentially 'ignores' the observer. Animals normally active at night provide special challenges. However, modern low-light video, night-vision light amplification and radio-tracking technologies can assist with nocturnal observations. An alternative is to compromise to some extent by caging the animal in such a way that it will behave as naturally as possible when undisturbed. This has advantages in that experimental manipulation of the animal's physical and social environments can be made to tease apart relationships between the animal's environment and its behaviour. However, the captive environment often removes constraints such as finding food and avoiding predation which must be taken account of in the animal's repertoire. Therefore even though much behavioural data is gathered in captive studies, interpretation should be supplemented by field observations whenever possible.

It is necessary to divide up a virtually continuous behaviour record into meaningful and useful units of behaviour so that a problem can be tackled quantitatively. Two important points to remember are that such units should normally: (a) be distinct from another (i.e. mutually exclusive), and (b) be defined with regard to what you want to find out after you have classified the behaviour. You may then proceed to lump or split units according to these constraints.

Building up a description of the behaviour an animal uses is often tedious. It requires that you spend much time watching the animals (either first hand or from film/video). You may at first be confused by the great variety of complex movements that follow so quickly upon each other that you cannot see what is happening. Then you will begin to see signs of order: the consistent use of a certain posture in certain situations, eg. a particular configuration of the shapes and colours of the fins of a male fish when it is courting a female, or a particular position of the head of a male bird. By taking note of every instance of this kind, you soon begin to be able to predict what an animal is going to do in a new situation, and to discern which behaviour patterns are rigidly stereotyped, and which are variable. By relating this to variations in the circumstances under which the behaviour occurs, you can begin to understand its motivation.

You may be able to make only a little progress towards achieving a complete picture of any of the behaviour patterns that you study. Nevertheless as you approach a problem, try to keep the goal of a total picture in mind, forming your own impressions rather than simply checking for behaviour patterns which may be mentioned in something you have read in the literature.

Description

The problem of description is central to the modern approach to the analysis of behaviour in animals. This problem has long since been overcome in the physical sciences where there is fairly general agreement on the parameters to be used for the purposes of analysis. A trained investigator confronted with a new problem knows where to start in seeking to relate the new phenomenon to what is known already. In the study of animal behaviour, one is often unable to anticipate in this way. One has to approach a new animal with an open mind, to look for those parameters of behaviour which will lead to a more general understanding. Short cuts may be possible if one is familiar with close relatives of the species in question, but previous assumptions should not be allowed to dominate what is actually seen.

Gradually, as one describes the behaviours one observes, a picture is constructed of the motor patterns an animal uses in its daily life, the stimuli from the environment or from other animals to which the focal animal seems to be responsive, and the ways in which the behaviour changes with the physiological condition of the animal. Such information is essential for any further investigation of the function of observed behaviour or of aspects of social behaviour. Even an incomplete picture of this type is better than none at all as a prerequisite for the selection of behavioural parameters for a specific experimental purpose.

Description of elements of behaviour may be:-

1. *Morphological* (or *Physical*), eg. in terms of the detail of change of posture, movement (either details of muscles moved, or shorthand such as walk, run etc.).
2. *Functional* (by consequence), eg. the result of an element of behaviour rather than its form. One might describe a piece of behaviour as A approaches B, regardless of whether A walks, runs or flies.
3. An alternative approach is to focus on the regularities observed between various instances of an element of behaviour. The regularities may lie in one or more of five domains:
    a. *Location is space*, i.e. fixed or changing locus of animal in relation to some specified component(s) of the environment.
    b. *Orientation to the environment*, i.e. disposition of the structures of the animal in relation to some part(s) of the organic or inorganic environment.
    c. *Topography of the animal*, i.e. 3-dimensional topography of the animal itself.

d. *Intrinsic properties of the animal*, i.e. variation in the integument of the animal.
e. *Changes effected in the physical environment*, i.e. physical effects of behaviour.

Ethograms

A complete detailed inventory of the behaviour of a species is called an **Ethogram**. Producing an ethogram may be the culmination of the initial observation and description phases of a study, but an ethogram is very seldom a useful end in itself.

