Imperial College
London

Masters in Computational Methods in Ecology and Evolution

Programme Handbook

2014 – 2015

Department of Biological Sciences, Imperial College London, Silwood Park Campus, Ascot, Berkshire, SL5 7PY, UK

Contents

1 Course Overview

Welcome to the Masters programmes in Computational Methods in Ecology and Evolution (CMEE) at Silwood Park!

The frontiers of biology are increasingly at the interface between mathematics, computing, and large data sets. Answering important problems about issues ranging from disease dynamics and epidemiology to the effects of climate climate and over-fishing on aquatic ecosystems, require computational approaches for management & analysis of "big data", theoretical modelling, and fitting the models to data. Indeed, biology is *the* new frontier for applied computer science and mathematics. As Donald Knuth, an eminent mathematician and computer scientist has said: "*It is hard for me to say confidently that, after fifty more years of explosive growth of computer science, there will still be a lot of fascinating unsolved problems at peoples' fingertips, that it won't be pretty much working on refinements of well-explored things. Maybe all of the simple stuff and the really great stuff has been discovered. It may not be true, but I can't predict an unending growth. I can't be as confident about computer science as I can about biology. Biology easily has 500 years of exciting problems to work on, it's at that level.*"

Msc and MRes CMEE aim to teach computational approaches towards the empirical and theoretical study of ecological and evolutionary systems. We focus on Computational *Ecology and Evolutionary Biology* in particular because some of the most complex and important dynamics in human-dominated as well as natural environments arise from ecological and evolutionary processes. Therefore, computational skills needed to analyse data and model ecological and evolutionary systems are very relevant to other disciplines. For example, it is now generally recognized that a major new frontier in understanding disease dynamics and epidemiology is the need to consider the *Ecology* of infectious diseases. Furthermore, ecological and evolutionary models and computational tools are also relevant for non-biological disciplines — for example, ecosystem models are increasingly being relevant for understanding microeconomic systems.

Both courses run for one year commencing the first week in October through to the end of September. The first eight weeks of the first term is shared between both courses and includes a combination of lectures, workshops and practicals to cover a range of fundamental skills. The MRes option then focuses on a substantial research project for the second and third terms whilst the MSc option continues with more advanced taught modules followed by a shorter project. Switching between the courses is straightforward during the initial part of the first term, and possible at later stages. MRes students are welcome to choose further MSc lectures that are relevant to their research project.

Research projects are undertaken from the 9th week of the course (MRes) or from the 25th week (MSc). See timetables (section 2.2).

Daily lectures and practicals, unless otherwise stated, commence at 10:00 and would normally finish by 1700, incorporating breaks. Additional independent work is also required. On Wednesday the afternoon is normally, but not always, reserved for private study, sports and leisure activities for MSc CMEE students.

In addition to the formal taught and research components of the programme, there are two research seminar series that run at Silwood Park. The first series (running on Mondays 1pm) are internal departmental seminars, presenting research by Imperial PhD students and research staff. The second series (running every other Thursday at 1pm) are external research seminars presented by visiting academics.

Teaching materials and other course materials will be provided using the online Blackboard virtual

learning environment http://vle.imperial.ac.uk, and/or for certain modules, using a git version control repository to provide code and data files. Paper copies of lecture notes and handouts are not normally provided but you will receive printing credit for use during the course on your security card.

It is anticipated that reading and coursework will require additional study in your own time. During research projects, you are expected to work full time on the project, but with flexible hours, and in general, students who work extra hours do get more out of the course. Some projects may require out-of-hours work, for example maintaining greenhouse experiments.

The full programme specifications for the MSc and MRes are available on Blackboard and from the course websites below, but the following sections provide a summary of the programme and assessment structure for the two courses. Aims, objective and learning outcomes for the course are in section 1.

MSc website
http://www3.imperial.ac.uk/lifesciences/postgraduate/courselist/msc-cmee

MRes CMEE website
http://www3.imperial.ac.uk/lifesciences/postgraduate/courselist/mres-cmee

A student handbook containing general guidelines for living, working, and studying at Silwood Park and Imperial College is available from the course websites above, on Blackboard, and can also be obtained by emailing the Course Administrator Mrs. Amanda Ellis (*amanda.ellis@imperial.ac.uk*).

1.1 Course Administration

MSc & MRes CMEE Course Director	Dr. Samraat Pawar (ext. 42213, s.pawar@imperial.ac.uk)
MSc & MRes CMEE Course Co-Director	Dr. James Rosindell (ext. 42242, j.rosindell@imperial.ac.uk)
Postgraduate Administrator	Mrs. Amanda Ellis (ext. 42251, amanda.ellis@imperial.ac.uk)
Course Tutor	Mr. Tin-Yu Hui & Mr. Dimitrios (Dimitris) Kontopoulos (d.kontopoulos13@imperial.ac.uk)
Course Representative	Up to you (see note below)!

(Add 020 759 to extension numbers to call from external phones)

Each Masters course has one or more Course Representatives to represent the student body at Student-Staff meetings and act as a first point of contact if and when issues arise that need to be discussed with the Course Directors. MSc CMEE and MRes CMEE will each have one Representative. The student union will email you about an electronic election for the Reps.

1.2 Course Aims

Both MSc and MRes CMEE aim to:

- Provide training in key biological, statistical, computational, and mathematical topics and how they are integrated.

- Provide students with a background to computational biology with particular focus on theoretical and empirical approaches towards the study of ecological and evolutionary systems.
- Teach state-of-art, scientific computing techniques for the management and analyses of big data ad simulation as well as mathematical modelling.
- Provide a thorough understanding of a range of modern techniques in bioinformatics, genomics and ecoinformatics.
- To show how these principles and skills can be applied to solve real world problems and make an informed choice of research topic.
- To prepare for PhD studies and other appropriate career paths in industry or NGOs focusing on any combinations of biology, maths and computing skills.

The main rationale for having an MSc as well as MRes CMEE is to give students the choice to find a right balance between learning technical skills and learning research skills. With this flexibility, students can choose to tailor a course and a project that best suits their personal interests and future plans.

1.3 Learning outcomes

Students will develop:

- Competence in computational methods required to address a range of topical real-world questions in a range of ecological and evolutionary topics, including population biology, population genetics, genomics, and complex systems
- An ability to choose an appropriate quantitative method, in possibly including statistical and mechanistic mathematical modelling, for answering a particular biological question
- An ability to develop, analyse, and numerically simulate theoretical models for ecological and evolutionary systems and fit empirical data to these models

1.4 Transferable Skills

A central objective of the CMEE Masters' is to prepare students for PhD studies and/or a career in computational biology by teaching a suite of transferable skills, be it within academic institutions, government, or industry, by developing a professional approach towards developing and delivering high-quality science along with qualitative, critical thinking and problem solving skills. Students will learn a unique set of transferrable skills in computation relevant not just to biology but also other fields that involve large datasets and complex dynamics and patterns, such as economics, medicine, or sociology. Students will be able to:

- apply computational, statistical and modelling skills;
- communicate effectively through oral presentations, written reports and scientific publications;
- management skills: decision making, problem definition, project design and evaluation, risk management, teamwork and coordination;
- integrate and evaluate information from a variety of sources;
- transfer techniques and solutions from one discipline to another;
- use Information and Communications Technology;
- manage resources and time;
- learn independently with open-mindedness and critical enquiry;
- learn effectively for the purpose of continuing professional development;

- depending upon choice of taught modules and research project, learn lab and field techniques.

The course objectives will be achieved by providing:

- A course of lectures, seminars and practicals within distinct modules, linked to cutting edge academic research and research groups in Silwood Park and collaborator institutions elsewhere. Both MSc and MRes students will attend the first 8 weeks of modules where they will learn fundamental concepts and techniques in computational biology, with particular focus on ecological and evolutionary theory, data, and systems.
- Hands-on experience of a wide repertoire of methods and techniques involved in the application of computational techniques to ecological and evolutionary systems.
- A research project (~9 months for MRes, ~5 months for MSc) based upon theoretical/analytical work, possibly including field and/or laboratory study, on an advanced and original topic from systems biology, ecology, evolution, conservation or another biological field, supervised by academics from either biological, computational or mathematical combinations of these in Silwood Park or elsewhere.
- Strategically timed workshops on publishing scientific manuscripts, selecting a research project, and selecting Job/PhD opportunities and applying to them.

1.5 Course activities and assessment overview

1.5.1 Course structure

Activity	MSc CMEE	MRes CMEE
Lectures + practicals, with assessment	Required for first 17 weeks	Required for first 8 weeks, optional attendance in MSc modules within reason thereafter
Coursework exams	Required	Not required
Project report (Dissertation)	Required	Required
Seminars	Required, seminar diary required for a minimum 16 weeks	Required, seminar diary required for a minimum 16 weeks
Workshops	All optional	All optional

1.5.2 Assessment Overview

Component	MSc CMEE	MRes CMEE
Coursework from taught component	25%	25%
Exams (two)	25% (10 + 15%)	NA
Mid-year oral presentation & Viva	5%	5%
Mid-project report	NA	10%
Thesis report	25%	40%
Final oral presentation	10%	10%
Viva	10%	10%

1.5.3 MSc CMEE

MSc CMEE students will attend 17 weeks of taught modules over the Autumn and Spring Terms followed by a 5 month research project leading to a dissertation (thesis report). There are three main components to the course assessment:

i) *The coursework*: 25% of final mark, made up a number of components and modules, assessed by weekly problem sets and practical submissions as well as a seminar diary (see below)

ii) *Two examinations*: 25% of final mark. January exam covers Autumn material (10%), April exam (15%), mainly covers Spring term material, but assumes knowledge of previous material

iii) *The research project*: 45% of final mark, including mid-year presentation + oral presentation + final viva + thesis

1.5.4 MRes CMEE

MREs CMEE students will attend eight weeks of taught modules over the Autumn Term followed by a 9 month research project leading to a dissertation (thesis report). There are two main components to the course assessment:

i) *The coursework*: 25% of final mark, made up a number of components and modules, assessed by weekly problem sets and practical submissions as well as a seminar diary (see below)

ii) *The research project*: 75% of final mark, including mid-project viva + Mid-project report + oral presentation + final viva + thesis report

1.6 External vivas and examiners

All students on both the MSc and MRes programme will undertake a final 30 minute viva with one of the External Examiners, to be held between the internal summer project viva and the final meeting of the Board of Examiners. The dates are shown above and these vivas form a part of both the exam moderation process and oversight of the course by the External Examiners. The current External Examiners are:

Prof. Rob Freckleton	University of Sheffield
Prof. Andrew Leitch	Queen Mary University of London

1.7 Weekly Seminars and Seminar Diary

Two weekly seminars take place most weeks, usually on Monday and Thursday at 1pm in the Hamilton Building. Both MSc and MREs students must attend all the Thursday seminars unless told otherwise, even if one is rescheduled to a day other than Thursday. You will write a half-page on at least 16 of these seminars and create a "seminar journal" for submission as part of their coursework mark (see section on the Coursework Element).

Monday seminars are internal, informal, and intended for work in progress. Attendance is optional. However, they are a good way to practice critical thinking about research, since that is explicitly what the seminar speakers are hoping to get from the audience. Once you start your research project you are not only welcome to give one of these seminars, but also encouraged. It may be sensible to split the time of a one-hour seminar with another MSc/MRes student, effectively diving two shorter seminars. You can get very good feedback from the community on your project by doing this. Sign-ups are online.

The seminar links are http://www3.imperial.ac.uk/silwoodparkcampus/research/thursdayseminars and http://www3.imperial.ac.uk/silwoodparkcampus/research/mondayseminars

The Seminar diary is due at the end of the Spring term, the week before your final (project) dissertation submission.

1.8 Workshops

We will organize a series of general skills workshops on certain Wednesday afternoons (see the timetable in section 2.2), such as those involved in choosing a project, writing skills, choosing and applying for PhD places, etc.

In addition, in terms 2 and 3 workshops will be organized by you, geared more towards research techniques and topics, especially those in rapidly-changing fields. The focal research techniques will depend on you and the projects you choose, the interests you develop, and anything you all want to learn about. Through term 2 and 3 workshops, you will learn how to engage and discuss with your peers (classmates) to prioritize topics for workshops, and to invite speakers when necessary. In most cases, we expect that you will find personnel with the necessary skills right on campus, but you can invite people from outside when needed (please discuss with the Course Directors and Administrator when the time comes).

1.9 Summer school on Frontiers in Ecology and Evolution

This two to three-day summer school, practically an extended workshop, will be organized by the MRes CMEE students, with optional participation, in terms of organization and attendance, by the MSc CMEE students. The reason for this is that the MSc's have limited time for their research projects, and the period of the workshop will likely be a particularly crucial phase in their research.

The CMEE Summer School will provide a relaxed set-up to discuss challenges in Ecological and Evolutionary research. It will also be a valuable opportunity to develop your organisational skills, from selecting, inviting and hosting speakers to dealing with the logistics of catering. A few external invitees will run forums on current 'hot' topics, such as ecological and evolutionary responses to climate change, deforestation and the global carbon cycle, responses of food webs and plant-pollinator networks to climatic warming, etc.

You may want to consider hosting the the School in a venue outside Silwood Park, if the logistics in terms of time and money will allow it. Please discuss with your Course Directors and Administrator around the beginning of the Spring term. Possibilities for external venues include Imperial College's Mountain Hut located within the Snowdonia National Park between Porthmadog and Caernarfon (approx. three miles from the western base of Snowdon) and the Royal Society's Kavli International Centre (Chicheley Hall) near Milton Keynes.

1.10 Graduation

The postgraduate graduation ceremony for MSc and MRes students will be held in the Royal Albert Hall in South Kensington, London at the start of the following May. The exact dates are available at http://www3.imperial.ac.uk/graduation/graduationtimetable

1.11 Submission of work and penalties for late submission

Project reports and written coursework must be handed in as PDF documents. The method of submission will be announced in class, but will typically involve submission to a version-control (e.g., bitbucket) repository and/or to Blackboard. The final report will additionally have to be emailed to the Postgraduate Administrator by the deadline. In real life, research reports, grant proposals and other outputs that are submitted late or that do not conform to instructions (e.g. word limits) would not be considered. Therefore, we will dock marks for late projects, using a standard penalty of 5% per day, and for written work not conforming to the stated requirements.

