CONSERVATION BIOLOGY

M.Sc. Course Handbook

UNIVERSITY OF CAPE TOWN

THE PERCY FITZPATRICK INSTITUTE is recognised as a Centre of Excellence by the South African Department of Science and Technology and the National Research Foundation. It is part of the Department of Zoology at the University of Cape Town (UCT), with a focus on research and post-graduate education. Although the Institute focuses primarily on ornithological research, the Conservation Biology MSc Programme is broad-based, drawing on teaching expertise from across the academic spectrum at UCT and further afield.

Nestled on the slopes of Devil's Peak, UCT overlooks the cosmopolitan city of Cape Town. It is South Africa's oldest university, and is one of Africa's leading teaching and research institutions. It has more than 15 000 undergraduate and 6000 post-graduate students, and attracts a large number of international students, with more than 4000 students from over 100 countries.

UCT has a strong tradition in conservation research. Situated in the heart of the Cape Floristic Kingdom, it is well placed for research in two global biodiversity hotspots, the Fynbos and the Succulent Karoo. In a 2008 review, UCT ranked top among Southern Hemisphere institutions in terms of the impact of its conservation research, equivalent to the fourth-placed institution in North America.

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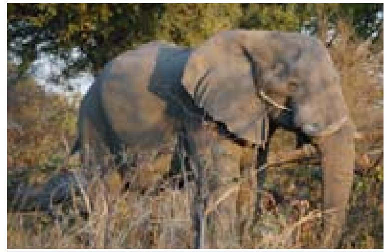


CONTENTS OF COURSE

UNIVERSITY OF CAPE TOWN

introduction

Conservation biology is the study of how best to sustain and manage linked systems of people and nature. It is a new science that builds on a range of existing disciplines, ranging from ecology and evolution to sociology and economics. Conservation biology is becoming increasingly important for human wellbeing as the impacts of human activities on the biosphere become more significant.

A programme in Conservation Biology was established at the Percy FitzPatrick Institute in 1991 to educate students and conservation practitioners in the fast developing field of conservation science. The FitzPatrick Institute is housed within the Department of Zoology in the Faculty of Science at the University of Cape Town. The Fitztitute promotes and undertakes scientific studies, mainly involving birds that contribute to the theoretical and practical development of ecology, evolution, and conservation biology. The central focus of the conservation biology programme at the Fitztitute is an intensive MSc degree comprising 7 months of coursework and a 6-month individual research project.

South African society has been through a set of massive changes in the last 20 years; much of the resulting dynamism and openness to new ideas is mirrored in South African conservation. The discipline of conservation biology is undergoing a similar paradigm shift, in which notions of preservation and paternalism are being replaced by an ethic that recognizes the complexity of linked social and ecological systems and the critical need for solid interdisciplinary research. The Percy FitzPatrick Institute is contributing to this disciplinary transformation through research and teaching, while also collaborating with others to support sound, action-oriented science.

aims & objectives

Our teaching philosophy follows the observation of William Butler Yeats: "Teaching is not the filling of a bucket, but the lighting of a fire". The general aims of the Conservation Biology MSc programme are to produce graduates with a broad understanding of conservation issues and to provide them with the scientific background and tools to be able to analyse and solve practical, conservation-related problems. A synthetic, holistic approach is encouraged to problem solving through exposure to a variety of disciplines. Emphasis is also placed on developing oral and written communication skills. We have found that this broad approach to postgraduate education produces graduates who compete successfully in the job market and go on to make a difference in the field. Although emphasis is given to solving conservation challenges in an African context, students are provided with a broad-based education that will stand them in good stead throughout the world. In 2007, in a study published in Conservation Biology, the University of Cape Town was ranked equivalent with the fourth highest North American institution in terms of the impact of its conservation-related research publications.

who is eligible to enrol?