An important problem in the observation and description of behaviour is that one is seeking to impose separate categories on to a continuous system. This is to some extent possible. For example, we can recognise behaviour as grooming or mating. But when we come to compare separate occurrences of grooming or mating, we find they are different. However, if we recognise this problem, we can take account of it. Our first steps in the study of behaviour involve the observation of behaviour and the developing of names and descriptions of the elements we can discern in the behaviour. These two processes of observation and description must go together. As you become more practiced in observation, so you will see more to describe; as you try to describe what you see, you will find you see more detail than you thought possible.

A Note on Terminology

The act of describing inevitably requires the naming of things. This means that we should be aware of what the process of naming implies. Certain assumptions, often quite unconscious, underlie the bestowing of a name. These assumptions are partly a help and partly a hindrance to the achievement of the rarely attainable goal which we nevertheless seek, a perfect description.

Consider an example.

There are a variety of cylindrical, hollow glass objects, each with a flat bottom and a cylindrical neck that is commonly blocked by a cylindrical piece of cork. These glass objects we call 'bottles'. Whenever we call something merely a bottle, we assume that for the purposes of discourse, it is unnecessary to indicate this particular object's individual properties that distinguish it from other bottles. The use of language for description encourages emphasis upon the properties that certain objects as a class have in common. Once a name has been created, we tend to overlook variations within the category - a tendency that may be an essential part of the act of perception. The way out of this paradox is to qualify the first name, so that we may have, for example, 'ink' bottles, 'milk' bottles, or 'wine' bottles. Such a system works reasonably well for describing objects of our daily life. Instead of continuing with our physical description of the different bottles on a strictly empirical basis, we have taken a short cut and defined them in terms of the liquids that they usually hold - usually, but by no means exclusively. We have in fact a functional rather than an empirical description, which is confused by the fact that milk, for example, is sold in some parts of the world in what we would call wine bottles. To resolve this we must go back and describe what we mean by a wine bottle, beyond just, 'a bottle that holds wine!'.

It is easy to slip into the same habit in describing behaviour. Yet if you do so, you subtly change the description in a manner that can be exceptionally dangerous and misleading in the analysis of behaviour.

This source of confusion can be avoided only by describing on a strictly empirical basis. If you see birds regularly using an upright posture while fighting, call it an 'upright posture' and not an 'upright aggressive posture'. You may find that the same bird uses the same posture in other situations. If the name you bestow includes a functional connotation (in this example 'aggression'), it may colour your subsequent descriptions in a misleading manner. Even if your original judgement is correct, related species may use the same or a similar posture in quite different circumstances. A preoccupation with functional situations may lead you to overlook such parallels, simply because you were not expecting to see the posture in another situation. This type of error can be avoided by using descriptive words that are not inherently attached to a particular functional situation, as are 'submissive', 'appeasing' or 'sexual'. Only in this way can we build up a body of knowledge in which free cross-reference is possible, both within a species and between species.

At the same time, when you are building up familiarity with the basic behavioural repertoire of the animal, it is important not to include your initial interpretation of what you see in your description. When you have a good clear objective description of what you have seen, then you may be able to interpret it.

Measurement

If a unit of behaviour is unitary and discrete, there is little difficulty in working out the descriptions and techniques for quantification. A simple present-absent statement can be made. For many animals defecation exemplifies this response. It is easy for the observer to record, 'the animal defecated'. In addition, most of these types of responses are readily quantified in terms of frequency or number. Some elements of behaviour, however, characteristically occur either briefly or continually. For example, an animal may groom, but in many short bursts. One way to quantify this is to record the cumulative time spent grooming during the observation period.

From our measurements of behaviour, we try to find patterns in space and time. Parameters to measure include:

- Frequency of occurrence
- Total duration
- Bout length
- Inter-bout interval
- Intensity (difficult)
- Position (of animals concerned)
- Orientations (of animals concerned)

Classification:

An important aspect of quantification of an animal’s behaviour is the process of classifying behaviours into broader types that are associated functionally or otherwise.

