Academic Year	AY2022/2023	**Semester**	1
Course Coordinator	Eleanor Slade (Asst Prof)		
Course Code	ES3307		
Course Title	Experimental Design & Analysis for Ecology		
Pre-requisites	BS1008 Bioinformatics & Statistics MH3511 Data Analysis with Computers *This course is a pre-requisite for ES4002 Final Year Project Ecology specialization students.*		
No of AUs	4		
Contact Hours	Total hours – 52 hours Lectures: 20 hours, tutorials: 16 hours, computer lab tutorials: 16 hours		
Proposal Date	25 March 2022		

Course Aims

This course introduces you to the basic principles of experimental design and analysis of ecological experiments. It introduces you to methods and key concepts for designing and implementing experiments in both the field and laboratory. You will learn how to plan and execute an experiment, key concepts in designing experiments, and how to analyse and present your results. This course builds on the statistical and R skills you should have learned in BS1008, ES0002, and MH311, and you will learn how to apply these statistical methods to real-life ecological field and lab experiments. This course uses R, and assumes some introductory knowledge of statistics and the R language.

This course is a pre-requisite for ES4002 Final Year Project Ecology specialization students.

Intended Learning Outcomes (ILO)

By the end of the course, you should be able to:

1. Plan and design an experiment or field study.
2. Formulate hypotheses and predictions.
3. Recognise, chose, and justify when to use different designs and key statistical tests.
4. Select and employ appropriate experimental designs and statistical tests to analyse ecological datasets.
5. Critically evaluate the methods and results of published papers.
6. Analyse and present your data using R statistical package.
7. Interpret graphs, figures and statistical tests.
8. Present and communicate your results clearly and concisely.

Course Content

1. Questions, hypotheses & predictions

Understand how to formulate a question, hypotheses, and predictions. Understand the difference between observational and experimental studies and why they might differ in the way they are analysed.

2. Variation, randomisation, replication and sampling

Understand the importance of spatial, temporal, and with-in subject variation, and how to design replicated experiments, and select appropriate sampling designs.

3. Blocking/Grouping variables, co-variates, and random effects

Understand the concept of blocking/grouping variables, and the advantages and disadvantages. Understand interactions between covariates and factors. Understand random vs fixed effects and how specify these.

4. Selecting the correct design and statistical test

Apply different experimental designs (single, factorial, split-plot). Understand how to account for interactions. Apply the correct statistical tests for count, proportional, and continuous data.

5. Model Selection

Recognize the difference between observational and experimentally-designed studies and when to use the information theoretic approach and AICs versus the likelihood approach and P values

6. Multivariate analyses

Understand how to analyse community datasets, and account for environmental covariates.

7. Effect sizes

Understand the difference between inaccuracy vs imprecision. Explain the difference between statistical vs biological significance, and how to use and report P-values. Recognise the difference intervals that can be fitted and when to use them.

8. Presenting your results and evaluating published papers

Understand how to graph data, interpret results, and write and present results. Critically evaluate published work. Identify questionable research practices and explain the importance of open science.

Assessment (includes both continuous and summative assessment)

Component	Course ILO Tested	Related Programme LO or Graduate Attributes	Weighting	Team/Individual	Assessment rubrics
1. Contributions during class time, online discussion board, and tutorials	2,3,5,7,8	1,2,3,4,5,6	5%	Individual	Appendix 1
2. MCQs quizzes – 5 online quizzes	1,3,4,7	1,3,4	25% (5% each quiz)	Individual	Appendix 2
3. Computer tutorial assignments 1-4	1,2,3,4, 6, 7, 8	1,2,3,4	40% (10% each assignment)	Individual	Appendix 3
4. Project report	1,2,3,4,6, 7,8	1,2,3,4,5,6	20%	Pairs with individual report	Appendix 4
5. Project presentation	1,2,3,4,6, 7,8	1,2,3,4,5,6	10%	Pairs	Appendix 5
Total			100%		

These are the ASE Learning Outcomes:

At the completion of your course of study in ASE, you will be able to:

1) Demonstrate intellectual flexibility and critical thinking in order to apply environmental knowledge in the real world

2) Communicate environmental concepts with enthusiasm to varied audiences both orally and in writing

3) Formulate scientific questions, and be able to access and analyse quantitative and qualitative information to address them

4) Exhibit the motivation, curiosity and skills for lifelong learning

5) Demonstrate ethical values and responsibility

6) Collaborate and lead by influence

Formative feedback

Feedback is central to this course. You will receive formative feedback through written responses to your assignments and discussion Slack, and verbal feedback through in-class discussion and tutorials.