Applicants to join the course must hold at least a BSc Honours (or equivalent qualification). Applicants will be drawn mainly from two groups: young people who have just obtained a degree and wish to become conservation biologists, and qualified, practising nature conservators who wish to update and/or expand their knowledge of the modern theory and practice of conservation biology. The course is an intensive one, and only a limited number of participants are accepted each year. Details regarding registration fees, and approximate accommodation and living expenses in Cape Town are available on request. Prospective applicants should apply to the Director, FitzPatrick Institute, University of Cape Town, Rondebosch, South Africa 7701. Applications must reach this address before the end of August each year to be considered for a place on the course the following year. Applicants from outside South Africa are encouraged to apply early so that they have plenty of time to apply for funding and study visas. Applicants should please consult the Checklist for Applicants for the relevant documents and information that must accompany applications.

structure of the course

The coursework component is intensive and exacting, but represents a huge learning opportunity and the chance to interact with a wide range of excellent conservation biologists, both within and outside the university environment. It includes 7 months of intensive coursework and a 6-month individual research project.

Coursework consists of a series of modules, each taught by experts in their field. Modules typically include lectures, practicals, essays, discussion groups, seminars and field excursions. Reading lists are provided. Emphasis is placed on African examples and case histories.

Appropriate computer courses are available for participants who do not have the relevant skills, but applicants are encouraged to develop at least rudimentary computer skills before enrolling. The Institute has excellent computer and library facilities.

Modules fall into four different sections: an introduction, an ecological core, an interdisciplinary core, and a synthesis. Each module lasts between one and four weeks.

The **INTRODUCTION** occupies the first three weeks and includes orientation, an overview of conservation biology, and a week studying the philosophy of science.

The **ECOLOGICAL CORE** includes modules in community ecology, population ecology, biodiversity basics, aquatic ecology, molecular ecology, disturbance and restoration ecology, and invasion biology.

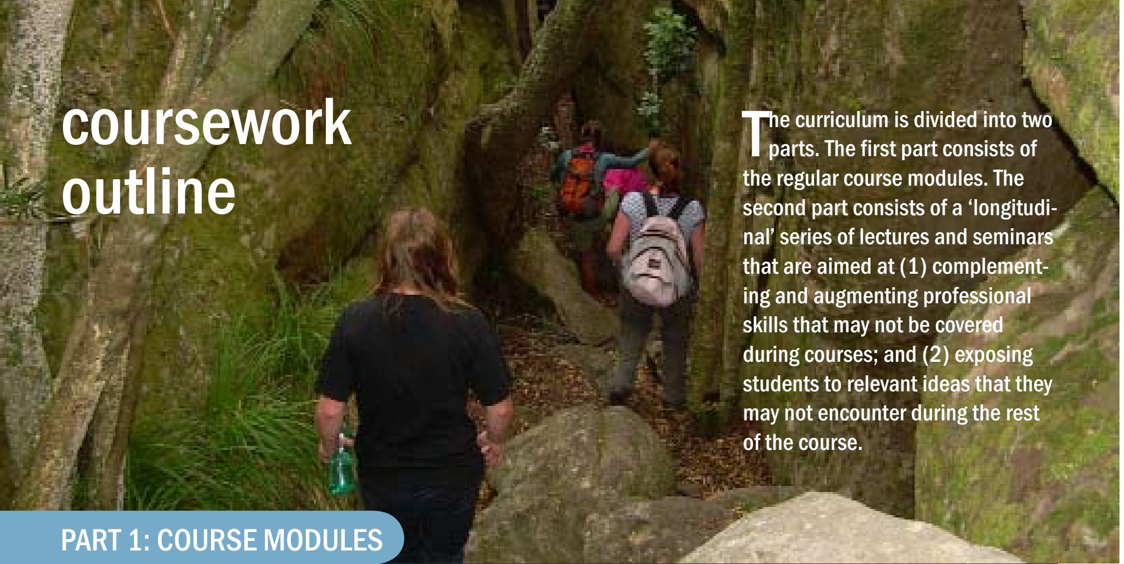
The **INTERDISCIPLINARY CORE** includes modules in complex systems concepts, landscape ecology and conservation planning, climate change, resource economics, and societies and natural resources.

The **SYNTHESIS SECTION** consists of a section on decision support systems, discussion of "emerging issues" and a review of the course.