We can associate various elements because they have common characteristics, so that we recognise them as the 'same' type of behaviour. Thus we might group behaviours whose form varies only within prescribed limits or behaviours that produce a common effect.

There are basically three types of classification.

A. Causal Classification

Elements of behaviour are grouped according to the causal factors on which they depend; eg. activities whose frequency or intensity is increased by female gonadal hormones we might group as female sexual behaviour.
Two methods are used to determine causal relations.

1. Administer the suspected causal factor - eg. inject the female gonadal hormone, monitor its effect on behaviour.
2. Look for correlations in time - two elements of behaviour that occur together are likely (but not certain) to be causally related.

B. Functional Classification

Classify according to function - eg. threat, courtship, fighting, etc. This may overlap with a causal classification sometimes, but not always. For example, “Reproductive Behaviour” includes sexual and parental behaviour with different causal factors.

C. Historical Classification

Group behaviours together according to mode of acquisition, eg. learned, ritualised, innate.

Recording and Scoring Behaviour

Qualitative - the first descriptive stage, for recognition of elements, etc.

- Written description - paper, pencil and what you see.
- Film - cine and still.
- Videotape.
- Tape recording - describe in words, and later produce a written transcript.
- Keyboard to data logger, personal computer (PC) or personal digital assistant (PDA)

The most sophisticated systems now in use have a keyboard with many keys, and instead of producing a record on paper or tape, the information from the keyboard is fed directly into a computer, which can be programmed to score time on, time off, etc., and then count up durations, frequencies, etc.
The most reliable, flexible and cost-effective method is still paper-and-pencil.

Sampling and recording behaviours in time

Many methods have been developed for scoring behaviour, which do not depend on a continuous record. They can produce a measure of the distribution of time spent in various behaviours but they do not produce an absolute record of frequency and duration. In many cases, such sampling is quite adequate. The basis of such sampling is some form of checklist.

Two types of sampling are commonly used:

a. *Scan sampling* is a technique in which the observer records an individual's current activity at pre-selected moments in time (eg. every minute throughout the day, or every 5 seconds for an hour). It is a sample of 'states', not 'events'. States are behaviour patterns that persist for some time (eg. holding a pen) whereas events are of rapid duration (eg. picking up a pen). Events are better described in terms of their frequency.

Scan sampling can be used to obtain data from a large number of animals by observing each in turn within the period of the scan. Scan sampling has been shown to give a good measure of time spent in various activities.

b. Alternatively one can focus on a single individual ('focal animal sampling') for a period of time and then sequentially sample other individuals after a period of time has elapsed (eg. sample all females in a group for one hour choosing the focal female at random and proceeding through all females).

An advantage of these methods is that the results can be recorded simply with pen and paper. One draws up a score-sheet (or check-sheet) of the type shown below:

	Behaviour				
Time period	**A**	**B**	**C**	**D**	**.**
0	√				
1		√			
2	√				
3			√		
4				√	
5		√			
6			√		
.					

Time sampling procedures can be used in conjunction with a continuous record, as they provide a more rapid means of scoring from film or tape.

Film and videotape are particularly useful in the very early stages of familiarisation with the behaviour of an animal; because you can see the same thing over again, slow it down etc. However, **scoring is extremely tedious**, and for quantitative recording it is usually preferable to use some other method, where compression of information is made at the time of scoring.

Remember that we are trying to record things like frequency, total duration, bout length, and interval between bouts, position, orientation, and sequence.

Much of this can be scored from a film, video tape or spoken commentary on a magnetic tape, but this takes a long time, since the film or tape record lasts as long as the original behaviour, and scoring it takes even longer and film especially is expensive.

Many people, after they have finished the initial descriptive phase, develop some sort of system for scoring behaviour directly while they watch the animal (the same scoring systems can be used with film or tape). However, this may mean taking one's eyes off the animal while one writes. This problem can be avoided by using two people - one who watches the animal and says what happens, and a second who scores this on paper. This is similar to talking to a tape recorder, except that the transcription phase is avoided. However, the presence of two 'observers' may prove too invasive for some species. Whenever a spoken record is made one must ensure that this does not attract the attention of the animal under observation and thus disturb its behaviour. In some captive studies, animals are habituated to this type of disturbance by playing a radio during their normal activity period.