1.12 Teaching facilities

The majority of teaching will take place in the Hamilton building and in these locations. The locations of all teaching activities are given in the timetables below.

1.12.1 Lectures

Most lectures will be held in the Hamilton lecture room on the ground floor of the Hamilton Building.

1.12.2 Lab work

The Field Laboratory is on the ground floor of the Hamilton building directly opposite the main entrance.

1.12.3 Computing facilities and support

There are three levels of computing solutions available to students.

At the lowest and most immediately available level are student laptops, issued to students in the Autumn (and returned in September at the end of the course). A 64 bit Linux operating system (most likely Ubuntu 12.04) will be available on the laptops (that's all you should need for the course). Necessary software will be installed and more can be installed by the students as and when needed. Part of being a good quantitative biologist is achieving a level of mastery of your computer and the software on it these are your main tools. Much more information will be provided on using your computer in many ways, but you should also take it upon yourself to develop expertise in this area beyond what is taught. In addition, the Hamilton Computer Room is on the first floor of the Hamilton Building and provides 44 desktop computers, charging and network points for laptops and printing

facilities. Certain computer practicals will be held in the Hamilton Computer Room. Food and drink – other than drinks in sealed sports drink bottles – are not permitted in the computer room and you must abide by the College's Conditions of Use for IT Services, details of which are here: http://www3.imperial.ac.uk/ict/newusers

At the intermediate level are two local, multi-core linux machines in the Reuman lab, called William and Harvey. These make it relatively easy to learn to run large-ish parallel jobs. If you want access, please ask Samraat Pawar. You would be able to log onto one of them remotely and run single-core or multi-core simulations, statistical fitting, and other computing jobs, with few rules or constraints except for a few guidelines to be followed out of respect for other users. William has 16 cores and Harvey has 12. They each have around 50Gb memory.

At the highest level is the Imperial College High Performance Computing (HPC) Cluster, which puts over 10,000 cores at the disposal of the researcher. For most purposes in quantitative biology this is essentially infinite computing power, if you learn to harness it. You will be taught how to harness it during the Advanced Computing in Biology module.

ICT Computer support is available in Room 1.12 Hamilton Building (on the 1st floor) from 12.30 to 13.30 Mondays to Fridays during term. Online support is also available: https://imperial.service-now.com/ict/

1.12.4 Library facilities

The Michael Way Library at Silwood Park is on the first floor of the Hamilton Building. It maintain a specialised collection of books ranging from entomology, conservation, ecology, evolution and pest management to mathematical and computational biology, and holds a collection of textbooks for the Masters courses at Silwood: http://www3.imperial.ac.uk/library/usethelibrary/silwood

While many academic journals are available across the College as electronic journals, the Imperial College Library facilities in South Kensington also houses a wide collection of scientific literature, which may be requested through the Michael Way Library. The full range of library services and e-journals available are described at http://www3.imperial.ac.uk/library and http://www3.imperial.ac.uk/library/find/ejournals

1.12.5 Study guides

The College provides a booklet to help with Master's level study. The booklet contains advice, lessons and tips to help you to enhance your learning skills and get the very best from your degree. The booklet explain what you can expect from your study at Imperial, and will provide sources of support and guidance. You should receive a copy of the guide at the start of your course, but you can also download a copy from http://www3.imperial.ac.uk/students/studyguide

1.13 Prizes and Awards

1.13.1 William Harvey Prize for the best student, MSc CMEE

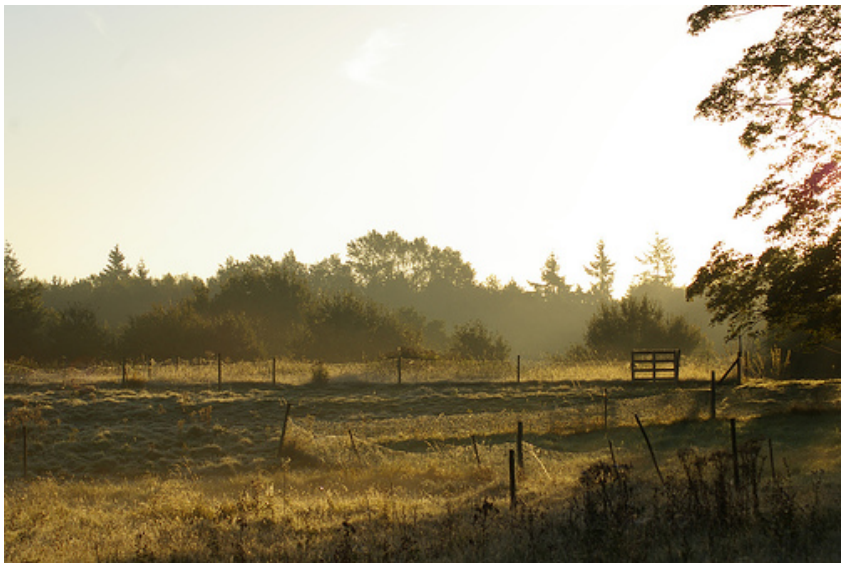
The student with the highest final mark in MSc CMEE will be awarded the William Harvey Prize, which comes with a small cash award, but more importantly is an honour for a job very well done in

a difficult course.

William Harvey (1578–1657) provided a very early and very compelling example of combined quantitative and biological reasoning, leading to the first proof that blood circulates in the human body, and capillaries must exist connecting the arteries and veins in the circulatory system. Before the invention of the microscope, scientists were aware of arteries and veins but could not see the connections between them (capillaries), and so assumed they were not connected. They knew the heart was a pump, and dominant theories were that blood ebbed and flowed, back and forth like the tides in the arteries and veins, and that blood went out from the heart, was absorbed by the body, was regenerated in the liver which was thought to feed the veins, and the new blood flowed back to the heart. Harvey used biological reasoning, by observing that veins have valves, so blood can only flow through veins toward the heart, showing that the ebb-and-flow theory cannot be correct. Harvey used quantitative reasoning, by calculating the volume of the ventricles of the heart (about 1.5 imperial ounces) and the fraction of blood expelled from the ventricles on each heartbeat (about $/frac18$), and thereby calculating that if your heart beats 1000 times every half hour, the liver would have to produce 540 pounds of blood in a day for the dominant theory to be correct. He then developed the hypothesis of capillaries and blood circulation, later confirmed by Harveys experimental work and by the invention of the microscope.

1.13.2 The Illumina Prize for the best project, MRes CMEE

A £1000 cash prize sponsored by Illumina will be awarded by the external examiners to the best project in the BIG course. Illumina is a global company that develops innovative array-based solutions for DNA, RNA, and protein analysis; they are also some of the world-leaders in Ne t Generation DNA sequencing Technologies (www.Illumina.com).



2 Course details, timetables, and module descriptions

2.1 Teaching Staff

Dr Koenraad Audenaert, Royal Holloway University of London	Mathematics, Quantum Dynamics and Information Theory (*01784 276272, Koenraad.Audenaert@rhul.ac.uk*)
Prof Tim Barraclough	Evolution of species diversity; speciation; asexual evolution; evolution in multi-species systems; experimental evolution. (*ext. 42247, t.barraclough@imperial.ac.uk*)
Prof Austin Burt	Evolutionary biology of selfish genetic elements; homing endonuclease genes and their applied uses. Population and evolutionary genetics of yeasts. (*ext. 42266, a.burt@imperial.ac.uk*)
Mr Tin-Yu Hui	Statistical genetics (*tin-yu.hui11@imperial.ac.uk*)
Prof Vincent Jansen, Royal Holloway University of London	Mathematical biology (*01784 443179, Vincent.Jansen@rhul.ac.uk*)
Dr Igor Lysenko	Geographical Information Systems; Spatial analysis (*ext. 42211, i.lysenko@imperial.ac.uk*)
Dr David Orme	Global biodiversity patterns; GIS; conservation and climate change biology (*ext. 42352, d.orme@imperial.ac.uk*)
Dr Samraat Pawar	Theoretical Ecology; Ecological Systems Biology; Ecological Networks; Ecoinformatics; Metabolic theory and physiological ecology. (*ext. 42213, s.pawar@imperial.ac.uk*)
Dr James Rosindell	Theoretical Ecology; Biodiversity theory; Island biogeography; Ecological neutral theory; Scientific data visualisation. (*ext. 42242, j.rosindell@imperial.ac.uk*)
Prof Vincent Savolainen	Molecular phylogenetics; Population genetics and genomics; Origins of biodiversity. (*ext. 42374, v.savolainen@imperial.ac.uk*)

2.2 Outline timetable and important dates

Week	Dates	MSc CMEE	MRes CMEE
		Autumn term	
1	6 Oct	Induction	Induction
1	7–10 Oct	Foundations of Computing	Foundations of Computing
2	13–17 Oct	Biological Computing in Python I	Biological Computing in Python I
3	20–24 Oct	Spatial Analyses and GIS	Spatial Analyses and GIS
4	27–31 Oct	Introduction to R and Statistics	Introduction to R and Statistics
5	3–7 Nov	Biological Computing in R	Biological Computing in R
6	10–14 Nov	Biological Computing in Python II	Biological Computing in Python II
7	17–21 Nov	High Performance Computing	High Performance Computing
8	24–28 Nov	Genomics and Bioinformatics	Genomics and Bioinformatics
9	1–5 Dec	Mathematics Primer I	Project and Workshops
10	8–12 Dec	Mathematics Primer II	
11	15–19 Dec	Reading	

		Spring term	
15	12–16 Jan	Exam 1	Project and Workshops
16	19–23 Jan	Mathematics Primer III	
17	26–30 Jan	Dynamical Models in Ecology	
18	2–6 Feb	Models in Population Genetics and Genomics	
19	9–13 Feb	Maximum Likelihood Statistics and Model Fitting	
20	16–21 Feb	Introduction to Bayesian Statistics	
21	23–27 Feb	Networks and Complex Systems in Ecology and Evolution	
22	2–6 Mar	Advanced Topics in Ecology and Evolution	
23	9–13 Mar	Reading	
24	16–20 Mar	Reading	
25	23–27 Mar	Exam 2	
26	30 Mar–3 Apr	Project and Workshops	
For later weeks and other dates see below			

Other important dates and deadlines:

Date	**Activity**
1 December	MRes: Two-page project proposal submission
18 March	MSc: Two-page project proposal submission
27 April, 1pm	MRes: Mid-project report
29 April	MSc, MRes: Presentations
29 April	MRes: Mid-project viva (following presentation)
Week 1 or 2 of August	MRes (optional for MSc): CMEE Summer School
1 Sep, 5pm	MSc, MRes: Seminar Diary Submission
9 Sep, 1pm	MSc, MRes: Final project submission
17 Sept	MSc, MRes: Final project presentations
18 Sept	MRes, MSc: Vivas (with External Examiners)

Workshops:

Date & Time	**Workshop**
Wednesday 8th October 2014, 15:30 – 16:30	*MasterClass: Stress Management* (Haldane lecture Theatre, TBD)
Thursday 9th October, 14:30 – 16:30	*Choosing and designing a research project* (Wallace room, Samraat Pawar)
Wednesday 15th October, 15:00 – 16:30	*Masterclass Workshop: Academic Writing Skills* (Haldane Room, Dr. Helal Ahmed)
Wednesday 15th October, 16:45 – 17:45	*Masterclass Workshop: Informational Posters* (Haldane Room, Dr. Helal Ahmed)

Wednesday 12th November, 14:30 – 18:00	*Workshop: Applying for PhD / Academic Jobs / Industry Jobs (CVs, Interviews, etc.)* (Haldane room, Various)
Wednesday 11th March 2015, 14:30 – 16:30	*MasterClass: Preparing & Writing a Literature Review* (Haldane lecture Theatre, Helal Ahmed)

2.3 Taught Module Descriptions

All teaching activities are typically scheduled from 10.00am until 5.00pm, except Wednesday afternoon. Also, please note that all the recommended readings and resources in the following module descriptions are available in Central or Silwood Libraries, and often also as e-books.

2.3.1 Course Induction and Foundations of Computing

Week: 1 (*Monday 6th October – Friday 10th October*)

Convenor: Samraat Pawar

This module focuses on the fundamentals of scientific computing, including an introduction to Unix and Linux, writing handsome documents using LaTeX, and version control. Along with technical training, we will introduce you to the philosophy of the course, and have a workshop on choosing research questions and projects. The week begins with a number of important induction events.

All lectures and practicals will be in Wallace unless indicated otherwise, and will be laptop-based.