Modules are complemented by regular Wednesday afternoon seminars, which cover additional topics and provide students with the opportunity to meet current conservation practitioners. The coursework component of the course starts in mid-January and the modular component is completed by the end of August.

From September to mid-February, students conduct and write up research culminating in a paper on a research topic chosen by the student and supervised by a member of academic staff. The research report is in the format of a manuscript suitable for publication, which should facilitate the dissemination of results. It must be stressed that these research reports are not equivalent to dissertations produced for the award of an MSc based on a thesis alone.

Modules are examined in April-May and August. Exams are 'open book', and emphasize the solving of practical problems with a full range of resources available to students. The MSc degree is awarded to students who achieve grades in excess of 50%, and is awarded with distinction if grades exceed 75% for both the coursework and project components of the course. There is a minimum requirement for the first examination to allow students to continue with the course.



coursework outline

The curriculum is divided into two parts. The first part consists of the regular course modules. The second part consists of a 'longitudinal' series of lectures and seminars that are aimed at (1) complementing and augmenting professional skills that may not be covered during courses; and (2) exposing students to relevant ideas that they may not encounter during the rest of the course.

PART 1: COURSE MODULES

SECTION	WEEK	MODULE NAME	LIKELY DETAILS
Introduction: *Conservation contextualized*	1	**Orientation** Peter Ryan	Use of library, basic skills, etc.
	2	**Overview** Norman Myers	Conservation in a global context
	3	**Philosophy of Science & Conservation Ethics** David Cumming	Limits of hypothetico-deductive science, less predictable social/ecological interactions, emergent properties
Ecological core: *Ecological foundations of conservation science* *Revisits key concepts from a conservation-oriented perspective*	4-5	**Community Ecology** Phil Hockey	Biological diversity, interspecific competion, niche concepts, trophic cascades, ecosystem engineers, some models
	6-7	**Population Ecology** Peter Ryan	Extinction risk, threat categories Demography and PVA
	8-9	**Biodiversity Basics** Tim Crowe	Units of biodiversity, definitions, basic evolutionary processes, macroecology
	10-11	**Ecosystem/Aquatic Ecology** Jackie King Colin Attwood	Nutrients, abiotic and biotic environment, biogeochemical cycles, nitrification, limnology Terrestrial vs marine approaches to conservation
	12	**Molecular Ecology** Jacqui Bishop	Genetic diversity, forensics, non-invasive sampling Gene flow and phylogeography
	13-14	**Disturbance & Restoration Ecology** Sue Milton	Fire, herbivory, invasive species, restoration
	15	**Invasive Species** John Hoffman, Dave Richardson	Biology of invasions Biocontrol and other control measures
	16	EXAM 1	

SECTION	WEEK	MODULE NAME	LIKELY DETAILS
Interdisciplinary core: *Conservation as a human-oriented discipline*	17	**Complex Systems Concepts** Graeme Cumming	Systems perspective on social-ecological systems Resilience, emergence, non-linearities, self-organization, etc.
	18-21	**Landscape Ecology, GIS & Conservation Planning** Graeme Cumming	Key concepts (scale, heterogeneity, stratification) and their application in conservation Key skills, especially GIS and conservation planning
	22	**Develop project proposals**	
	23	**Climate Change & Conservation** Phoebe Barnard, Guy Midgley	Climate change and its importance for people and ecosystems
	24-27	**Resource Economics** Jane Turpie	Ecosystem goods & services valuation (field based) Links to livelihoods & poverty Over-harvesting Pricing & globalisation – subsidies, easements
	28-30	**Societies & Natural Resources** Sheona Shackleton Michael Schoon	Governance, institutions, livelihoods, land tenure, social networks, policy, management & implementation, resource access Ethical/cultural valuation Environmental law and policy, including international conventions & agreements
Synthesis	31	**Decision Analysis** Astrid Jarre	Decision support tools Facilitation and conflict resolution
	32	**Emergent Issues & Synthesis** Peter Ryan	Current 'hot topics' considered in light of course contents Review of the course
	33	EXAM 2	
	34	**Research project starts**	