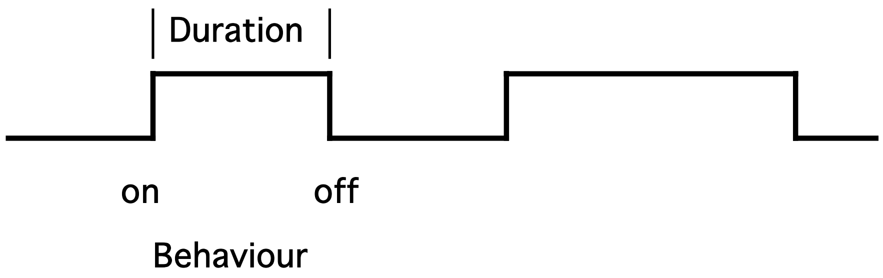
Event Sampling

This type of sampling, and the scoring methods associated with it, records every occurrence of a particular event. Suppose one was concerned with recording episodes of feeding behaviour. Then one would record time of starting and stopping of each episode of feeding, and perhaps make other notes at the same time.

Event sampling can be done with:

- Film
- Videotape
- Magnetic tape (spoken)
- Event recorder (data logger, microcomputer, PDA) and keyboard.

The basic structure of an event record is:



In the past observers laboriously transcribed data from paper records derived from event recorders. These are now largely gathering dust on shelves and have been replaced with notebook and palm-sized computers or data-loggers for acquisition of remote events. In the future the computer keyboard is likely to be replaced by a pen and handwriting recognition followed by voice recognition. The popularity of computer-encoded data acquisition is such that there is now commercial software for this function.

References

There is not a great deal written on methods. You will find the following useful on description and classification -

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Analysis Of Data

Measurement

Different kinds of measurement permit only certain types of statistical treatment. These can be considered as different levels of measurement.

Nominal (classificatory)
Ordinal (ranking)
Interval and ratio

The ways in which data may be analysed depend upon the level of measurement used.

Nominal: This is the weakest level of measurement. Animals are classified, according to a particular characteristic, into one of a number of mutually exclusive sub-classes. For example, the circadian activity of a particular species of animal might be classified as either nocturnal or diurnal. Animals might be classified by habitat as pelagic, planktonic or benthic.

Ordinal: The classification of animals into sub-groups according to some feature may be such that particular sub-classes can be said to be of higher or lower measure than other subclasses. For example, animals might be classified into 4 groups according to activity:

1. Motionless
2. Slightly active
3. Active
4. Very active

This is a four-point scale of activity giving an order or rank of sub-classes 4 3 2 1. It is not permissible to say, using such a scale of measurement that, for example, a score of 4 is twice as high as a score of 2, but only that it is a higher score. This level of measurement is particularly useful for behavioural data.

Interval and ratio: When the scale of measurement is such that values not only can be ranked according to size but also bear an exact relationship to their distances along the scale, then the scale is an interval scale. If, in addition, the scale has a true zero point, it is a ratio scale. In a ratio scale the ratio between two measures on the scale is independent of the units used to measure it. So, for example, the ratios between 30 and 60 kph and between 44 and 88 m/s are both 2. Both scales have interval measurement and a true zero.

Parametric And Non-Parametric Tests

The first introduction to statistical procedures for determining levels of significance of observed differences between experimental groups tends to be through tests such as the t-test. This is a parametric test and, together with other parametric tests, has certain disadvantages that do not arise in non-parametric tests. Non-parametric tests are more attractive at introductory levels because

(a) they may be used on small samples;
(b) some of them require only very simple computation.

They are more attractive for behaviour data because
(i) they do not assume normally distributed data;
(ii) they may be used on data no better than those of ordinal or nominal measurement, whereas parametric statistics may be applied only to data of interval or ratio measurement.

These features together make non-parametric statistical tests particularly suitable for introducing to students the concepts of null hypothesis, probability and significance.