Timetable:

Monday 6th October	
09:00 – 10:00	*Welcome to Silwood Park* (Introduction, Fisher, David Orme)
10:00 – 11:00	*Computer and key issue, meet each other* (Wallace room)
11:00 – 13:00	*Silwood treasure hunt* (Introduction, Silwood Park, David Orme)
13:00 – 14:00	*Buffet lunch* (Introduction, Hamilton Foyer)
14:00 – 16:00	*The Big Picture* (Discussion, Hamilton Foyer, EJ Milner-Gulland)
Tuesday 7th October	
10:00 – 11:00	*Introduction to CMEE* (Wallace room, Samraat Pawar and James Rosindell)
11:30 – 12:30	*Computer setup* (Wallace room, Samraat Pawar)
13:30 – 16:30	*Intro to Unix and Linux* (Wallace room, Samraat Pawar)
17:00 – 20:00	*Welcome Reception* (Introduction in commons room on floor 1 of CPB building) Introduction to student activities and people running them + nibbles and drinks. Prizes for the treasure hunt will be presented. Staff and students will attend to meet the new students.
Wednesday 8th October	
10:00 – 11:00	*How to get addicted to the terminal and shell scripting* (Lecture, Wallace room, Samraat Pawar)
11:30 – 12:30	*Version control with Git* (Lecture, Wallace room, Samraat Pawar)
14:00 – 15:30	*Introduction to library services* (Introduction, Hamilton Computer Room, Elizabeth Killeen)

15:30 – 17:00	*MasterClass Workshop: Stress Management* (Haldane lecture Theatre, TBD)
Thursday 9th October	
10:00 – 11:00	*Scientific typesetting using LaTeX* (Lecture, Wallace room, Samraat Pawar)
11:30 – 12:30	*LaTeXcontinued* (Lecture, Wallace room, Samraat Pawar)
13:30 – 14:30	*LaTeXcontinued* (Lecture, Wallace room, Samraat Pawar)
14:30 – 16:30	*Workshop: Choosing and designing a research project* (Wallace room, Samraat Pawar)
Friday 10th October	
10:00 – 11:00	*Provost's Welcome* (Introduction, Haldane, Prof. James Stirling)
14:15 – 15:15	*Safety induction* (Introduction, Fisher, Stefan Hoyle)
15:30 – 16:30	*Project introductions* (Introduction, Fisher, David Orme)

Readings and Resources:

- There are LOTS OF UNIX tutorials out there. I really like the lectures you can find on http://software-carpentry.org (Chapter "shell"). Either watch the video tutorials or read the pdfs of the presentations.
- The Imperial COllege library provides you with access to several e-books on UNIX, some specific to Mac OSX or Ubuntu, and some more general. Go through the http://www3.imperial.ac.uk/library website.
- An extensive list of UNIX commands can be found here (along with their man page): www.oreillynet.com/linux/cmd/.
- http://git-scm.com/book hosts a wonderful book on git. There are several tutorials on the internet. I really like the approach taken by http://www.sbf5.com/~cduan/technical/git/ and https://www.atlassian.com/git/
- (Health?) benefits of using latex: http://www.andy-roberts.net/writing/latex/benefits
- Word vs. LaTeX: http://openwetware.org/wiki/Word_vs._LaTeX
- Leslie Lamport, LaTeX: A document preparation system, users guide and reference manual, 1994, Addison-Wesley.
- Also see also myriad online resources for LaTeX, including www.http://en.wikibooks.org/wiki/LaTeX/Introduction, www.ctan.org/tex-archive/info/lshort/english/, and http://ftp.uni-erlangen.de/mirrors/CTAN/info/lshort/english/lshort.pdf
- Bibliographies in LaTeX: www.lecb.ncifcrf.gov/~{}toms/latex.html

2.3.2 Biological Computing in Python I

Week: 2 (*Monday 13th October – Friday 17th October*)

Convenor: Samraat Pawar

This is the first of a two-week module on biological computing in the Python language. With the profusion of genomic, environmental and ecological information, the ability to develop automated, reproducible analyses of massive datasets using computer scripts and programs is an essential skill for any aspiring research student. The aim of this module is to introduce the basics of programming using Python, which is a modern, easy-to-write, interpreted (semi-compiled) language that was conceived

with readability of script in mind. It has a feature-rich set of packages that can be used for a wide variety of applications and analyses. The approach will be hands-on and informal, involving lectures interspersed with short exercises in class. There will be longer exercises during the last two hours at the end of each day. The last two days of this first week will mostly be dedicated to practicals in which you will choose (from two or three different options) and work on projects where you will develop a reproducible workflow and use Python to test ecological or evolutionary hypotheses.

Aims: To learn basic principles of computer program design using Python. Learn to write simple functions and programs in Python. Understand of the basics of Python program testing, debugging and documentation. Learn to run analyses by patching together R or R+Python scripts and functions. Learn to use Python for retrieving, managing, and analyzing data from local and remote databases. Learn to automate file handling, string manipulation, and run shell scripts. Learn to use Python for efficient numerical analyses.

All lectures and practicals will be in Wallace room in the Hamilton Building, and will be laptop-based.

Timetable:

Monday 13th October	
10:00 – 11:00	*Why write computer programs?* (Lectures + Exercises, Wallace room, Samraat Pawar)
11:30 – 12:30	*OK, but why program in Python?* (Lectures + Exercises, Wallace room, Samraat Pawar)
14:00 – 17:00	*Programming in Python - basics* (Lectures + Short Practicals, Wallace room, Samraat Pawar)
Tuesday 14th October	
10:00 – 11:00	*Python basics continued* (Lectures + Exercises, Wallace room, Samraat Pawar)
11:30 – 12:30	*Python basics continued* (Lectures + Exercises, Wallace room, Samraat Pawar)
14:00 – 17:00	*Python basics continued* (Lectures + Short Practicals, Wallace room, Samraat Pawar)
Wednesday 15th October	
10:00 – 11:00	*Writing Python Code* (Wallace room, Samraat Pawar)
11:30 – 12:30	*Writing Python Code* (Lectures + Exercises, Wallace room, Samraat Pawar)
15:00 – 16:30	*Masterclass Workshop: Academic Writing Skills* (Haldane Room, Dr. Helal Ahmed)
16:45 – 17:45	*Masterclass Workshop: Informational Posters* (Haldane Room, Dr. Helal Ahmed)
Thursday 16th October	
10:00 – 11:00	*Writing and testing Python functions* (Wallace room, Samraat Pawar)
11:30 – 12:30	*Writing and testing Python functions* (Lectures + Exercises, Wallace room, Samraat Pawar)
14:00 – 17:00	*Writing and testing Python functions* (Lectures + Practicals, Wallace room, Samraat Pawar)
Friday 17th October)	
10:00 – 11:00	*Writing and testing Python functions* (Wallace room, Samraat Pawar)
11:30 – 12:30	*Writing and testing Python functions* (Lectures + Exercises, Wallace room, Samraat Pawar)
14:00 – 17:00	*Writing and testing Python functions* (Lectures + Practicals, Wallace room, Samraat Pawar)

Readings and Resources:

- Browse the Python tutorial: www.docs.Python.org/tutorial/
- For functions and modules: www.learnPythonthehardway.org/book/ex40.html
- For IPython: http://iPython.org/documentation.html and https://github.com/iPython/iPython/wiki?path=Cookbook

2.3.3 Spatial Analyses and GIS

Week: 3 (*Monday 20th October – Friday 24th October*)

Convenor: David Orme and Igor Lysenko

This week will teach key skills in using and handling GIS data, along with the application of GIS data in species distribution modelling. This week is shared with MSc/MRes EEC. Please bring laptops to all computer room sessions and use them instead of the desktops, which are for EEC.

Timetable:

Monday 20th October	
09:30 – 10:30	*Introduction to GIS* (Lecture, Fisher, David Orme) The main concepts and data types underlying Geographic Information Systems.
10:30 – 13:00	*Raster data* (Computer Practical, Hamilton Computer Room, David Orme, Igor Lysenko) Handling raster data
14:00 – 17:00	*Vector data* (Computer Practical, Hamilton Computer Room, David Orme, Igor Lysenko) Creating and using vector data
Tuesday 21st October	
10:00 – 13:00	*GIS tools* (Computer Practical, Hamilton Computer Room, David Orme, Igor Lysenko) Using GIS commands
14:00 – 15:00	*Data interoperability* (Lecture, Fisher, Igor Lysenko) Sources, format and interoperability
Wednesday 22nd October	
10:00 – 13:00	*Manipulating and integrating data sources* (Computer Practical, Hamilton Computer Room, David Orme, Igor Lysenko) Data acquisition, format conversion and exchange
Thursday 23rd October	
10:00 – 11:00	*Spatial Analysis* (Lecture, Fisher, Igor Lysenko) Great opportunities gaps and traps
11:30 – 12:30	*Spatial dimensions* (Lecture, Fisher, Igor Lysenko) Spatial overlays and data extraction
14:00 – 17:00	*Spatial overlays* (Computer Practical, Hamilton Computer Room, David Orme, Igor Lysenko)
Friday 24th October	
10:00 – 11:00	*What not to do with GIS* (Lecture, Fisher, Igor Lysenko) Pitfalls and time sinks.
11:30 – 12:30	*Applied GIS: Species Distribution modelling* (Lecture, Fisher, Sarah Whitmee) Using environmental niche models to predict the potential distribution of species.
14:00 – 17:00	*MAXENT Practical* (Computer Practical, Hamilton Computer Room, Sarah Whitmee) Practical introduction to using MAXENT for niche distribution models.

Readings and Resources:

- Coordinate systems: Van Sickle, G (2010) Basic GIS coordinates. CRC Press Ebook: http://www.dawsonera.com/depp/reader/protected/external/AbstractView/S9781420092325
- GIS overview: Longley, PA (2011) Geographical information systems and science. Wiley.

2.3.4 Introduction to R and Statistics

Week: 4 (*Monday 27th October – Friday 31st October*)

Convenor: David Orme

This module provides an introduction R and key statistical skills. This week is shared with MSc/MRes EEC. Please bring laptops to all computer room sessions and use them instead of the desktops, which are for EEC.

Timetable:

Monday 27th October	
09:30 – 10:30	*Introduction to R* (Lecture, Fisher, David Orme)
10:30 – 13:00	*Loading and exploring data* (Computer Practical, Hamilton Computer Room, David Orme)
13:30 – 14:30	*Probability and p-values* (Lecture, Fisher, David Orme)
14:30 – 17:00	*More loading and exploring data* (Computer Practical, Hamilton Computer Room, David Orme)
Tuesday 28th October	
09:30 – 10:30	*Categorical data and analysis* (Lecture, Fisher, David Orme)
10:30 – 13:00	*Chi squared and inter-rater reliability* (Computer Practical, Hamilton Computer Room, David Orme)
13:30 – 14:30	*One sample tests* (Lecture, Fisher, David Orme)
14:30 – 17:00	*Wilcoxon and t-tests* (Computer Practical, Hamilton Computer Room, David Orme)
Wednesday 29th October	
09:30 – 10:30	*Two sample tests and correlations* (Lecture, Fisher, David Orme)
10:30 – 13:00	*Mann-Whitney, t-tests and correlation coefficients* (Computer Practical, Hamilton Computer Room, David Orme)
Thursday 30th October	
09:30 – 10:30	*Simple linear models* (Lecture, Fisher, David Orme)
10:30 – 13:00	*Regression and anaysis of variance* (Computer Practical, Hamilton Computer Room, David Orme)
13:30 – 14:30	*Extended linear models* (Lecture, Fisher, David Orme)
14:30 – 17:00	*Analysis of covariance and more explanatory variables* (Computer Practical, Hamilton Computer Room, David Orme)
Friday 31st October	
09:30 – 10:30	*Model criticism and simplification* (Lecture, Fisher, David Orme)
10:30 – 13:00	*Residuals and the minimum adequate model* (Computer Practical, Hamilton Computer Room, David Orme)
13:30 – 14:30	*Here be dragons - stats in the wild* (Lecture, Fisher, David Orme)
14:30 – 17:00	*Statistics practice session* (Computer Practical, Hamilton Computer Room, David Orme)

Readings and Resources:

- Hilborn, R. and Mangel, M., The Ecological Detective: Confronting Models with Data, Princeton University Press, 1997.
- Crawley, MJ (2005) Statistics: An Introduction Using R. John Wiley.
- The Use R! series (the yellow books) by Springer are really good. In particular, consider: "A Beginner's Guide to R", "R by Example", "Numerical Ecology With R", "ggplot2" (we'll see this in another week), "A Primer of Ecology with R", "Nonlinear Regression with R", "Analysis of Phylogenetics and Evolution with R".
- Ben Bolker's "Ecological Models and Data in R" is also good.

2.3.5 Biological Computing in R

Week: 5 (*Monday 3rd November – Friday 7th November*)

Convenor: Samraat Pawar

In this module, we will build upon the introduction to R you received in the *Introduction to R and statistics* to learn how to use this freely available statistical software with strong programming capabilities. R has become tremendously popular in Biology due to several factors: i) many packages are available to perform all sorts of statistical and mathematical analysis; ii) it can produce beautiful graphics; iii) it has a very good support for matrix-algebra. Being able to program R along with something like Python means you will have am expanded and versatile suite of biological computing tools at your fingertips, especially for automating statistical analysis and the generation of figures. Therefore, R should become an indispensable component of your biological research work flow.

Aims: To learn how to use R for tasks ranging from data exploration and visualization to producing publication quality graphics. To learn R data types and structures and control flows. To learn how to write and debug efficient R scripts and functions. Learn how to use R packages, and generate elegant graphics.

frequentist useful

Timetable:

Monday 3rd November	
10:00 – 11:00	*What is R, and why both R and Python?* (Lecture, Hamilton Computer room, Samraat Pawar)
11:30 – 12:30	*Useful R commands and functions* (Lecture, Hamilton Computer room, Samraat Pawar)
14:00 – 17:00	*Useful R commands and functions* (Practical, Hamilton Computer room, Samraat Pawar)
Tuesday 4th November	
10:00 – 11:00	*Writing functions in R* (Lecture, Hamilton Computer room, Samraat Pawar)
11:30 – 12:30	*Writing and debugging programs in R* (Lecture, Hamilton Computer room, Samraat Pawar)
14:00 – 17:00	*Writing functions, programs, debugging in R* (Practicals, Hamilton Computer room, Samraat Pawar)
Wednesday 5th November	

10:00 – 11:00	*Writing efficient programs in R* (Lecture, Hamilton Computer room, Samraat Pawar)
11:30 – 12:30	*Writing efficient programs in R* (Lecture, Hamilton Computer room, Samraat Pawar)
Thursday 6th November	
10:00 – 11:00	*Numerical analyses and data fitting in R* (Lecture, Hamilton Computer room, Samraat Pawar)
11:30 – 12:30	*Numerical analyses and data fitting in R* (Lecture, Hamilton Computer room, Samraat Pawar)
14:00 – 17:00	*Numerical analyses and data fitting in R* (Practicals, Hamilton Computer room, Samraat Pawar)
Friday 7th November	
10:00 – 11:00	*Advanced graphics and ggplot* (Lecture, Hamilton Computer room, Samraat Pawar)
11:30 – 12:30	*Advanced graphics and ggplot* (Lecture, Hamilton Computer room, Samraat Pawar)
14:00 – 17:00	*Advanced graphics and ggplot* (Practicals, Hamilton Computer room, Samraat Pawar)

Readings and Resources:

- The Use R! series (the yellow books) by Springer are really good. In particular, consider: "A Beginner's Guide to R", "R by Example", "Numerical Ecology With R", "ggplot2" (we'll see this in another week), "A Primer of Ecology with R", "Nonlinear Regression with R", "Analysis of Phylogenetics and Evolution with R".
- Ben Bolker's "Ecological Models and Data in R" is also very good.
- For more focus on dynamical models: Soetaert & Herman. 2009 "A practical guide to ecological modelling: using R as a simulation platform".
- There are excellent websites: besides cran (containing all sorts of guides and manuals, you should check out `www.statmethods.net`, `http://archive.today/gallery.r-enthusiasts.com` and `http://en.wikibooks.org/wiki/R_Programming`.