PART 2: LONGITUDINAL SEMINAR SERIES

These sessions will occur on Wednesday afternoons between 2pm and 4pm. They will alternate conservation-focused topics with skills-building seminars. These may include some or all of the following:

- presentations – how to use visual aids (powerpoint) effectively
- paper writing
- paper submission
- literature searches
- grantsmanship and finding funding
- writing project proposals
- project management
- financial management
- media relations
- report writing
- reviewing papers/grants
- critical reviews of academic papers
- leading workshops/team building

selection criteria

We accept only 12-14 students each year into the conservation biology masters programme. There are often 2-3 times this many applicants each year, resulting in competition for places. In addition to academic ability, preference is given to candidates with experience in the conservation arena, particularly in an African context. Because of the intensive nature of the programme, students spend a lot of time working closely with their peers. Having students from a diversity of backgrounds contributes significantly to the success of the programme. Consequently we strive each year to select students that combine a mix of youthful enthusiasm and mature experience, as well as a mix of students from first and third world countries. The ideal class comprises roughly one third students from South Africa, one third from the rest of Africa, and one third from the rest of the world.

Since its inception, almost 200 students have graduated from the CB programme from more than 30 countries.

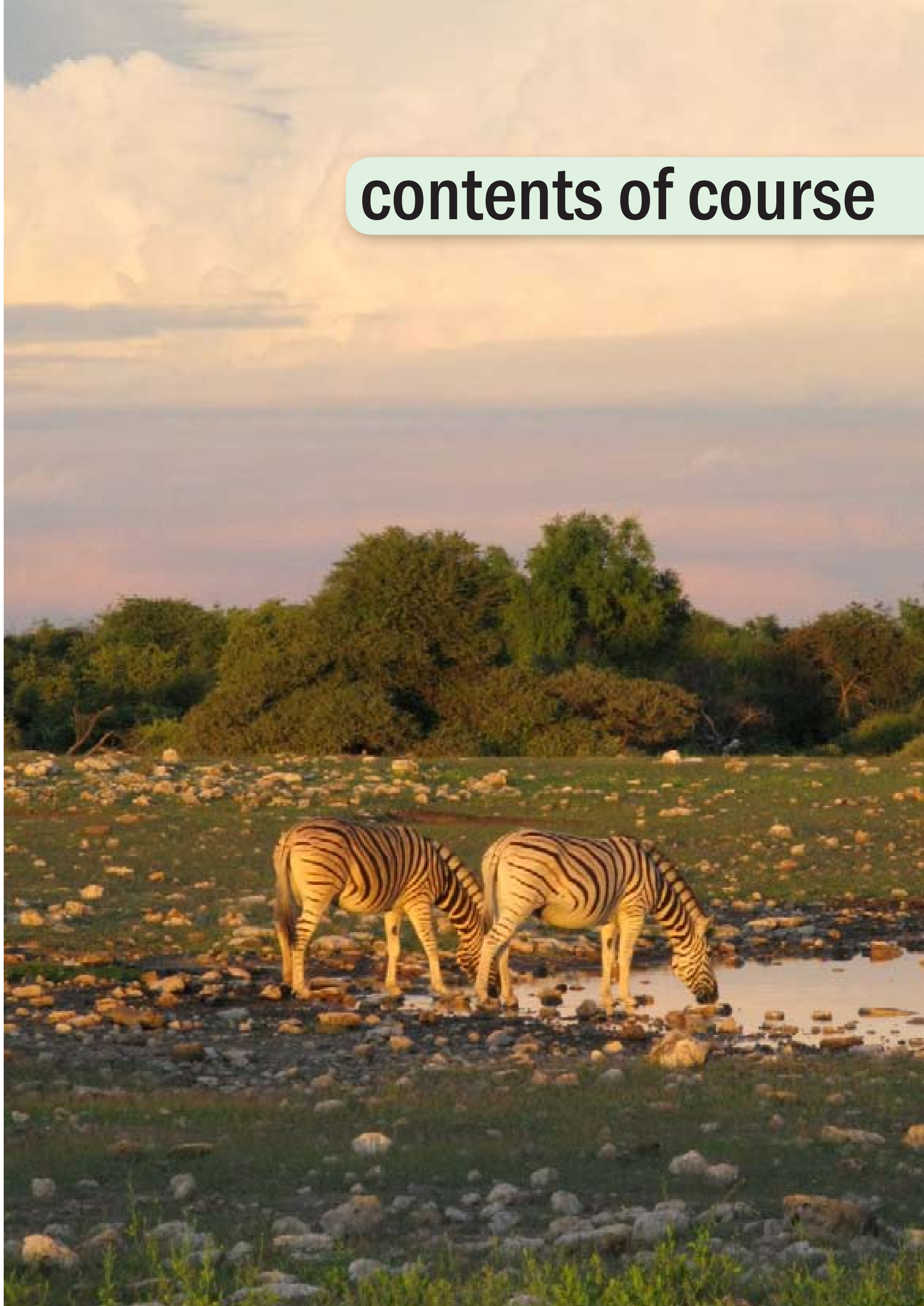
checklist for applicants

Applicants to the course, please check that you include all the following documents and information with your application. Please note that applications must reach the Percy FitzPatrick Institute by the end of August to be considered for the following year.

1. Letter of application to the Director, FitzPatrick Institute.
2. Full Curriculum Vitae giving permanent address and telephone/fax numbers, date of birth, full names, nationality, educational history up to present date, employment history (if any) up to present date, details of computer systems and software packages used to date, and details of any research publications.
3. Names, addresses, fax numbers, telephone numbers and e-mail addresses (if possible) of at least two referees who can comment on your academic ability, suitability for postgraduate study, and also give a confidential personal evaluation of your sense of initiative and computer literacy.