Detailed information on the appropriate use of non-parametric tests, together with a clear explanation of each of a number of non-parametric tests, may be found in Siegel (1956), Conover (1980) **or** Neave and Worthington (1988). Barnard *et al.* (1993) discuss the design, analysis and presentation of practical work with many examples from animal behaviour studies. Bart *et al.* (1998) provide some more advanced methods

Reference
Barnard, C., Gilbert, F. and McGregor, P. (1993). ‘Asking Questions in Biology’. (Longman Scientific & Technical, Harlow.)
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Presentation Of Results

Tables

Tables (eg. Table 1) are a convenient way of representing information where several sets of data concerning several animals or situations have to be shown. Tables are most effective when the following points are considered.

(a) its headings are brief and clear
(b) it is composed of only a few columns and rows
(c) if possible, there is a single line at the bottom which summarises the main finding illustrated by the table.

Table 1. Number of aggressive interactions between three size classes of red kangaroo males.

	Large	Medium	Small	Total by:
Large	20	10	5	35
Medium	5	50	10	65
Small	0	5	15	20
Total to:	25	65	30	

Graphs

If there is a choice between summarising the results in the form of a table or of a graph, almost invariably a graph is better, because it makes apparent the essential findings at a glance. A number of points should be noted:-

(a) A graph is used to represent the change in value of one parameter resulting from the change in the value of the other. The independent variable is conventionally represented along the horizontal x-axis (axis of abscissae) and the dependent variable along the vertical y-axis (axis of ordinates).

(b) The points on a graph should be joined up by a series of straight lines. 'Best-fit' straight lines or curves should only be drawn when the appropriate formulae have been used to construct them (eg. regression lines).

(c) Commonly the same experimental procedure is applied to more than one group of animals, in which case direct comparisons may be made by plotting all the results in one graph. However, even when different types of lines and points are used to represent different groups, for reasons of clarity it is not advisable to plot more than three lines on one graph - unless they show no overlap, when more can be included without affecting the clarity of presentation.

(d) The y-values represented on a graph are usually mean values for the group: they do not, therefore, give any impression of the variation or range of the sample upon which the mean value is based. The variation, however, can be conveyed on the graph by the inclusion of bars to indicate +1 or -1 standard deviation or standard error of the y-values about each point.

Another convenient way of presenting results is to plot each point as a median value (of observations), then divide each half of the range above and below the median into halves of equal length to find the quartile points. The bars obtained by joining the quartile points represent the interquartile range.

Histograms and Bar Charts

Histograms and bar charts also provide a clear way of presenting results which might otherwise have been displayed less clearly as a table. A histogram is used when quantity or intensity of a given behaviour is represented on the y-axis, while the x-axis contains numerical categories (e.g. deciles). In a bar chart the x-axis contains classes which may be arranged in any order (eg. Fig. 1).

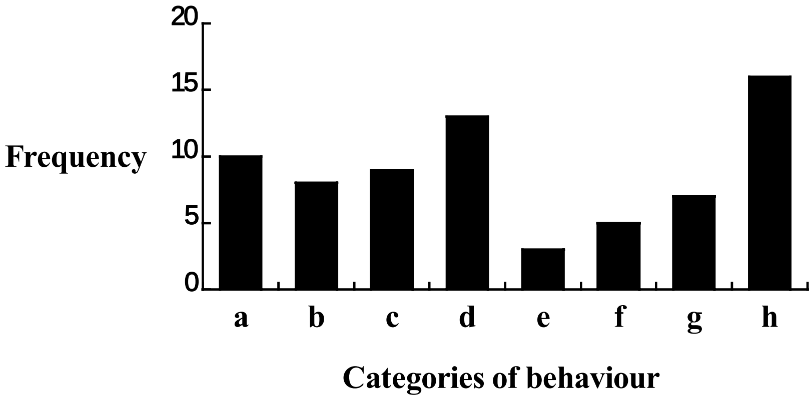

Figure 1. Bar chart showing the mean frequency of 8 different categories of behaviour a to h.

Y-values are usually mean values, represented by the heights of the columns, and the variation about a mean may be indicated by the inclusion of a standard deviation bar in the same manner as for graphs. Again, as is the case of graphs, results from two or more groups may be compared on the same bar chart (eg. Fig. 2).