2.3.6 Biological Computing in Python II

Week: 6 (*Monday 10th – Friday 14th November*)

Convenor: Samraat Pawar

This is the second of the two-week module on biological computing in the Python language. The aims, format, and venue of the lectures and practicals are same as same as *Biological computing in Python II*.

Timetable:

Monday 10th November	
10:00 – 11:00	*Profiling and debugging in Python* (Lectures + Exercises, Wallace room, Samraat Pawar)
11:30 – 12:30	*Profiling and debugging in Python* (Lectures + Exercises, Wallace room, Samraat Pawar)

14:00 – 17:00	*Profiling and debugging in Python* (Lectures + Short Practicals, Wallace room, Samraat Pawar)
Tuesday 11th November	
10:00 – 11:00	*Useful Python packages and tools* (Wallace room, Samraat Pawar)
11:30 – 12:30	*Useful Python packages and tools* (Lectures + Exercises, Wallace room, Samraat Pawar)
14:00 – 17:00	*Useful Python packages and tools* (Lectures + Short Practicals, Wallace room, Samraat Pawar)
Wednesday 12th November	
10:00 – 11:00	*Scipy and scientific computing (number crunching!) in Python* (Lectures + Exercises, Wallace room, Samraat Pawar)
11:30 – 12:30	*Scipy and scientific computing (number crunching!) in Python* (Lectures + Exercises, Wallace room, Samraat Pawar)
14:30 – 18:00	*Workshop: Applying for PhD / Academic Jobs / Industry Jobs (CVs, Interviews, etc.)* (Haldane room, Various)
Thursday 13th November)	
10:00 – 11:00	*Databases and Python* (Lectures + Exercises, Wallace room, Samraat Pawar)
11:30 – 12:30	*Databases and Python* (Lectures + Exercises, Wallace room, Samraat Pawar)
14:00 – 17:00	*Databases and Python* (Lectures + Practicals, Wallace room, Samraat Pawar)
Friday 14th November)	
10:00 – 11:00	*Using Python to build and run your workflow* (Wallace room, Samraat Pawar)
11:30 – 12:30	*Using Python to build and run your workflow* (Lectures + Exercises, Wallace room, Samraat Pawar)
14:00 – 17:00	*Using Python to build and run your workflow* (Practicals, Wallace room, Samraat Pawar)

Readings and Resources:

- www.docs.Python.org/2/howto/regex.html
- Googles short class on regex in Python: www.code.google.com/edu/languages/ and www.google-Python-class/regular-expressions.html
- www.regular-expressions.info has a good intro, tips and a great array of canned solutions
- For SciPy and Matplotlib, the official documentation is best: www.docs.scipy.org/doc/scipy/reference/ and www.http://matplotlib.org/
- "The Definitive Guide to SQLite" is a pretty complete guide and freely available from http://evalenzu.mat.utfsm.cl/Docencia/2012/SQLite.pdf

2.3.7 High Performance Computing

Week: 7 (*Monday 17th – Friday 21st November*)

Convenor: James Rosindell

The use of high performance computing is becoming increasingly important in biology. For certain computational tasks we can use large numbers of CPUs in parallel to get numerical results in days that would otherwise have taken years. This module will introduce students to the tools and techniques of high performance computing for biological problems using R. It will also be a good opportunity

to develop practical programming skills in the R programming language. This course has a greater proportion of practical than usual because the best way to learn about programming is to try it, the convener will help students individually and be available to answer questions throughout all practical sessions. The biological topics covered will include individual based models, ecological neutral theory and fractals in biology but the techniques learned will be useful much more generally. A significant number of CMEE students typically end up using high performance computing as a tool for their research projects.

Timetable:

Monday 17th November	
10:00 – 11:00	*L1* (Lecture - Introduction and individual based models, Wallace room, James Rosindell)
11:30 – 12:30	*L2* (Practicals, Wallace room, James Rosindell)
14:00 – 17:00	*P1* (Practicals, Wallace room, James Rosindell)
Tuesday 18th November	
10:00 – 11:00	*L2* (Lecture - Using HPC, Wallace room, James Rosindell)
11:30 – 12:30	*L3* (Practicals, Wallace room, James Rosindell)
14:00 – 17:00	*P2* (Practicals, Wallace room, James Rosindell)
Wednesday 19th November	
10:00 – 11:00	*L4* (Lecture - Coalescence methods, Wallace room, James Rosindell)
11:30 – 12:30	*L5* (Practicals, Wallace room, James Rosindell)
Thursday 20th November)	
10:00 – 11:00	*L6* (Lecture - Fractal geometry, Wallace room, Samraat Pawar)
11:30 – 12:30	*L7* (Practicals, Wallace room, James Rosindell)
14:00 – 17:00	*P3* (Practicals, Wallace room, James Rosindell)
Friday 21st November)	
10:00 – 11:00	*L8* (Lecture - Fractals in nature, Wallace room, Samraat Pawar)
11:30 – 12:30	*L9* (Practicals, Wallace room, James Rosindell)
14:00 – 17:00	*P4* (Practicals, Wallace room, James Rosindell)

Readings and Resources:

- The best preparation for this course is to be well practiced at programming, especially in R.

2.3.8 Genomics and Bioinformatics

Week: 8 (*Monday 24th November – Friday 28th November*)

Convenor: Helen Hipperson and Vincent Savolainen

There have been formidable developments in genomics technologies (e.g.next generation DNA sequencing), as well as a dramatic increase in the use of DNA data in biodiversity research over the past several years. In addition to analyses of population genomics, gene expression, phylogenetics, etc., DNA-based techniques are now routinely used in areas such as taxon identification, conservation assessments and biodiversity monitoring. The aim of the course will be to introduce basic molecular biology techniques in the lab, and a series of lectures and computer exercises to introduce the students to some common topics and analyses (data formats and computational methods) to give an overview of the latest developments in biodiversity genomics in particular.

This week is shared with MSc/MRes EEC. Please bring laptops to all computer room sessions and use them instead of the desktops, which are for EEC.

Aims: To gain fluency in basic molecular laboratory work. Develop a working knowledge of DNA sequencing techniques and technologies. learn to manipulate and analyse genomic data. Develop an understanding of the relevance of genomics data and techniques for research in biodiversity, ecology, evolution, conservation and environmental sciences.

The format for the week will be as follows. Each day will run around one of the research areas in genomics. Each day will usually comprise a lecture about the topic, and laboratory (Monday) or computing practicals. We will also discuss important papers related to genomics. The paper discussions will be guided by a series of questions given to the students the day before.

Timetable:

Monday 24th November	
10:00 – 11:00	*Introduction to the week, overview of genomics techniques and introduction to the lab practical* (Lecture, Fisher, Helen Hipperson)
11:30 – 13:00	*Microbial metagenomics part I DNA extraction* (Practical, Hamilton Teaching Lab, Helen Hipperson)
14:00 – 17:00	*Microbial metagenomics part II PCR* (Practical, Hamilton Teaching Lab, Helen Hipperson)
Tuesday 25th November	
10:00 – 11:00	*Population genomics* (Lecture, Fisher, Helen Hipperson)
11:30 – 15:30	*Genotyping by sequencing, RAD* (Practical, Hamilton Computer Room, Helen Hipperson)
16:00 – 17:00	*Paper discussion I* (Discussion, Fisher, Helen Hipperson)
Wednesday 26th November	
10:00 – 11:00	*Transcriptomics and gene expression* (Lecture, Helen Hipperson, Luke Dunning)
11:30 – 13:00	*Differential gene expression analysis from RNAseq data* (Practical, Hamilton Computer Room, Helen Hipperson, Luke Dunning)
Thursday 27th November	
10:00 – 11:00	*Genome assembly: technical challenges* (Lecture, Fisher, Helen Hipperson)
11:30 – 13:00	*Assembling a bacterial genome, from raw data to full assembly and annotation* (Practical, Hamilton Computer Room, Xueping Quan)
14:00 – 16:00	*Microbial metagenomics results* (Practical, Hamilton Computer Room, Helen Hipperson)
16:00 – 17:00	*Thursday seminar* (Seminar)
Friday 28th November	
10:00 – 11:00	*Phylogenomics* (Lecture, Fisher, Alfried Vogler)
11:30 – 15:30	*Phylogenomics Genbank data mining and tree searches* (Practical, Hamilton Computer Room, Alfried Vogler)
16:00 – 17:00	*Paper discussion II* (Discussion, Fisher, Helen Hipperson)

Readings and Resources:

- Discussion papers (Provisional)
  - The Heliconious genome consortium (2012) Butterfly genome reveals promiscuous exchange of mimicry adaptations among species. Nature 487:94–98.
  - Scally et al (2012) Insights into hominid evolution from the gorilla genome sequence. Nature

483:169175.

- Stapley et al (2010) Adaptation genomics: the next generation. TREE 25:705–12.
- Ekblom & Galindo (2011) Applications of next generation sequencing in molecular ecology of non-model organisms. Heredity 107:1–15.
- Savolainen et al (2013) Ecological genomics of local adaptation. Nature Reviews Genetics 14:807–20.

2.3.9 Mathematics Primers I – III

Week: 9 (*Monday 1st – Friday 5th December*), 10 (*Monday 8th – Friday 12th December*), and 16 (*Monday 19th – Friday 23rd January*)

Convenor: Koenraad Audenaert

This is a three-week module. The aim is to provide a primer in core mathematical topics that will be of use in the rest of this course and indeed, throughout students careers! Students will receive an introduction to the most fundamental applied concepts of calculus, linear algebra, probability theory, and dynamical systems, and will become comfortable to receive more in depth training in these fields. The first two parts of the module will be in the Autumn term, and the third part in the Spring.

Scheduling for this module in all three weeks will be:

10:00–11:00: Lecture

11:30–12:30: Lecture

1400–1700: Practical, except Wednesdays

Readings and Resources:

- Sarah P Otto and Troy Day, A Biologists Guide to Mathematical Modelling in Ecology and Evolution, Princeton University Press, 2007.
- C. Neuhauser, Calculus for Biology and Medicine, 3rd edition (2009)
- D. C. Lay, Linear Algebra and its Applications, 4th edition (2010)
- Linear Algebra, Schaum's Outlines, 4th edition (2008)
- Any of numerous basic texts in calculus, linear algebra, and probability theory. There are many of these and students prefer different ones, so try a few and choose one. many are available in the Silwood or Central libraries.

2.3.10 Dynamical Models in Ecology

Week: 17 (*Monday 26th – Friday 30th January*)

Convenor: Vincent Jansen

Dynamical systems theory plays a major role in modern theoretical approaches to ecological concepts and phenomena such as competition, predation, metapopulation dynamics, diversity and evolution, and disease spread. This module will introduce some of the key basics of dynamical systems theory

in application to these topics. We will look at ordinary differential equations and difference equation models and will use stability analysis and bifurcation analysis as tools to understand the qualitative behaviour of ecological models.

Scheduling for this module will be: 10:00–11:00: Lecture 11:30–12:30: Lecture 1400–1700: Practical, except Wednesdays

Readings and Resources:

- Sarah P Otto and Troy Day, A Biologists Guide to Mathematical Modelling in Ecology and Evolution, Princeton University Press, 2007.
- May, R.M. & McLean, A. 2007 Theoretical Ecology. Blackwell Scientific. 5 copies in the library.
- Nicholas Gotelli, A Primer of Ecology, Sinauer Associates, 4th Edn, 2008.
- Bart Ermentrout: Simulating, Analyzing, and Animating Dynamical Systems: A Guide to XPPAUT for Researchers and Students. SIAM. 2002
- Bifurcation analyses using Python http://www.ni.gsu.edu/~rclewley/PyDSTool/FrontPage.html

2.3.11 Models in Population Genetics and Genomics

Week: 18 (*Monday 2nd February – Friday 6th February*)

Convenor: Austin Burt and Timothy Barraclough

This module will give an introduction to the classic models in population genetics that have been used to study the action and interaction of mutation, drift, migration selection, and transmission ratio distortion.The theory will be integrated with practicals involving microbial population genetics/genomics data. We will use Mathematica in class; please download a 30 day trial (free) copy the previous week from http://www.wolfram.com/mathematica/trial/. Alternatively, you can try sage, which works just as well, and is free and open source, with some great tutorials to help you get started http://www.sagemath.org/.

Readings and Resources:

- TBD

2.3.12 Maximum Likelihood Statistics and Model Fitting

Week: 19 (*Monday 9th February – Friday 13th February*)

Convenor: Tin-Yu Hui

Maximum likelihood estimation (MLE) plays a key role in statistical estimation. It provides a framework to obtain the best set of parameters given the observation with an associated statistical model. Many statistical methods used in ecology and evolution, including most of the general and generalised linear models described in the statistics module, are consequences of maximum likelihood under specific applications. This module aims to give a formal definition to MLE, and to apply the technique to problems in ecology. By the end of this module, student will be able to understand the concepts of MLE, and implement MLE in R for standard and non-standard problems.