4. Undergraduate academic transcript showing marks for each course taken in each year. This should be a photocopy of the original, but the photocopy should have an original stamp certifying that it is a true copy of the original transcript. Certified copies of transcripts of any subsequent postgraduate qualifications should also be included here.
5. A certified copy of the original degree certificate (and any subsequent qualifications mentioned above).
6. A summary (1-2 pages, typed) outlining why you chose to apply for a place on the CB Course, what your long-term career aspirations are, and how you think the successful completion of the CB Course will benefit those aspirations.
7. Completed UCT admission forms (with the admission fee). This will be kept at the FitzPatrick Institute until the results of the Selection Committee are known. If successful, the forms (and fee) will then be sent to UCT Central Admissions Office for processing. This saves approximately one month in postal lags at a time when prompt communication becomes vital. Copies of UCT admission forms are available on request.
8. Please provide the Percy FitzPatrick Institute with details about where you are applying for funding. If appropriate, a letter of support can then be sent to them (if your application for a place is successful) to strengthen your funding application.

Address your application (or any queries) to:
The Director, FitzPatrick Institute, University of Cape Town,
Private Bag X3, Rondebosch 7701, South Africa
Tel. (+27-21) 650 3290/1, fax (+27-21) 650 3295
or e-mail the course coordinator at peter.ryan@uct.ac.za

contents of course



INTRODUCTION

overview

After a week of basic orientation and skills evaluation, the opening module of the course provides an overview of a number of the fields that make up the larger context within which conservation must find its "policy space". It is important the conservation biologists have a grasp of the multiple linkages between these fields and their sub-disciplines. The module therefore places much emphasis on lateral thinking and other prerequisites of the holistic approach.

The focal question for the module is how one might ensure that environmental science is implemented in policy making. A series of environmental problems are examined, including such topics as biodiversity hotspots, ecosystem services and their shadow-priced values, compromises to future evolutionary potential, population/poverty, over- and mis-consumption, water shortages, deforestation and desertification, energy deficits, and eco-agriculture.