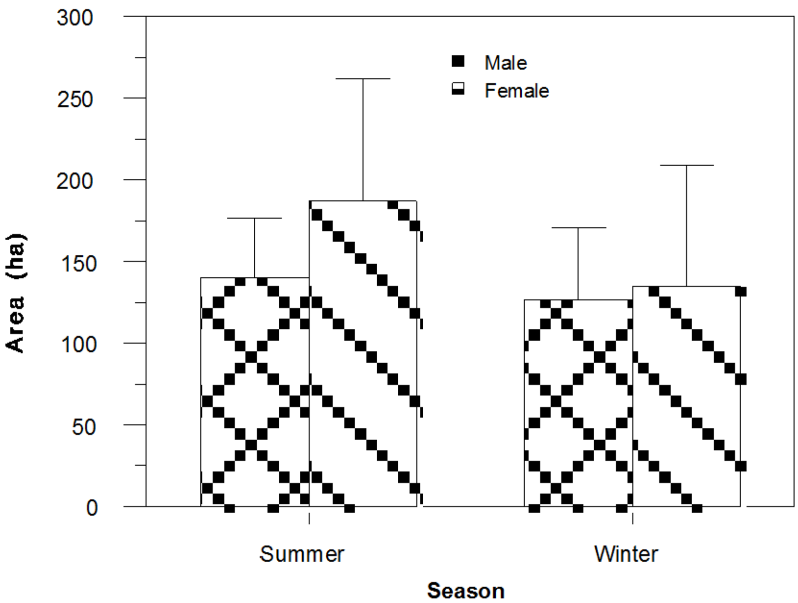

Figure 2. Mean (± 1 SE) daily home-range are of Red Kangaroos at Fowlers Gap, northwestern New South Wales.

Photographs

Photographs may be used as sources of behavioural information that must then be assessed and analysed. An example of this would be measurement of individual distance within a group of animals, as a study of their social structure. Photographs taken for this purpose alone are, therefore, not appropriate to the "Results" section, but rather to the "Appendix". However, it may be desirable to include photographs in the "Results" section as the clearest way of conveying particular information - for example, to illustrate a characteristic posture adopted by an animal, which would be difficult to convey verbally.

Line drawings

A photograph is often not as good at illustrating particular behaviour as a simple line drawing from which all unnecessary detail has been excluded. Line drawings may be drawn or traced from photographs, as from frames of a cine film, or from life.

Other types of presentation

Orientation diagram

The orientation of animals at a point, or their direction of movement from that point, can be recorded as a series of wedge-shaped bars radiating from the point, where the length of each bar is proportional to the number of animals orienting in that direction (eg. Fig. 5).

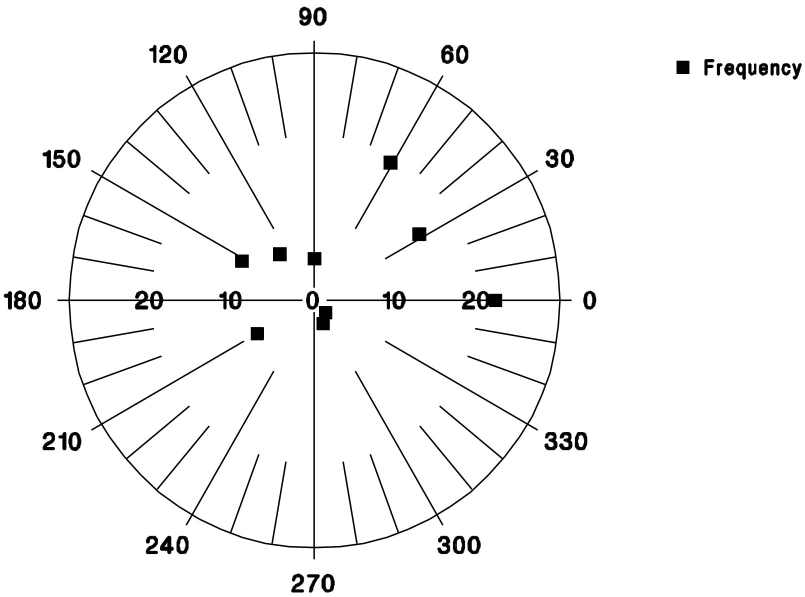

Figure 5. Diagram showing the frequency of animals moving in various compass directions.