Timetable:

Monday 9th February	
10:00 – 11:00	*Background probability theory* (Lecture, Wallace, Tin-Yu Hui) Common discrete/continuous random variables. Probability mass/density function. Expectation of random variables. Central limit theorem.
11:30 – 13:00	*Background probability theory continued* (Lecture, Wallace, Tin-Yu Hui)
14:00 – 17:00	*Background probability theory continued*(Practical, Wallace, Tin-Yu HuiHui)
Tuesday 10th February	
10:00 – 11:00	*Probability and Likelihoods* (Lecture, Wallace, Tin-Yu Hui) Multivariate random variables. Definition of a likelihood function. Maximisation in R.
11:30 – 13:00	*Probability and Likelihoods continued* (Lecture, Wallace, Tin-Yu Hui)
14:00 – 17:00	*Probability and Likelihoods continued*(Practical, Wallace, Tin-Yu HuiHui)
Wednesday 11th February	
10:00 – 11:00	*Properties of maximum likelihood estimators* (Lecture, Wallace, Tin-Yu Hui)
11:30 – 13:00	*Properties of maximum likelihood estimators continued* (Lecture, Wallace, Tin-Yu Hui)
Thursday 12th February	
10:00 – 11:00	*Likelihood-ratio test* (Lecture, Wallace, Tin-Yu Hui)
11:30 – 13:00	*Confidence interval estimation* (Lecture, Wallace, Tin-Yu Hui)
14:00 – 17:00	*Likelihood-ratio test and Confidence interval estimation*(Practical, Wallace, Tin-Yu HuiHui)
Friday 13th February	
10:00 – 11:00	*MLE examples* (Practical, Wallace, Tin-Yu Hui)
11:30 – 13:00	*MLE examples* (Practical, Wallace, Tin-Yu Hui)
14:00 – 17:00	*MLE examples* (Practical, Wallace, Tin-Yu Hui)

Readings and Resources:

- Millar, R.B., Maximum Likelihood Estimation and Inference With Examples in R, SAS and ADMB. Wiley-Blackwell, 2011.
- Casella, G. & Berger, R.L., Statistical Inference, second edition, Cengage Learning, 2001.

2.3.13 Introduction to Bayesian Statistics

Week: 20 (*Monday 16th February – Friday 20th February*)

Convenor: Koenraad Audenaert

This module will introduce students to background theory and computational practice of using Bayesian statistics. Topics to be covered include the Bayes theorem, fitting by Bayesian methods, MCMC, and other basics of Bayesian statistics as applied to biology.

All activities will be in Wallace.

Scheduling for this module will be:

1000–1100: Lecture

1130–1230: Lecture

1400-1700: Practical, except Wednesday

Readings and Resources:

- R. Christensen et al, Bayesian Ideas and Data Analysis (Chapman & Hall/CRC Texts in Statistical Science)

2.3.14 Networks and Complex Systems in Ecology and Evolution

Week: 21 (*Monday 23rd – Friday 27th February*)

Convenor: Samraat Pawar

In this module a series of lectures and practicals will introduce you to theoretical basics, current topics and empirical data on the structure and dynamics of networks arising from (structurally and dynamically complex) ecological and evolutionary systems. The main aim of this module is to introduce students to the key network-oriented ideas, mathematical/computational tools, and data analyses methods. The week will kick off with introductory lectures ands practicals on networks in ecology and evolution where you will be given an overview of types of networks that arise in in ecology and evolution, why networks are a powerful and necessary representation of such systems, and an overview of the approached used to study different kinds of networks. Here is a list of topics that will be covered:

Day 1: Introduction to complex systems, scaling and networks (Pawar)

Day 2: Inference on Complex networks (Till Hoffman)

Day 3: TBD / Free Day

Day 4: Bayesian Networks (Veronique Lefebvre)

Day 5: Maximum entropy and interaction networks (Katharina Brinck)

All activities will be in Wallace room in in Hamilton building.

Scheduling for this module will typically be:

1000–1100: Lecture

1130–1230: Lecture

1400-1700: Practicals, except Wednesday

Readings and Resources:

- Proulx, S. R., Promislow, D. E. L. & Phillips, P. C. 2005 Network thinking in ecology and evolution. Trends Ecol. Evol. 20, 34553.
- R. Albert and A.-L. Barabási. Statistical mechanics of complex networks. Reviews of Modern Physics, 74:4797, 2002.
- Albert-László Barabási and Réka Albert. Emergence of scaling in random networks. Science, 286(5439):509512, 1999.
- Paul Erdős and Alfréd Rényi. On the evolution of random graphs. Publications of the Mathematical Institute of the Hungarian Academy of Sciences, 5:1761, 1960.
- Santo Fortunato. Community detection in graphs. Physics Reports, 486(35):75174, 2010.

- Paul Holland, Kathryn Blackmond Laskey, and Samuel Leinhardt. Stochastic blockmodels: First steps. Social Networks, 5(2):109137, 1983.
- Mark Newman. The structure and function of complex networks. SIAM Review, 45:167256, 2003.
- Mark Newman. Networks: An Introduction. OUP, 2010.
- Mason A. Porter and James P. Gleeson. Dynamical systems on networks: A tutorial. arXiv, page 1403.7663, 2014.

2.3.15 Advanced Topics in Ecology and Evolution

Week: 22 (*Monday 2nd March – 6th March*)

Convenor: Samraat Pawar

Quantitative biology is a large and diverse field. This module will introduce additional topics in the field not covered in the taught modules. Lecturers will spend 1-2 days each with the class and will introduce a field. Lecturers come mainly from within Imperial College or nearby institutions, so this module will also make students aware of other possible areas in which they can do their research projects. Topics may include: quantitative topics in virology; epidemiology; game theory and populations; evolution in complex microbial communities, signal processing of population time series using wavelets. Specific speakers and topics to be determined.

All activities will likely to be in Wallace, and will typically follow the normal schedule starting at 10:00 AM, and ending at 5:00 PM.

Readings and Resources:

- TBA

3 Research project and Thesis guidelines

Each MSc and MRes student will carry out an independent research project leading to a written report (dissertation). The project must have at least one supervisor from the Department of Life Sciences at Imperial College. A list of potential internal supervisors from Silwood Park as well as external supervisors and institutions are given below.

3.1 Choosing and proposing your research project

Research project topics are generally part of ongoing active research within the Department and across a range of academic partners. We maintain an online list of available projects to which new project proposals are added throughout the year. The details of available projects are available at:

Webpage http://goo.gl/GWtgy6

Tab delimited text file http://goo.gl/awH7Vf

This list will provide broad details of research projects but the precise topics of projects will be finalised in discussion between the student and potential supervisors. Project descriptions will appear throughout the year but we aim to provide the majority of project topics by 15th October 2014.

The main difference between MRes and MSc projects will be the scope — keep in mind that the MRes projects have an extra four months or so available. The project can be on any *biological* topic and must entail significant amounts of mathematical theory or statistical analyses of large datasets, or combinations of these.

Both CMEE MRes and MSc students will select a project and turn in a two-page project outline in pdf format on by the respective deadline given in the summary timetable (section 2.2). Submission will be to a git repository (instructions will be provided after the course begins) and/or to blackboard. The proposal should be on A4 paper with 2cm margins, in 12pt font, single-spaced, and must not exceed 2 pages *including* references. The references can be formated compactly, but must contain the full title of the paper. The proposal should begin with a title, supervisor name(s) with affiliation(s) and contact details (including email). It should contain the following sections (all quite brief, of course): (i) Introduction to the project idea and questions in a relevant context (background), (ii) describe proposed methods, (iii) defend the feasibility of the project supported by a time line of tasks (gannt chart), and (iv) list the cited references. The proposal will be briefly reviewed by the Course Administrator for completeness and sent to the supervisors for perusal and feedback to the student. ideally, the proposal will have been prepared in close collaboration with the supervisor in the first place!

3.2 MRes project oral presentations and mid-project reports

CMEE MRes students will make make two project related presentations (see section 2.2 for dates). The first presentation will follow submission of a mid-project report, and the second following submission of the final report (the thesis – see section 3.5). Both presentations will be marked, and count towards 15% of the total grade (5% for the mid-project and 10% for the final).

The mid-project presentation and report are aimed at providing the Supervisor and the Course Director an account of the status of the project. The report should give an account of the project's progress

and make a convincing case that the project continues to be feasible and approximately on schedule. It is the supervisor's job to give feedback on these aspects and more.

The 10 minute presentation will be followed by 10 minutes for questions and discussion, attended by the Course Directors as well as the project supervisor. Student responses in the post-presentation discussion will be incorporated into the marking.

The mid-project should should be formatted along the lines of the project proposal described above, but can be upto 5 pages long (including references and all figures and tables).

The final project presentation will also be 10 minutes long followed by 5 minutes for questions.

3.3 MSc project oral presentations and mid-project reports

CMEE MSc students will also make make two project related presentations (see section 2.2 for dates). The first presentation will be about a month after the project proposal submission and will coincide with the MRes mid-project presentations described above. The second will follow submission of the final report (the thesis – see section 3.5). Both presentations will be marked, and count towards 15% of the total grade (5% for the first and 10% for the final).

The first presentation will be on a paper or a set of papers related to the Research project, and will aim to put the proposed project in a scientific context. The 10 minute presentation will be followed by 10 minutes for questions and discussion, attended by the Course Directors as well as the project supervisor.

The final project presentation will also be 10 minutes long followed by 5 minutes for questions.

3.4 Lists of potential supervisors

The following sections on potential supervisors and broad research areas are intended to guide you in thinking of the topics you might be interested in and in which staff to approach. All projects must have a Life Sciences supervisor or co-supervisor, but can also be based at external organisations with additional external supervision. Previous external organisations include ZSL, the Met Office, Royal Botanic Gardens, Kew, English Nature, the Game Conservancy and so on. You are encouraged to look up titles and abstracts of previous year projects from CMEE as well as quantitative projects from other courses such as MSc/MRes EEC, which can be obtained from Mrs. Amanda Ellis (amanda.ellis@imperial.ac.uk). A list of previous CMEE project topics is also provided on Blackboard, and example titles and reports are also available from the course websites: http://www3.imperial.ac.uk/lifesciences/postgraduate/courselist/msc-cmee and http://www3.imperial.ac.uk/lifesciences/postgraduate/courselist/mres-cmee.

As and when new supervisors add projects after printing the handbook, details of their research interests may be downloaded from these links:

Webpage http://goo.gl/okOvZS

Tab delimited text file http://goo.gl/aVGHs4

3.4.1 Internal supervisor research areas

Miguel Araújo

I have a wide range of interests in biogeography, conservation biology, global change biology, and macroecology. My research is driven by three unifying questions: 1) how did past climate changes affect the distribution of biodiversity? 2) how might current and future environmental changes affect biodiversity? 3) how can biodiversity be conserved given current and future challenges? To address these questions, I integrate large climatic and species distributions databases with descriptions of behavioural and physiological traits of species, molecular phylogenies, and the fossil record. Most research involves statistical analyses of ecological data, including data mining, bioclimatic modelling and mathematical simulations, but large-scale experiments, including mesocosm experiments, are now being devised for testing ecological and evolutionary models and theory.

Cristina Banks-Leite

Understanding bird responses to deforestation in South America and the consequences of species extinction to the loss of functional diversity. An example projects could use data previously collected on birds from the Atlantic Forest and Amazon as well as collate a database on species morphological and behavioural traits. The aim is to address questions such as; which response traits are related to species sensitivity to deforestation; does species extinction lead to loss of functional diversity; and are response and effect traits correlated.

Tim Barraclough

Evolutionary biology and species diversity; speciation in asexual rotifers; evolution in bacterial communities including human gut bacteria.

Morgan Beeby

I am interested in how the molecular machinery of the cell assembles, functions, and evolves. To tackle this problem I use electron cryo-tomography, a technique that enables us to visualize this machinery inside living cells – to resolutions capable of discerning individual proteins. The technique involves flash-freezing the specimen then imaging it over a range of angles in an electron microscope. The resulting images can then be used to determine the 3-D structure of the specimen in a manner directly analogous to CT or CAT scans. Bacteria are the biological subjects of my studies: the (relative) simplicity of bacteria make them ideal subjects for study of basis biological principles, yet with considerable practical application in, for example, antibiotic development or sustainable re-utilization. My primary focus at the moment is the bacterial flagellar motor, a nanoscale motor that spins a helical filament to act as a propeller for the bacterium. I am particularly interested in a number of curious variants of the motor that we recently identified, as these differences promise to shed light upon some basic principles of assembly, function, and evolution.

Tom Bell

Projects are available on microbial ecology and evolution. Projects will involve testing ecological and evolutionary theory using microbial communities as a model system. Projects could typically include laboratory and field work. General areas of interest include:

- Biodiversity and ecosystem functioning. Biodiversity is thought to be an important determinant of ecosystem-level processes (e.g. decomposition). Projects in this area will look at the ecological mechanisms that contribute to biodiversity-ecosystem functioning relationships, and at how biodiversity affects functioning over evolutionary timescales.
- Microbial biogeography. Spatial patterns of microbial community composition and diversity

remain understudied. Projects might include, for example, manipulating rates of colonisation to understand how community assembly affects community membership.

- Trophic interactions. Projects will involve examining the role of protists in structuring bacterial community composition. Several hundred protist and bacterial isolates are available to construct food webs and to examine the relative roles of resource competition and predators in determining bacterial community dynamics.

Martin Bidartondo (Royal Botanic Gardens, Kew)

I supervise projects on the ecology and evolution of plant-fungal interactions that may be field, glasshouse, laboratory and/or computer-based. Current interests include the evolutionary ecology of the fungal symbioses of ancient plant lineages and the ecological drivers of mycorrhizal diversity in trees.

Austin Burt

I supervise computer-based projects on population genetic data analysis and population genetic modelling.