The question is also posed as to why we allow such problems to arise in the first place. Factors at issue include political ignorance, the media, corporate oligarchies, special interests and lobbyists, government inertia, perverse subsidies, tramlines thinking and establishment values. Particular topics of relevance that are covered include

eco-economics, population/consumption, environmental security, environmental surprises/discontinuities, scientific uncertainty and public policy, the interdisciplinary animal, government and governance, and sustainable development.

philosophy of science

Conservation biology has been described as a 'crisis discipline'. Because of its action-oriented stance and potentially strong impacts on society, it is important to appreciate the diversity of its philosophical underpinnings. Conservation actions have a long history of causing controversy, particularly when they are perceived as discriminating against the rights of the rural poor. Both conservation science and conservation action are based on the world views, values and ethics of their proponents.

Much of the controversy surrounding conservation action, and the interpretation and application of relevant scientific results, stems from differing and poorly understood ethical and scientific standpoints and assumptions on the part of proponents. This is particularly true when the underlying philosophies and assumptions of proponents are neither apparent nor explicit. This module exposes students to aspects of the philosophy of science and ethics that will help them to appreciate the wider context of the conservation science that will follow during their course and the conservation practice in which they may become involved after graduating.

This one-week course introduces students to:

Philosophy of science, its history, changing approaches to science, and the problems of establishing causality in ecology and conservation.
The diversity of ethical and cultural approaches to conservation, the recent development of the environmental movement and some of the current underlying philosophical problems in environmental ethics.
Inter-disciplinarity and the links and interplay between science, ethics and advocacy.

ECOLOGICAL CORE

biodiversity and the units of conservation

Because the preservation and wise utilization of biodiversity is the essence of conservation biology, the fundamental point of departure for the course is to characterize biodiversity through the identification of its various components. More specifically, this module

- identifies the genetic, taxonomic, phylogenetic, ecomorphological, demographic, biogeographical and socioeconomic components of biodiversity;
- puts these components into a conservation context through the identification of key questions pertinent to each component;
- discusses various means of quantitatively summarising within- and between-area patterns of biodiversity; and
- outlines processes which produced these patterns.

Because this module lays the foundations for the course, coverage of components receiving greater attention in subsequent modules will be relatively brief.

The following major components of biodiversity are considered:

TAXONOMIC AND PHYLOGENETIC COMPONENTS

Biodiversity can be represented as variation in rates of speciation in pairs of phylogenetic lineages. For example, speciation has been frequent in the wildebeest/hartebeest group, but extremely limited in the monospecific Impala lineage. Key questions addressed in this part of the module relate to preservation of taxa which represent major lineages. For example, from a phylogenetic perspective, it might be better to conserve the Impala than one wildebeest species. Retention of these lineage representatives could be important in order to retain phylogenetic evolutionary potential. The taxonomic and phylogenetic components of the module focus on the theory and practice of biological classification, including exploring various species concepts and the use of cladistics.

ECOMORPHOLOGICAL COMPONENT

Biodiversity can be represented as variation in growth form (e.g. trees vs bushes) or guild composition (e.g. nectarivores, granivores, carnivores). Key questions asked by ecomorphologists relate to the functional roles and importance of species within ecosystems. For example, from a functional viewpoint, certain species (e.g. pollinators, predators or perch-providers) may be equivalent and others may be indispensable. Thus, a large capital outlay to preserve one of many ecomorphologically similar species (e.g. one of the hundreds of species of ericoid plants in the fynbos biome) would be difficult to justify, whereas a relatively ecomorphologically distinct species such as Protea nitida (the only protea to regenerate by stem resprouting) might warrant preservation. Other species which need to be given more importance in the ecomorphological component of any conservation exercise are keystone species (e.g. biotope modifiers, pollinators, dispersers of propagules, water-trapping or nutrient-cycling agents). Ecomorphological concepts are elucidated by applying multivariate numerical approaches (e.g. cluster analysis, factor analysis, discriminant functions analysis) to the study of anatomy, behaviour and ecology.

GENETIC AND DEMOGRAPHIC COMPONENTS

At its finest degree of resolution, biodiversity is represented by genetic variation within and between species and populations. The key questions addressed by the genetics component of this module relate to the possible harmful effects of loss of variation (known as inbreeding depression), 'pollution' of coadapted genomes by genetic material from translocated conspecifics (known as outbreeding depression), and the loss of genetic variation through failure to conserve genetically distinct geographical variants.