The MCQs will have the correct answers given on completion. These check your understanding of the key concepts in previous lectures and encourage you to revise and raise questions on subjects which you do not understand. Questions will be discussed in class on completion of the quiz.

A discussion group online will be set up for students to communicate between themselves and with the instructors.

You will work on a project in pairs. You will discuss the project and do the analysis together, but produce individual reports, and qualitative feedback will be provided on the report at the end of the semester. You will give a joint presentation to your peers, and feedback will be given during your presentation and through peer-review appraisal.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Lectures	There will be lectures at the beginning of each week to pass on the theoretical knowledge required to understand the different components of experimental design and analysis. These will be done in an interactive way, involving your participation in the form of discussions and contributions. The discussion board will also allow a forum to ask questions and discuss topics, and you are expected to actively engage in this. The assignments will also allow you hands-on application of the content covered during lectures (LO 3, 4,6,7,8).
Quizzes	The MCQs will be based on the topic of the previous lectures, tutorials, and readings. These will facilitate content assimilation and ensure that you are learning in an active way (LO 1,3,4,7).
Computer lab tutorials	During the computer tutorials you will have access to computers you will complete the exercises that will help you build connections between the theory and concepts of design and the practical applications and links to statistical analysis. (LO 3,4,6,7,8). You will also become familiar with using the statistical programme R (LO 6,7).
Tutorials	During tutorials we will discuss pre-assigned papers and datasets. The tutorials will allow you a space to discuss in-depth what you have learned in the lectures and readings. You will learn to critically evaluate methods and designs in the literature and to think about potential pitfalls when designing your own experiments (LO 2,3,4,5,7,8). You will be encouraged to share your thoughts and observations with your classmates informally through discussion groups and as presentations to learn how to present and communicate results clearly and concisely (LO 5,8).
Project & presentation	You will work in pairs to come up with a question you would like to test and design an experiment to test this. You will then be given representative datasets to analyse and interpret, or if you have datasets already you can use these (LO 1,2,3,4,6,7,8). You will work together but produce independent reports. Together you will then present your experiment and analyses to your classmates (LO 8), who will peer-review your presentation. This will allow you to put everything you have learnt into practice, and enable both independent learning and critical thinking, as well as learning from each other. This will develop both your research, team-work and presentation skills.

Reading and References

Main course texts

Ruxton & Colegrave (2011) Experimental Design for the Life Sciences, OUP.
This is the main course text book on the process of designing experiments. I encourage you to read the relevant chapter(s) between lectures to help you get a more in depth knowledge of the subject discussed each week. The book is in the library.

Hector (2018 or 2021 edition) The New Statistics with R
More advanced statistics and R coding. We will follow this book in later parts of the course on statistical tests. This book is in the library.

Other texts

Holmes et al. (2010) Research Methods for the Biosciences. OUP.
A more mathematical and statistically focused book, for those more mathematically minded.

Spiegelhalter, D. The Art of Statistics: Learning from data.
Accessible non-technical and entertaining introduction to statistical thinking.

Knell (2014) Introductory R
Good introductory R book – if you want to start with the basics start here. Good for revising basic R coding.
Ebook www.introductoryr.co.uk

Wickham & Grolemund (2016) R for Data Science
A good reference for some more advanced codes and data visualization
Free online at https://r4ds.had.co.nz/

Course Policies and Student Responsibilities

(1) General

You are expected to complete all assigned pre-class readings and activities, attend all classes punctually and take all scheduled assignments and quizzes by due dates. You are expected to take responsibility to follow up with course notes, assignments and course related announcements for classes you have missed. You are expected to participate in all class and tutorial discussions and activities.