Lauren Cator

My lab works on increasing our basic understanding of mosquito behavior and using that knowledge to improve our capacity to control disease. Mosquitoes are responsible for transmitting some of the most devastating diseases on the planet. Despite this, we know surprisingly little about their basic behavior and ecology. We work to better understand of mosquito behavioral ecology and the evolutionary forces which have shaped it in order to more effectively control the disease they transmit. We attack these problems in both the laboratory and the field. Please visit http://laurencator.webs.com/

Magda Charalambous

I supervise projects on insect mating behaviour and sexual selection. In the past I have had projects on Drosophila, crickets and bulb mites (to look at alternate male mating behaviours). We have video/sound recording facilities available and have used jWatcher software both as an event recorder and to produce transitional probabilities for ethograms. I am happy to discuss any project with a behavioural angle and also to act as internal supervisor for behavioural projects undertaken away from Silwood.

Mick Crawley

Example projects include:

- Plant species richness and coexistence in annuals. Temporal variation is one of the mechanisms postulated as fostering coexistence in species-rich systems. This project uses a 12-year old, ongoing field experiment at Pound Hill in Silwood Park, where replicated plots have been cultivated in October, March or May each year. They now have highly distinctive floras and seed banks. The project addresses questions about the species specific details of coexistence under the 3 disturbance regimes, with particular attention to population densities, plant size, seed production and mortality.

- Invertebrate herbivores and plant biodiversity in grasslands. The Nash's Field experiment has run since 1992. It involves 12 different nutrient treatments in grassland (combinations of nitrogen, phosphorus, potassium and magnesium), crossed with two liming treatments (limed and unlimed) and 3 plant competition treatments (control, minus-grass and minus herb in the first 3 years). The project concerns the relative importance of vertebrate herbivores (rabbits and deer) and invertebrate herbivores (insects and molluscs) in determining species diversity and plant community composition. The project has direct relevance to

conservation of species-rich grassland.

- Experimental studies of the regeneration niche in plants.This project is about seed-limitation; if you add more seeds, will you get more plants? The work centres on the long-term field experiment in Oak Mead in which 60 species were sown in 1996 under a range of conditions relaxing the intensity of plant competition and herbivory. When seed addition leads to the establishment of more plants, then evidently regeneration niches of that species existed at the time of sowing. The project involves the collection of new field data on the invasion of grassland from these sown epicenters (e.g. Linaria repens) and analysis of existing data sets (e.g. local extinction of species that established from seed under conditions of low competition, or low herbivory).

- Impacts of red deer (Cervus elaphus) grazing on plant communities on Rum. The issue of deer numbers in Scotland is well known, and the impact of grazing on plant communities has been studied for many years on the island of Rum. There is an opportunity to join the team on Rum to gather new data on plant-herbivore dynamics.

Rob Ewers

I work on spatial patterns of forest and the biodiversity contained within those forests. Work involves investigating and trying to predict patterns of forest cover from local through to global scales, sampling of taxa within selected landscapes, and manipulative field experiments. Most of the work uses invertebrates as a model system, and is focused at the Stability of Altered Forest Ecosystems (SAFE) Project in Malaysian Borneo.

Jason Hodgson

My research focuses on human and primate evolutionary genetics. I use genomic SNP and next-gen sequence data, as well as bioinformatic approaches to test evolutionary hypotheses.

I am particularly interested in the way that local adaptation and gene flow have contributed to the distribution of genetic variation. As a globally distributed species, human populations have experienced myriad selective environments and consequently local adaptation has driven population differentiation between regions. Recent migrations associated with the development of agriculture and efficient transportation have spread locally adapted genetic variants across the landscape. I use recently admixed populations to understand the fate of locally adapted alleles when they are introduced to new environments through migration. I am currently working with the people of Madagascar, but also work on populations from the Horn of Africa, Middle East, and Oceania.

I am also interested in all aspects of primate evolution. I am particularly interested in integrating molecular phylogenetics with the fossil record to produce a more nuanced understanding of primate evolution.

Aidan Keane

I combine empirical and model-based approaches to study how human behaviour and decision-making affect the outcomes of conservation actions in complex social-ecological systems. Specific areas of research include (1) the effects of conservation interventions on Maasai pastoralist livelihood choices, and their consequences for poverty and wildlife in East African drylands, (2) the importance of rule-breaking in conservation and the effects of enforcement measures on levels of compliance, and (3) methods for studying sensitive or illegal behaviours in conservation. I have previously worked with students on a variety of projects including interview-based studies of illegal carnivore killing in South Africa, analyses of bushmeat consumption in Madagascar's eastern rainforests and applying experimental games to predict behaviour in response to conservation

interventions in Cambodia.

Alex Lord

I am interested in how climate change will affect trophic interactions through changes in phenology, and the consequences for population dynamics. I have a long term study based at Silwood Park that uses an oak-winter moth-blue tit field system to build a fine-scale understanding of species interactions. Potential projects with me range through desk based analysis and modeling, theory development and field based experiments.

E.J. Millner-Gulland

I supervise projects on a broad range of topics in conservation and development, human-wildlife interactions, hunting and wildlife trade, human behaviour and evaluation of conservation successes and failures. Each year I offer one or more specific projects on my saiga antelope research, in collaboration with the Saiga Conservation Alliance. For more detail on my research interests see www.iccs.org.uk.

David Orme

My research has centred on trying to explain distributions of biodiversity across phylogenies and in space: why are some groups of organisms or places unusually species rich and species poor. I have also looked at differences in diversity between taxonomic groups and possible implications for conservation. More recently, I have been exploring how dispersal and evolutionary history give rise to patterns of species distribution and how these variables may be used in predicting responses to climate change. I have supervised projects on both the phylogenetic and spatial distribution of diversity on small and large scales and also have in interest in marine systems.

Samraat Pawar

My group studies dynamics of biological systems across levels of organization, from individuals to communities. We use a combination of mathematical and computational modeling and analyses of massive ecological data sets. We work across organisms and ecosystems, and are particularly interested in the structural and functional differences and similarities between terrestrial and aquatic communities. You can find further details and information on specific projects we are currently involved in by visiting http://imperial.ac.uk/people/s.pawar.

Iain Colin Prentice

Understanding and modelling fundamental carbon, water and nutrient cycling processes at the plant and ecosystems levels. Global carbon cycle modelling and climate feedbacks. Assessment of the impacts of global climate and CO2 changes for natural ecosystems, water resources and crops.

Andy Purvis

Integrative biodiversity science: interests in conservation biology (modelling and projecting responses of species, populations, functional diversity and ecosystem services to human impacts, in both natural and managed systems), macroevolution (primarily in planktonic foraminifera), and phylogenetic comparative biology (especially models of trait evolution)

James Rosindell

My main areas of research interest are biodiversity theory, island biogeography, ecological neutral theory and scientific data visualisation. I offer a range of projects on these topics all of which would involve the opportunity to develop programming skills and apply scientific computing to ecology and evolution. The island biogeography projects would involve modeling the richness and abundance of endemic and native species on island archipelagos. Ecological neutral theory is a controversial area of biodiversity theory that uses very simple models; projects here would

involve introducing extra realism to these models and fitting them to tropical moist forest tree datasets. Students working on the data visualisation project would be contributing to a wider initiative to provide software to visualize the tree of life and information on each species within it. The software will be for use by scientists and as a tool for public outreach and education on the subjects of ecology and evolution.

Vincent Savolainen

Work in my lab combines field ecology, molecular phylogenetics, population genetics, and genomic approaches to help explain the origin of biodiversity and, where possible, find solutions for its preservation in a rapidly changing world. Most projects will have a wet lab component (genetics and genomics), possibly a field component too (UK, Australia, Africa).

Mike Tristem

I am interested in projects in the following areas:

- Endogenous retrovirus insertional polymorphisms in humans. The published human genome sequence contains over 98,000 endogenous retroviruses (ERVs) but all are defective, containing lethal mutations or major deletions. Only one family of HERVs (human ERVs), termed HERV-K(HML2), has been active since the divergence of humans and chimpanzees approximately 6 mya. The family contains many members that are human-specific as well as several that are insertionally polymorphic, an integrated element being present in some human individuals but not in others. Possible projects will identify additional insertional polymorphisms via PCR screening of different human individuals. Any polymorphisms will be useful as (i) population markers, (ii) in assessing prehistoric human migration patterns and (iii) investigating the present day activity of HERVs.

- Domestication of human endogenous retroviruses. Some ERVs have become domesticated or co-opted and hence fulfil a function of benefit to the host (e.g. preventing infection by other viruses). Identifying such elements has been very slow to date. However, with the recent sequencing of the human and chimpanzee genomes the process will be much faster and can be accomplished using bioinformatics. Thus possible projects will compare orthologous (in the same location) ERVs in the two genomes. Selection since the divergence of the two hosts will be examined with any evidence of purifying selection indicating domestication of the elements being examined.

Alfried Vogler

My main interest is in the phylogeny and evolution of Coleoptera (beetles), arguably the largest radiation of animal species on Earth. I use DNA sequences and phylogenetic analysis to study a wide range of questions to explain the great diversity of beetles, at all hierarchical levels, from populations to basal relationships of the order. In addition, I develop DNA-based approaches as short-cut for taxonomy, in particular in poorly known tropical groups. This permits novel analysis of entire insect communities for surveys of total diversity or for monitoring the response to environmental disturbance. I have a joint appointment with the Natural History Museum (NHM) London where I conduct most of my research.

3.4.2 External supervisor and organization research areas

The examples below give outlines of project areas from some recent partners. More projects with external partners are likely to arise during the course. In the first instance, please contact the course directors about possible projects with external organizations.

Projects outside Silwood but within Imperial College

Recommended websites to read about research interests of IC staff in other departments and colleges are :

- Mathematics, http://www3.imperial.ac.uk/mathematics, their staff list with personal web pages are at http://www3.imperial.ac.uk/mathematics/about/people
- Biomathematics Group: http://www2.imperial.ac.uk/mathematics/php/researchgroups/bms/
- Statistics http://www3.imperial.ac.uk/statistics/research, especially the Statistical Genetics and Bioinformatics Group http://www3.imperial.ac.uk/statistics/research/statgenbio.
- Other divisions in Life Sciences: http://www3.imperial.ac.uk/lifesciences

ZSL Institute of Zoology (IoZ)

http://www.zsl.org/science/ioz-staff-students; Contact Dr. Chris Carbone http://www.zsl.org/users/chris-carbone

Natural History Museum (NHM)

NHM has a massive collections digitization project going on that are yielding unique and massive datasets on species morphologies, and spatio-temporal distributions, among other things . Contact Andy Purvis *Andy.Purvis@nhm.ac.uk* or Steve Brooks *S.Brooks@nhm.ac.uk* for more information and project ideas.

Centre for Environment, Fisheries, and Aquaculture Science (CEFAS) - Simon Jennings and others

A wide range of projects in applied and fundamental aspects of fisheries management and marine ecology and ecosystem management may be available linked with the CEFAS Lowestoft Laboratory in Suffolk. Projects may be located at Silwood or possibly at Lowestoft. For more information about CEFAS and what work goes on there, read http://www.cefas.co.uk/ and then initially contact Dan Reuman (d.reuman@imperial.ac.uk) to discuss possible projects and to get CEFAS contacts.

Some specific project areas are:

- Exploring the CPR fish larvae datasets for link with environmental factors and/or fishing effects.

  The Continuous Plankton Recorder (CPR) survey, which was started in the North Sea in 1931, is one of only a few long-term biological monitoring programmes and the only one at a spatial scale that gives a systematic coverage of the North Sea in space and time. As well as the zooplankton and phytoplankton, fish larvae were also analysed until the 1970s. At that point cost cuts meant that analysis of fish larvae in the CPR samples was stopped but the samples themselves have been archived. The M1101 Defra funded project allowed for the analysis of the archived samples for fish larvae. The newly available fish larvae dataset from the CPR covers the entire UK shelf from 1950 to 2004 and comprises about 110,000 data points. This dataset offers a unique opportunity to investigate long term changes over decadal scales in the abundance and distribution of fish larvae in relation to physical and biological factors, as well as fishing effects. Unfortunately only a few species are well sampled by the CPR and can be used for further analysis. Among such taxons we have identified clupeids, sandeels, Atlantic mackerel, dab, Blue whiting. So far work has been done at Cefas on the following use of the dataset:

  - The potential for larval fish data from Continuous Plankton Recorder (CPR) surveys to inform the stock assessment of North Sea sandeels (paper in preparation).
  - North Sea spawning mackerel and the stock crash in Northern North East Atlantic mackerel (paper in preparation)
  - Regime shifts in the Celtic Sea and North Sea and their impacts on fish larvae (paper in preparation)
  - Long-term changes in the abundance of clupeids, sandeels, Atlantic mackerel and Dab from the CPR (1960–2004) in the North Sea, in relation to biological (prey fields) and environmental factors and using principal component analysis (temperature, salinity) (paper in preparations).

Clearly there is immense potential for further use of the fish larvae dataset from the CPR. For this particular project i would like to explore the clupeid dataset further. Unfortunately clupeids could not be identified to species level in the CPR samples. We suspect they are mostly herring and sprat, sardine and anchovies might also contribute to the clupeid index in some areas. However initial work on the dataset is encouraging and we have found statistically significant correlations between yearly abundances of clupeids larvae from the CPR and herring spawning stock biomass from stock assessment data from ICES. The idea for this project would be to try and find further links between environmental conditions (both physical and biological), fish larvae and stock assessments in order to:

- Assess the potential of the CPR dataset to be used in support of stock assessment purposes for selected fish.
- And/or explore further the link between environmental conditions and the survival potential of fish larvae.