Maps

In field studies or studies of social behaviour it is often desirable to include maps to show, for example, the distribution of territorial boundaries (eg. Fig. 6).

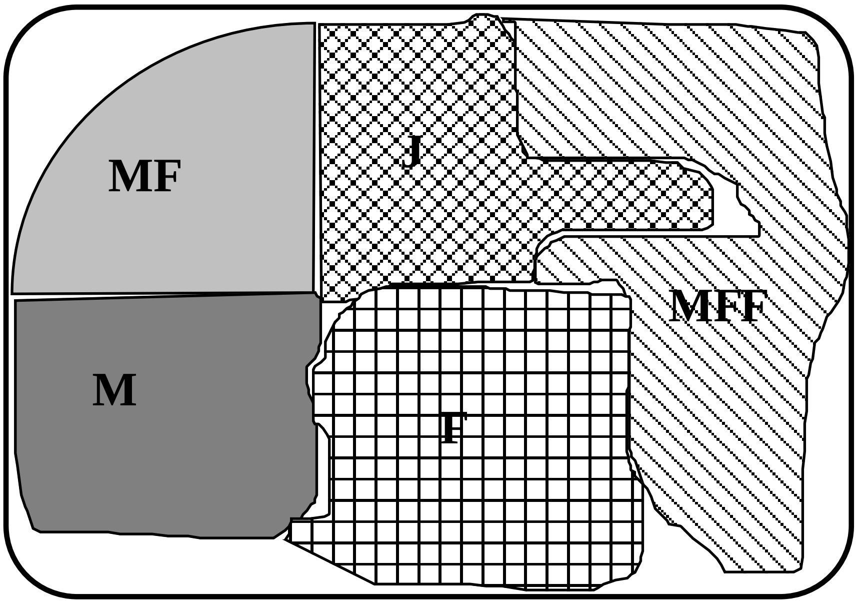

Figure 6. Map of the territories of a species. M = male territory, MF = territory of pair, MFF = territory of a polygamous male, F = territory of unmated female, J = territory of juvenile.

Interaction matrixes

In studies of social behaviour one often looks at interaction frequencies between social classes in dyadic interactions. For example, in a study of aggressive interactions between males, females and sub-adults one might draw up the following matrix of frequencies (f).

		Aggressee	
	Male	**Female**	**Sub-adult**
Male	f1	f2	f3
Female	f4	f5	f6
Sub-adult	f7	f8	f9

Sociograms

Social interactions between various classes in a population can also be illustrated diagrammatically. Circles represent the social classes and the thickness of the lines joining the circles is proportional to the number of interactions between two classes (eg. Fig. 7).