(2) Absenteeism

Absence from class without a valid reason will affect your overall course grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies.
If you miss a lecture, you must inform the course instructor via email prior to the start of the class. A student who is absent from assessment without valid Leave of Absence
will be given zero mark for the missed assessment. Course lecturers may, however, use his/her own discretion for extenuating circumstances. Policy on medical leave for student may be found from
http://www.ntu.edu.sg/Students/Undergraduate/AdminServices/Pages/Applyforshortleave.aspx.

(3) Compulsory Assignments

You are required to submit compulsory assignments on due dates, unless a valid reason is provided. Valid reasons include falling sick supported by a medical certificate. If you will miss a deadline for a valid reason you must inform me via email (eleanor.slade@ntu.edu.sg) prior to the deadline, and as soon as is possible.

(4) Special Accommodations

All courses will have some form of assessment and if you envision that you will have difficulty satisfying an assessment component due to your disability then you are advised to contact the Course Coordinator within the first 2 weeks of the course.
Students requiring assistance in the learning environment should contact and notify the Associate Chair (Academic) in their School within the first 2 weeks of their first semester so that you and School can work together to optimise your learning experience. Examples of services that may be provided or supported in individual courses include an editor service to help those with reading and writing difficulties, and access to a personal mentor within the School. Please access the NTU Office of Academic Services' website
http://www.ntu.edu.sg/sasd/oas/Pages/

Academic Integrity

Good academic work depends on honesty and ethical behavior. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honor Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Diversity and Inclusivity Statement

The classroom is a place where you will be treated with respect, and I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability - and other visible and non-visible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class.

Course Instructors

Instructor	Office Location	Phone	Email
Eleanor Slade	N2-01C-66	65911611	Eleanor.slade@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course ILO	Readings/ Activities
1	Introduction: why you should care about experimental design Starting at the beginning: What is your question & hypothesis?	1,2,4,5,8	Introduction to why good experimental design is important and relationship between experimental design and statistics. Questions, hypotheses, and predictions. **Lecture & tutorial**
2	R refresher: Introduction and review of stats in R	1,2,3,4,6,8	Review of basic R programming functions and packages for stats. Importing data and manipulating data. R Markdown and graphics packages such as ggplot. **Lecture & computer tutorial**
3	Linear models	1,2,3,4,6,7,8	Simple linear model structures **Lecture & computer lab tutorial** **Assignment 1**
4	Experimental designs	1,2,3,4,5,7,8	Experimental vs observational studies. Field vs lab studies. Different types of data and sampling, and designs. *Discussion of projects.* **Lecture & tutorial**

5	Variation, randomization, replication and sampling	1,2,3,4,5,7,8	Variation, replicated experiments, blocking, and appropriate sampling designs. Pseudoreplication. **Lecture & tutorial**
6	Factorial designs, covariates sums of squares, interactions	1,2,3,4,6,7,8	Blocking, covariates, Sums of squares and interactions **Lecture & computer lab tutorial** **Assignment 2**
7	Mixed models & split-plot designs	1,2,3,4,5,6, 7,8	Linear mixed effects models - random vs fixed effects *Project discussions – exp design* **Lecture & tutorial**
8	Effect sizes	1,2,3,4,5,7,8	Inaccuracy vs imprecision. Statistical vs biological significance. Calculating effect sizes and error bars. **Lecture & tutorial**
9	Model selection: AICS vs P values	1,2,3,4,5,6,7, 8	Discussions on the information theoretic approach and AICs and when to use them. **Lecture & tutorial** **Assignment 3**
10	GLMS	1,2,3,4,6,7,8	Statistical tests for count, proportional, and binary data. **Lecture & computer lab tutorial** *Project discussions - analysis*
11	Multivariate analyses	1,2,3,4,6,7,8	Understand how to analyse community datasets, and account for environmental covariates. **Lecture & tutorial** **Assignment 4**
12	Statistical literacy	1,2,3,4,5,7,8	Visualizing data, interpreting outputs, and writing and presenting results. Pre-registering. Open science. Biases. **Lecture & Tutorial**
13	Projects	1,2,3,4,5,6,7, 8	**Project Presentation and wrap-up**