Contact Sophie Pitois, Plankton ecologist (Cefas), *sophie.pitois@cefas.co.uk*

Centre for Ecology and Hydrology, Wallingford

Research areas for projects are based around ecological modelling of UK systems, often with practical or policy implications. Previous topic areas include the following:

- Are extinction risks of plant species larger on the edge of distributions than in the centre? Based on Atlas data of the UK and the Netherlands we will look at spatial patterns in range decay of over a wide range of species over the last 50 years. Next to geographical patterns, a range of alternative environmental indicators for correlated extinction will need to be explored. Such information could feed into priorities to set in conservation of declining species.
- Dynamics of butterfly range expansion. Understanding landscape effects on colonisation and extinction can help us to facilitate species movements under changing climates. This project will investigate how landscape structure affects the colonisation of new sites at leading range margins. In addition, local extinctions will be related to landscape characteristics.
- Managing habitats for butterfly populations. Butterfly populations are highly sensitive to land management and understanding the long term effects management regimes can aid conservation. This project will investigate how nature reserves managed in different ways affect butterfly population dynamics. For example, does a heterogeneous management regime lead to more robust and stable populations?
- Floral homogeneity in the UK: the effects of non-native plants and urbanisation. Biotic homogenisation is regarded as a potential cause of biodiversity loss and is strongly linked

with the arrival and dominance of non-native plants and animals and urbanisation. Using an extensive dataset on plant distributions at a tetrad scale collected at 2 time periods by the Botanical Society of the British Isles (BSBI) throughout the UK we will calculate similarity indices and look at spatial and temporal trends in similarity for native and non-native plants to investigate whether there is any signs of homogeneity in the British flora and what the mechanisms behind this are addressing questions such as: Are habitats that are more similar associated with higher numbers of alien species? Are urban habitats more similar than habitats in the wider countryside? Have plant communities become more homogeneous over time in the UK?

UNEP-World Conservation Monitoring Centre (UNEP-WCMC)

A wide range of projects addressing global/regional biodiversity and ecosystem services issues, including: international agreements synergies, conservation priority setting, international trade and regional economies, drylands and livelihood support, wildlife trade and socialLaTeX networks, access and benefit sharing, protected area targets and social values, monitoring deforestation and degradation, and more.

Somerset Wildlife Trust

Broad research interests cover the interaction of land use methods and biodiversity on lowland wetlands. A variety of projects are possible from looking at restoration of biodiversity on restored peat extraction sites through to examining the effects of drainage and re-wetting on peat soil integrity and micro-arthropod diversity. Many projects are available concerning the conservation of nationally rare invertebrate species.

3.5 Thesis format and submission

Note that different courses at Silwood have different guidelines and past projects are not all written in the style required here.

Your dissertation should ideally be written using /LaTex. A template can be found here: `http://www.prettyprinting.net/imperial/` (A beamer presentation template is also available there).

The write-up should be in the style of a scientific paper from a journal that it might be appropriate for submission to. By style, we mean the structure and how information is presented you do not need to make it look like a journal paper, but it should have an abstract, introduction, methods, results, and discussion (possibly conclusions). If the results of your project are publishable, this approach will save much time and will provide valuable experience in paper writing. You may provide appendices if necessary (for example outlining methods in detail).

Always aim to be clear and concise. The size of the thesis will vary according to the student and project, but aim to make it as short as necessary to describe the work done and to discuss it in a general context. However, *do not* omit relevant data and information such as experimental procedures. A CMEE Masters thesis should not exceed 10,000 words in length (excluding figures, tables, references and appendices). However, a common mistake is to assume that the reader knows the project as well as you do and to leave out clear descriptions of the motivation and structure of your research.

There are a few ways in which your thesis is likely to differ from a typical scientific paper:

1. You should make sure that you clearly state your aims/hypotheses/questions towards the end of your introduction.

2. You should take care to explain everything adequately so that the examiners can see clear evidence of understanding of all the concepts and methods – this might entail providing more detail or background in the introduction and methods than in a typical paper. However, some of this detail can be put in an appendix.For example, a molecular study might state in the Methods section of the main text that you extracted DNA according to a phenol/chloroform extraction protocol according to a particular reference. In the appendix, you should then describe the steps of your lab protocol in sufficient detail that other people could reproduce this procedure by following your description.

3. You should make it clear what you did versus what you were provided with. For example, did you collect the data that you analyzed or were they provided to you by someone else?

4. You should make sure to discuss limitations of your study and what future work you would do to address those limitations or any other questions raised by your work. In your project, most likely you will run out of time to complete everything you want to do. In most papers, the research would not be so time limited so limitations can be addressed by further work.

The class repository/Blackboard has a folder with more advice on scientific writing, and papers from Ecology Letters, Proceedings of the Royal Society B, Molecular Ecology, and Journal of Animal Ecology, which we recommend as well-written example papers.

The final thesis must follow these preparation guidelines:

Cover Page

The cover page *must* bear the project title, your name and the month and year of submission. In addition, the following text must appear at the bottom of the cover page:

> A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science/Research at Imperial College London
>
> Formatted in the journal style of XXX.
> Submitted for the MRes/MSc in Computational Methods in Ecology and Evolution

Obviously, insert your choice of journal and choose the appropriate degree course.

Declaration

The first page inside the cover must provide a brief declaration of the contributions made by you and by others to your project. Key points to address are:

- Was the data provided to you or did you collect or assemble it?
- Were you responsible for data processing or cleaning, if required?
- Were any mathematical models developed by you or by your supervisor?
- What role, if any, did your supervisor play in developing the analyses presented?

Layout

Print your thesis double-sided on A4 paper. The main body of the text should be printed using 1.5 line spacing and page numbering should be used. The thesis margins should be at least 2 cm and the main text font size should not be smaller than 11 point.

Binding

Use a ring binder to bind the thesis. You should include a transparent plastic sheet in front of the cover page and use a plain white A4 sheet of card at the back. You will be provided with printed cover sheets with the college crest and logo.

Number of copies

You *must* supply five bound copies of your thesis: one for the external examiners, which is later put in the Library, and one each for your supervisor and the internal marker and assessor. The final copy is your own, which you *must* take with you to your internal and external viva examination.

You must also submit an electronic version of your project report on Blackboard and your class git repository. This should be identical to the printed version, including the pagination and cover sheet.

3.5.1 Thesis content guidelines

The following guidelines on content include top tips from Andy Purvis, author of over 100 scientific papers and referee of many more.

Introduction

A good introduction should leave the reader with a clear idea of the problem to be tackled and looking forward to the more detailed sections to follow. It should include a section on the general way the problem has been approached. An essential concluding part of the introduction is to clearly define the aims of the research project and any hypotheses tested. Also, think about:

- *What is this paper about? (i.e., the broad area, big picture) Why is that interesting?*
- *Given its so interesting, why dont we know the answer?*
- *So, what is this about, more specifically? What are hypothesised to be the important things?* Build from the most general and fundamental hypotheses to the most refined or tenuous ones.
- *How, roughly and briefly, will you go about testing these hypotheses?* Why are you using this system? What approach will you use?
- State clearly what your hypotheses are. These are not usually stated explicitly in a paper.

Methods

This should contain details of any methods used extensively during the project, layout of field experiments, methods of statistical analyses etc. You can use subheadings for different procedures or tests. If field work is done, a general description of the study area may be included here. Extra methodological details can be placed in appendices. The golden rule is that the reader should be able to repeat what you did, should they so wish. The other rule – more important for your project than in a paper – is that you describe in enough detail to show youve understood what you did.

You should feel free to use subheadings in your methods and results to help organise different parts of your project. If so, keep the same order of the different parts of the project in all of your sections: the methods for testing each hypothesis and the results of those tests are described in the same order as the hypotheses are described in the introduction. Also, think about:

- What is the overall design of the study?
- What are the variables and how do they relate to the hypotheses?
- How did you get the data?
- What are the characteristics of the data set / experiment – how many observations, how many replicates etc.
- General procedures, if any, that are true in all of the analyses (e.g., transformation of data, model checking, how models were compared)

- How did you test the hypotheses, in the logical order outlined in the introduction (i.e., from the general to the specific)? Make sure you show that your tests are appropriate.

Results

Describe your results in a logical order: this may not necessarily be the order in which you did the experiments. Briefly summarise the main results at the end of each main experiment or sequence of associated experiments. Do not duplicate results – put a table or a graph but not both unless the two methods of presentation demonstrate different points of importance. You must refer appropriately to figures or tables in the text and remember to emphasise and perhaps quote significant results. In particular, think about:

- What were the results of your hypothesis tests, in the order you describe them in the Methods?

Discussion

This should attempt to tie together the results, what they indicate in a broader context, the extent to which the original aims have been satisfied and what future work is suggested. Return to and address the ideas raised in the introduction. In particular, think about:

- *Whats the main thing we know now that we didnt know before?*
- Whats the chain of logic and results that means we know it?
- *How does this affect our and other scientists view of the world? What are the implications?*
- What are the implications of the intermediate steps in the chain towards the main thing?
- What are the caveats that apply to this study? (Leave out caveats that apply to all studies.) What might be done about them? (Very important in a project write-up What would you do differently if you were doing the project again or had more time?)
- What future work could build more broadly on what weve found?
- A nice wrap-up, emphasising how this study in this system is of interest to people who work on other things, or other systems.

Abstract

Now, and only now, write the abstract, making sure it includes the key point from each of Andys top tips above that are *emphasized*. Dont rush the abstract – it is your first opportunity to tell a reader about the research and a clear, concise abstract sets them up to understand your work!

References

Make sure all cited references appear in this list at the end of the thesis using the standard style from your chosen journal. With /LaTeX comes BibTex, which you should use. If, in the horrible scenario, you decide to use something like MS Word,it is *highly* recommended that you use bibliographic software (e.g. Mendeley) to manage and format your citations. In particular, note that you can use Mendeley to output *.bib files that you can use in Latex.

Appendices

Large sets of data (e.g. census results, raw' experimental results) should go in an Appendix if these are of value, e.g. indicating an interesting range of variation. All summary tables or graphs and outline results of analysis should be put in the text. Any useful parts of the study not directly relevant to the main theme may also be put in an Appendix (e.g. taxonomic descriptions and drawings in an otherwise ecological study).

Computer Programs

If the program has been published, cite the reference, include it in the reference list and provide a brief outline of the methods it uses. If you are using a program or code generated for the project then a more complete description is needed in the main text. You should provide the code used

in an appendix and consider providing a flow chart and usage notes to help interpretation. You should take care to define all the input variables used in the program.

Figures

You should prepare figures to the same standard required for publication. All journals provide advice on preparing figures for publication, so do look at the advice to authors pages for your chosen journal. All figures must be numbered and have a caption that is sufficiently detailed to explain the main features of the content by itself. All figures *must* be referred to in the main text of the thesis. Put the figures in appropriate points in the text, close to the text that refers to them. In particular:

- The resolution of your figures is crucial. For plots, try to use vector image formats (exported as svg, pdf, or eps) and not bitmapped formats like JPG and TIFF. Standard /LaTex documents typically allow *.eps or *.pdf figures to be inserted. using the freely available (and very capable!) vector graphics program Inkscape to "fine-tune" your figures is often a good idea. Inkscape will also allow svg's to be exported in a /LaTex compatible format (see the Inkscape documentation). For RASTER graphics, the freely available GIMP editor works very well. When using Word 2007 on PC (heavens forbid!), figures in Windows Metafile format are the most reliable vector format. For Word 2011 on Mac, figures in PDF format should give a good result. If you do have to use bitmaps, make sure they are at a high resolution (300 dpi or more) – this can be particularly important if you need to present line drawings or photographs of specimens or equipment.
- Plots are all about the data, so reduce margins and maximise the space in the figure for showing the data.
- Create the figure at the right size – when it is included in your thesis are all the axis labels and text going to be clearly legible.
- Avoid 'chartjunk' (google Edward Tufte!) – and avoid superfluous lines, legends and titles along with 3D effects.

Tables

Each table should be numbered, have a full descriptive caption and again *must* be referred to in the main text. Column headings should state units of measurement. Avoid large, complicated tables in the main thesis and if you have a large body of numerical data put it in an appendix.

4 Masters Programme regulations

4.1 MSc course regulations

The following notes outline the Department of Biological Science's rules for awarding MSc Degrees (2008 edition updated September 2011). The University's General Regulations and the College's Special Regulations should be consulted in all cases of doubt.

Course credit requirements

The scheme outlined is that accepted formally by the University and by Imperial College London for the award of *MSc in Computational Methods in Ecology and Evolution.*

[All modules are compulsory; see section 2]

Class Boundaries

The final degree mark will be used to classify MSc degrees according to the following notional boundaries:

Distinction	70% or more
Merit	60% or more (less than 70%)
Pass	50% or more (less than 60%)
Fail	below 50%

These boundaries are moderated at the Examiners' Meeting to take account of your performance over the year and any difficulties you may have experienced (such as illness).

Assessment of Performance

Taking the Course

The word 'take' in the context of these regulations means that you have attended the timetabled parts of a course (unless prevented by illness), sat its examination, submitted the coursework specified for it and completed a research project.

Illness or bereavement

A student who is unable to complete his or her exams because of illness or the death of a near relative must either sit the examination at the next normal time or have a special paper set for them. Original documentation, e.g. doctors letter, should be provided as supporting evidence by the student at the earliest opportunity.

Taught Modules

All modules are assessed by a combination of a written examination and coursework, consisting of assessed computer practicals, reports or practical class write-ups.

Coursework

Receipt of marks for assessed coursework is absolutely dependent upon you delivering the work by the stated deadlines (making due allowance for sickness). Marks for assessed practical class reports can be gained only if you attend and perform the relevant practicals.

Research Projects

Assessment will be by written report and viva voce after the completion the project.

a) The Supervisor will complete Form I on your performance during the project, sending the mark direct to the Examinations Officer. This assessment is worth 20% of the final project mark).

b) Your project report will be marked by two internal examiners: a Marker who is a member of staff familiar with the relevant scientific field and an Assessor who is a member of staff marking many masters projects. Exceptionally, advice may be sought from scientists of equivalent standing from outside the Division;

c) The Marker and Assessor will both mark the thesis (report) and agree a mark (worth 60% of the final project mark).

d) The Supervisor and Marker and Assessor should each add a written justification of their marks to Forms I and II, to inform the External Examiners.

e) The Marker and Assessor will viva the student and assign a mark based on the students performance in the viva (worth 20% of the final project mark).

f) In the case of the Marker and Assessor differing in 10% or more in their mark, a third person, usually one of the Course Directors, will also assess the thesis and a thesis mark will be assigned based on agreement among the three markers.