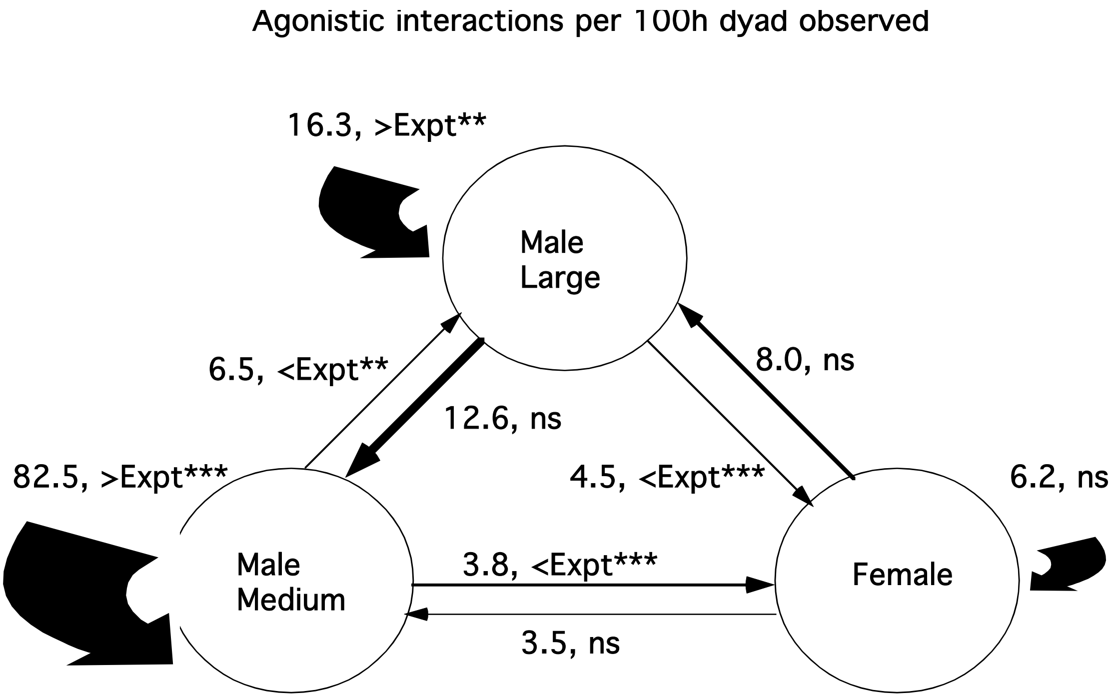

Figure 7. Sociogram showing the frequency of agonistic interactions between adult euros.

Flow diagrams

Flow diagrams are often used to illustrate sequences of behaviour. The probability of a transition from one act to another is usually illustrated by indicating the probability against the line joining two acts (eg. Fig. 8) or by joining acts with lines of a thickness proportional to this probability.

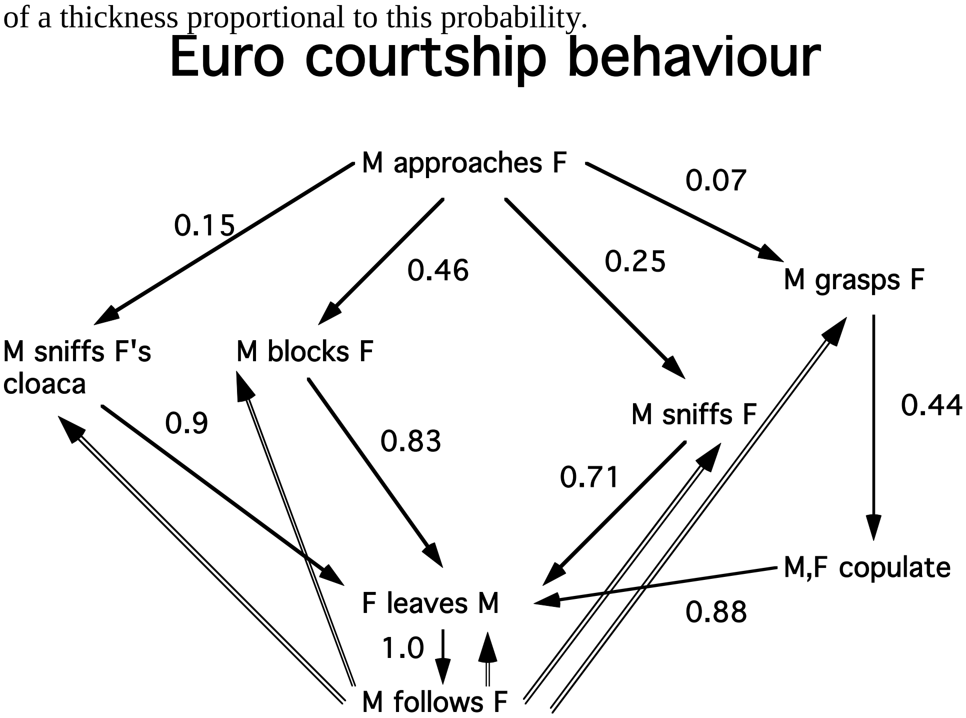

Figure 8. Flow diagram showing the sequences of behaviour observed in male courting of an oestrous female euro.

Reference

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