Appendix 1: Assessment Criteria for contributions during class time and tutorials

Standards	Criteria
A+ (Exceptional) A (Excellent)	Important contributions to class discussion, activities and online forum; uses discussion board to ask questions and respond to questions of other students; capacity to articulate and present points of view very clearly; participates in a meaningful and constructive manner including enabling other students to contribute and not dominating; evidence of having read and assimilated class material beyond the assigned reading; strong signs of evidence-based formation of points of view on the topics.
A- (Very good) B+ (Good)	Meaningful contributions to class discussion, activities and online forum; uses online forum to ask questions and respond to questions of other students; capacity to articulate and present points of view clearly; participates in a meaningful and constructive manner; evidence of having read and assimilated the class material; some signs of evidence-based formation of points of view on the topics.
B (Average) B- (Satisfactory) C+ (Marginally satisfactory)	Some contributions to class discussion, activities and online forum; uses online forum to ask questions; some evidence of constructive engagement during discussion; some familiarity with the assigned reading; some evidence of having thought about controversial topics.
C (Bordering unsatisfactory) D+ (Unsatisfactory)	Minimal contributions to class discussion or activities and online forum; limited capacity to articulate and present points of view; limited evidence of constructive engagement during discussion; little or no familiarity with the assigned reading.
D, F (Deeply unsatisfactory)	Very minimal or no contributions to class discussion, activities and online forum; no questions; no evidence of an individual viewpoint; failure to read the assigned reading; unexplained or unjustified absences from class.

Appendix 2: Assessment Criteria for quizzes

There will be 5 quizzes. These are designed to offer you the opportunity to revise and practice the topics learned in class and through the readings and tutorials. Quiz grading will be done accordingly to the table below.

A+	A	A-	B+	B	B-	C+	C	D+	D	F
100-85	84-80	79-75	74-70	69-65	64-60	59-55	54-50	49-45	44-40	39-0

Appendix 3: Assessment Criteria for computer tutorial assignments

Standards	Criteria
A+ (Exceptional) A (Excellent)	Takes an original approach to the questions; very well structured reports with good interpretations of results; evidence of excellent ability to apply knowledge taught in the course while thinking outside the box; provides clear, efficient, working and well-documented R code.
A- (Very good) B+ (Good)	Takes a conventional approach to the question; good interpretation of results; evidence of ability to apply knowledge taught in the course; provides clear, efficient, working and well-documented R code. Well structured report.
B (Average) B- (Satisfactory) C+ (Marginally satisfactory)	Takes a conventional approach to the question; limited interpretation of results; evidence of some (but not significant) ability to apply knowledge taught in the course; working but limited documentation of R code. Report lacking some structure.
C (Bordering unsatisfactory) D+ (Unsatisfactory)	Limited understanding of process; incorrect or miss-interpreted results; limited evidence of ability to apply knowledge taught in the course. Non-functional or limited R code documentation. Report not well structured.
D, F (Deeply unsatisfactory)	Inadequate in addressing the question; incorrect and/or miss-interpretation of results; lacks structure and focus, and is mostly or wholly off topic; inadequate capacity to apply knowledge taught in the course; non-functional R code. Unstructured report. OR failure to submit the report.

Appendix 4: Assessment Criteria for project report

Please note that teamwork is an important graduate outcome that we wish to inculcate in all students. Therefore, we expect everyone to meaningfully contribute to the project work. If there is any evidence that you are not contributing to your team's project, your individual score may be adjusted.

Standards	Criteria
A+ (Exceptional) A (Excellent)	- Clearly formulated hypotheses and predictions. - Appropriate and well justified experimental design. - Exceptionally well structured, concise report with excellent interpretation of results. - Shows clear understanding of the statistical tests used to analyse the data. - Excellent use of tables, and well-designed figures.