External Vivas

Each candidate will be interviewed on his/her project by the External Examiner, the purpose being to reveal any problems the candidate may have had with the project, and to probe their understanding of the research they undertook. There is no mark attached to the viva with the external examiner, but the examiner will take part in moderation discussions and use the feedback from students in assessing the quality of the course.

Resit Examinations a) If you should fail the examination you are entitled to resit it the next two times it is offered;

b) if the coursework element failed to reach the threshold 50% mark, whether through inadequacy or lateness of submission, the student will normally be asked to repeat the specific failed course components (i.e. take them again);

c) a candidate who has attended most of a course but fails its coursework element because of ill health or bereavement will normally be allowed to resubmit the relevant coursework by a new deadline;

d) a candidate who has taken a course but fails to sit its exam because of ill health or bereavement will normally be allowed to carry over their coursework mark for that course to when they next take the exam.

Rules a) All elements of the assessment must be passed before a degree of MSc can be recommended.

b) To pass the taught course element, the aggregate marks for both the coursework and the examination components must be above 50%, as well as receiving an aggregate mark for the taught course above 50%;

c) If you fail the taught course, then you would normally resit any failed exam papers the following year. If you fail the coursework component of the taught course you will be allowed to resubmit the failed coursework if it is deemed to be appropriate;

d) To pass the project element of the course you must obtain a mark of 50%;

e) If you fail the research project or the coursework component of the taught course then you would normally retake the course the following year.

f) All students must attend a viva by the External Examiner.

g) Project reports normally to be submitted in early September – vivas with the External Examiner are in late September prior to the Examinations Board Meeting.

h) Only when a detailed case has been made and accepted by the Board will candidates be moderated into a different degree class from that associated with their aggregate final mark. In such cases, the Board may be guided by a notional Grey Area (up to and including 2% below the threshold mark) within which the degree class might be moderated.

i) To achieve a Distinction, candidates should normally get 70% overall. Additionally, at least two of the three marks (for the project element, the coursework component of the taught course element, and the exam component of the taught course element) should be at least 70% and none should be less than 60%. To achieve a Merit, candidates should normally get 60% overall, with at least two of the three marks (for the project element, the coursework

component of the taught course element, and the exam component of the taught course element) being 60% or more.

j) Course convenors and project supervisors have a responsibility to notify the Examination Officer of exceptional circumstances known to them that might have affected the course mark given to a candidate; likewise personal tutors must record the existence of any medical or personal problems that might have affected performance in examinations or assessed coursework, and notify the MSc Office. All such circumstances must be made known to the Chair prior to the meeting of the Board of Examiners so that a preliminary assessment can be made of their likely effect, and additional information sought where necessary.

4.2 MRes course regulations

The following notes outline the Department of Biological Science's rules for awarding MRes Degrees (2008 edition updated September 2011). The University's General Regulations and the College's Special Regulations should be consulted in all cases of doubt.

Course credit requirements

The scheme outlined is that accepted formally by the University and by Imperial College London for the award of *MRes in Computational Methods in Ecology and Evolution.*

[section 2 lists the required modules]

Class Boundaries

The final degree mark will be used to classify MSc degrees according to the following notional boundaries:

Distinction	70% or more
Merit	60% or more (less than 70%)
Pass	50% or more (less than 60%)
Fail	below 50%

These boundaries are moderated at the Examiners' Meeting to take account of your performance over the year and any difficulties you may have experienced (such as illness).

Assessment of Performance

Taking the Course

The word 'take' in the context of these regulations means that you have attended the timetabled parts of a course (unless prevented by illness), sat its examination, submitted the coursework specified for it and completed a research project.

Illness or bereavement

A student who is unable to complete his or her exams because of illness or the death of a near relative must either sit the examination at the next normal time or have a special paper set for them. Original documentation, e.g. doctors letter, should be provided as supporting evidence by the student at the earliest opportunity.

Research Projects

Assessment will be by written report and viva voce after the completion of each of the two projects in March and September.

a) The Supervisor will complete Form I on your performance during the project, sending the mark direct to the Examinations Officer. This assessment is worth 20% of the final project mark).

b) Your project report will be marked by two internal examiners: a Marker who is a member of staff familiar with the relevant scientific field and an Assessor who is a member of staff marking many masters projects. Exceptionally, advice may be sought from scientists of equivalent standing from outside the Division;

c) The Marker and Assessor will both mark the thesis (report) and agree a mark (worth 60% of the final project mark).

d) The Supervisor and Marker and Assessor should each add a written justification of their marks to Forms I and II, to inform the External Examiners.

e) The Marker and Assessor will viva the student and assign a mark based on the students performance in the viva (worth 20% of the final project mark).

f) In the case of the Marker and Assessor differing in 10% or more in their mark, a third person, usually one of the Course Directors, will also assess the thesis and a thesis mark will be assigned based on agreement among the three markers.

External Viva

After the second project in September, you will be given a viva by one of the external examiners. External examiners will be given your project reports shortly after your internal viva. This external viva will contribute to moderation of the marks awarded by the Divisions assessors and examiners and determine whether students should be awarded a merit or distinction.

Rules

a) All elements of the assessment must normally be passed before a degree of MRes can be recommended.

b) If a research project mark is a fail then the student would normally retake the project the following year.

c) All students must attend a viva by the external examiner.

d) Project reports are normally to be submitted in March and September and vivas with the internal and external examiners are in late September prior to the Examinations Board Meeting.

e) Only when a detailed case has been made and accepted by the Board will candidates be moderated into a different degree class from that associated with their aggregate final mark. In such cases, the Board may be guided by a notional Grey Area (up to and including 2% below the threshold mark) within which the degree class might be moderated.

f) To achieve a Distinction, candidates should normally gain 70% overall, and at least 60% for both projects. To achieve a Merit, candidates should normally gain 60% overall. To achieve a pass, candidates should normally gain 50% overall, and at least 50% on both projects.

g) Course convenors and project supervisors have a responsibility to notify the Examination Officer of exceptional circumstances known to them that might have affected the course mark given to a candidate; likewise personal tutors must record the existence of

any medical or personal problems which might have affected performance in examinations or assessed coursework, and notify the MSc Office. All such circumstances must be made known to the Chair prior to the meeting of the Board of Examiners so that a preliminary assessment can be made of their likely effect, and additional information sought where necessary.

4.3 Regulations for Students

This reproduces the July 2012 version of the Imperial College London Regulations for Students. These regulations, along with Academic and Examination Regulations are available from http://www3.imperial.ac.uk/registry/proceduresandregulations/regulations

1. All registered students of the College are subject to the provisions of these Regulations for Students, the College Academic Regulations, and such other Regulations and Instructions for Students as the College may from time to time approve.

2. Any student whose sessional fees or whose residence charges (including charges made by the Du Cane Housing Association) have not been paid in full will not be allowed to proceed to the next year of the course and will be required to withdraw from the College. If any fees or charges are still unpaid at the time when a student enters for the last examination necessary to qualify for the award of a degree/diploma, the award will not be conferred and no certificate in respect of the award will be issued until the debt has been paid in full.

3. Any student wishing to occupy residential accommodation provided by, or on behalf of, Imperial College will be required to abide by the terms and conditions of the Licence. Acceptance of an offer of accommodation will signify acceptance of such terms and conditions.

4. Every registered student of the College is automatically a member of Imperial College Union unless, under the provisions of the Education Act 1994, a student has formally opted out of student union membership by recording that decision with the Academic Registrar in the manner prescribed.

5. Student disciplinary offences of a non academic nature are dealt with under a code of procedure agreed by Imperial College Union and approved by the Governing Body. In the case of serious offences, this may involve the suspension and/or expulsion of the student from the College. Students must not engage in any conduct which causes harm or unreasonable disturbance to students, staff, neighbours or visitors to the College, or damage to any property of the College or its students, staff, neighbours or visitors, or engage in any activity or behaviour which is likely to bring the College into disrepute. Illegal acts on or near College may also constitute offences under these College Regulations for students.

6. Candidates for the PhD or MPhil degrees are required by the College regulations to give conditional authority for their thesis or dissertation to be made available for public reference. Candidates who wish to retain personally, for a limited period, the sole right to grant permission to consult, borrow or copy their work must obtain the agreement of their supervisor and the Graduate School Committee. Approval will be given only in special circumstances and for a period not exceeding two years. Acceptance of a place as a research student at the College is deemed to imply acceptance of these conditions.

7. Undergraduates must inform their Senior Tutor and postgraduates their Postgraduate Tutor if they are absent from College for more than three days during term. If the absence is due to

illness a medical certificate must be produced after seven days. If an examination is missed on account of illness a medical certificate must be produced immediately.

8. A student who contracts an infectious or contagious disease may be required to present a medical certificate acceptable to the College Health Service, indicating freedom from infection, before resuming attendance at the College.

9. The College may require a student to be assessed by the College Health Service, or other appropriate medical practitioner approved by the Health Service, if there is reason to believe that the students state of health makes him/her unable to pursue his/her studies, or causes disruption to other members of the College, or causes or has the potential to cause harm to him/herself or others. If the medical assessment confirms that it is not in the interests of the student or the College that the student should continue his/her programme of study the Head of Department shall consult the College Tutors and, taking into account their advice, may suspend the student until he/she is fit to continue his/her studies or require the student to withdraw from the College. A student who refuses to undergo assessment may be suspended until such time as a medical practitioner acceptable both to the student and the College has assessed the student and confirmed in writing that the student is fit to resume study.

   A student who is required to withdraw has the right to appeal against the withdrawal decision but not against the results of the medical assessment on which the decision is based. The student may, however, request that a second medical assessment be obtained from a medical practitioner approved by the College Health Service. The responsibility for hearing and deciding upon appeals is vested in the Senate and is delegated by the Senate to Appeal Committees, whose decisions are final.

   A student who is suspended will be regarded as having taken an interruption of studies, and will be required to provide medical evidence as to fitness to return to study in accordance with the conditions attached to the granting of interruption of studies.

10. No work involving ionising radiation may be carried out in any part of the College except in accordance with the current edition of the Imperial College Local Rules for Safe Working Practices with Ionising Radiation (Second Edition Spring 1991).

11. Students who make use of College Computing facilities are required to familiarise themselves with and to abide by the current edition of the Imperial College Information Systems Security Policy and Codes of Practice and Guidelines.

12. Computer misuse will be regarded as a serious offence and will be dealt with under the College Disciplinary Procedure or, where appropriate, under the provisions of the Computer Misuse Act 1990.

13. Students who are authorised, as part of their studies, to make use of data and personal data as defined under the Data Protection Act 1998 are required to familiarise themselves with, and to observe the provisions of, the Act. Further details are available from the College Data Protection Officer.

14. All students must familiarise themselves and comply with the Colleges Student Intellectual Property Policy.

15. Students must ensure that their personal data on student e-service is kept up to date at all times including any change in their home or term time address or their emergency contact details.

16. Where a student has a pre-existing relationship, or develops a relationship during the course

of study, with a member of staff such that there is a potential conflict of interest, especially with regard to the students assessment, the student and member of staff must declare this in confidence to the Head of Department at the start of the course of study or at the point at which the relationship has started if this is during the course.

4.4 Plagiarism and cheating

You are reminded that all work submitted as part of the requirements for any examination (including coursework) of Imperial College must be expressed in your own words and incorporate your own ideas and judgements. Plagiarism, that is, *the presentation of another persons thoughts or words as though they were your own*, must be avoided, with particular care in coursework, essays and reports written in your own time. Note that you are encouraged to read and criticise the work of others as much as possible. You are expected to incorporate this in your thinking and in your coursework and assessments, but you must acknowledge and label your sources.

Direct quotations from the published or unpublished work of others, from the internet or from any other source, must always be clearly identified as such. A full reference to their source must be provided in the proper form and quotation marks used. Remember that a series of short quotations from several different sources, if not clearly identified as such, constitutes plagiarism just as much as a single unacknowledged long quotation from a single source. Equally, if you summarise another persons ideas, judgements, figures, diagrams or software, you must refer to that person in your text and include the work referred to in your bibliography. Departments are able to give advice about the appropriate use and correct acknowledgement of other sources in your own work.

The direct and unacknowledged repetition of your own work which has already been submitted for assessment can constitute self-plagiarism. Where group work is submitted, this should be presented in a way approved by your department. You should therefore consult your tutor or course director if you are in any doubt about what is permissible. You should be aware that you have a collective responsibility for the integrity of group work submitted for assessment.

The use of the work of another student, past or present, constitutes plagiarism. Where work is used without the consent of that student, this will normally be regarded as a major offence of plagiarism. If in doubt, please ask one of the lecturers or course directors for advice on what constitutes plagiarism.

Failure to observe any of these rules may result in an allegation of cheating and may result in a penalty being taken against any student found guilty of plagiarism. Cases of suspected plagiarism and of other forms of cheating will be dealt with under the Colleges Cheating Offences Policy and Procedures: http://www3.imperial.ac.uk/registry/exams/examoffences.This link also provides access to the College's statement on Academic Integrity in Examinations and Assessment.

4.5 Student Complaints and Appeals

Imperial College aims to give the highest specialised instruction and service to all its students, however, in some cases it recognises that students may not always be satisfied with the service that they have received. If you wish to raise a concern, you should first seek advice from your student representatives and raise the matter with the individual concerned. If you are not satisfied with the outcome, you should consult the Colleges Registry website which provides clear and consistent

procedures that indicate how you can take your comments further: http://www3.imperial.ac.uk/registry/proceduresandregulations/policiesandprocedures/complaintsappeals

4.6 College Principles

The following web page defines the guiding principles of the Imperial community. The principles were developed by academic and support staff in partnership with undergraduate and postgraduate students and will be reviewed annually; see http://www3.imperial.ac.uk/students/ourprinciples