A- (Very good) B+ (Good)	- Clearly formulated hypotheses and predictions. - Appropriate and mostly well justified experimental design. - Well structured, concise report with good interpretation of results. - Shows mostly clear understanding of the statistical tests used to analyse the data. - Good use of tables, and well-designed figures.
B (Average) B- (Satisfactory) C+ (Marginally satisfactory)	- Adequately formulated hypotheses and predictions. - Adequately justified experimental design. - Report is adequately structured, fairly concise report with adequate interpretation of results. - Shows adequate understanding of the statistical tests used to analyse the data. - Adequate use of tables, and figures.
C (Bordering unsatisfactory) D+ (Unsatisfactory)	- Unclear hypotheses and predictions. - Limited justification of experimental design. - Some attempt at a structured report, but not concise and with limited interpretation of results. - Shows some understanding of the statistical tests used to analyse the data. - Some attempt at the use of tables, and figures.
D, F (Deeply unsatisfactory)	- Failure to formulate clear hypotheses and predictions. - No justification of experimental design. - No attempt at a well structured, or concise report with no or incorrect interpretation of results. - Shows no understanding of the statistical tests used to analyse the data. - Inadequate use of tables, and well-designed figures. OR failure to submit project report

Appendix 5: Assessment Criteria for presentation

Please note that teamwork is an important graduate outcome that we wish to inculcate in all students. Therefore, we expect everyone to meaningfully contribute to the presentation. If there is any evidence that you are not contributing to your team's presentation, your individual score may be adjusted.

Standards	**Criteria**
A+ (Exceptional) A (Excellent)	- Clearly formulated hypotheses and predictions. - Appropriate and well justified experimental design. - Shows clear understanding of the statistical tests used to analyse the data. - Excellent use of tables, and well-designed figures. - Exceptionally prepared presentation, well structured, and keeps to time. - Excellent teamwork evident. - Delivery is clear, articulate and concise. - Any questions are answered knowledgably. - Students asks thoughtful questions to the other presenters, showing understanding and engagement with the rest of the class.

A- (Very good) B+ (Good)	- Clearly formulated hypotheses and predictions. - Appropriate and mostly well justified experimental design. - Shows mostly clear understanding of the statistical tests used to analyse the data. - Good use of tables, and well-designed figures. - Well prepared for the presentation, adequate structure and timing. - Good teamwork evident. - Delivery is clear, articulate and concise. - Any questions are answered correctly. - Students asks questions to the other presenters, showing understanding and engagement with the rest of the class.
B (Average) B- (Satisfactory) C+ (Marginally satisfactory)	- Adequately formulated hypotheses and predictions. - Adequately justified experimental design. - Shows adequate understanding of the statistical tests used to analyse the data. - Adequate use of tables, and figures. - Shows some preparation for the presentation, adequate structure, and timing. - Adequate teamwork evident. - Delivery is adequately clear, articulate and concise. - Any questions are answered correctly. - Students ask 1 or 2 questions to the other presenters, showing engagement with some of the class
C (Bordering unsatisfactory) D+ (Unsatisfactory)	- Unclear hypotheses and predictions. - Limited justification of experimental design. - Shows some understanding of the statistical tests used to analyse the data. - Some attempt at the use of tables, and figures. - Shows marginal preparation for the presentation, marginal structure, and timing. - Evidence of teamwork minimal. - Delivery is marginally clear, articulate and concise. - Any questions are answered mostly correctly. - Students ask no questions to the other presenters.
D, F (Deeply unsatisfactory)	- Failure to formulate clear hypotheses and predictions. - No justification of experimental design. - Shows no understanding of the statistical tests used to analyse the data. - Inadequate use of tables, and well-designed figures. - Shows no preparation for the presentation, no structure and does not keep to time. - No teamwork evident. - Delivery is not clear, articulate and concise. - Any questions are answered incorrectly. - Students ask no questions to the other presenters and show obvious lack of engagement. OR failure to give presentation.

GRADES

A+	A	A-	B+	B	B-	C+	C	D+	D	F
100-85	84-80	79-75	74-70	69-65	64-60	59-55	54-50	49-45	44-40	39-0