BIOGEOGRAPHICAL COMPONENTS

Biodiversity can be represented by other factors (e.g. endemicity, rarity, degrees of species turnover between adjacent biotopes and between similar, but geographically isolated biotopes). These need to be identified and assessed. One of the most important biogeographical questions to be addressed is whether there are indicator species (regardless of their need for conservation) whose survival is a strong predictor of the continued persistence of acceptable levels of biodiversity. Biogeographical assessments rely heavily on multivariate numerical approaches. Throughout the methodological portion of this module, the emphasis will be placed on the types of data which need to be collected and the analytical approaches necessary to transform those data into meaningful summaries. The mathematical and statistical theory underpinning the approaches employed will be discussed.

SOCIOECONOMIC COMPONENTS

Biodiversity can be represented by the variety of plants and animals needed by human societies for economic, agricultural, medicinal, cultural and hunting purposes. Many organisms also have symbolic value for man, which is reflected in their existence value.

PRODUCTION OF BIODIVERSITY

The ultimate processes which create evolutionarily significant variation are genetic mutation and recombination. The ultimate processes which partition that variation into the units of conservation are subspeciation (geographical variation) and speciation (usually via reproductive isolation). This module focuses on processes which promote subspeciation (e.g. selective gradients and partitioning of populations by biogeographical barriers), speciation (e.g. sympatric, parapatric, peripatric and allopatric) and hybridization.

demography and population viability analysis

Assessing extinction risk is a core goal of conservationists. This module considers the various factors, both stochastic (demographic, genetic and environmental) and deterministic (extrinsic factors such as exploitation, habitat loss, etc.) that combine to render populations and species vulnerable to extinction within the framework of Caughley's small population and declining population paradigms.

The module starts by tracing the history of the field, starting with the holy grail of a Minimum Viable Population, moving through the initial optimism regarding Population Viability Analysis as a quantitative tool, to the current position where demographic models are seen as valuable tools to support qualitative management decision rather than providing an absolute measure of extinction risk. Mirroring this attitudinal shift are changes in the IUCN Red Listing criteria.

Demography is the study of the age-specific rates of fertility and mortality, which determine whether a population or species is increasing, decreasing, or remaining stable. Change in population size is determined by the balance between birth and death rates. From the starting point of simple, deterministic Malthusian and logistic growth models, we add age structure and derive Leslie matrix models which are a useful starting point for any demographic investigation. We consider the family of Leslie matrices that describe pulsed reproduction in populations, and touch on the possibility of continuous reproduction. Concepts such as stable growth rate, stable age distribution, reproductive value and elasticity are explained and used to understand how populations perform. We then build simple harvesting or supplementation models, and consider the imposition of density dependence on age-structured models. Populations typically are in a state of dynamic equilibrium, driven by intrinsic and extrinsic stochastic events. It is important to distinguish short-term fluctuations from shifts in the equilibrium, but this is often hard to achieve in practice.

ESTIMATING POPULATION PARAMETERS

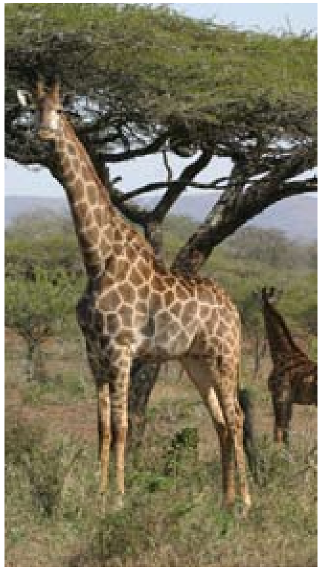
Building demographic models is fairly easy. The hard part is populating them with robust demographic parameters. Even simple, deterministic age-structured demographic models require a large amount of information. At a minimum one needs age-specific survival and fecundity estimates, but these entail a wealth of complexity. Survival may differ with sex and status (territory holder vs floater), whereas fecundity depends on the age at first breeding, the proportion of mature individuals that attempt to breed and the frequency of reproduction as well as crude birth rate and breeding success. Estimating demographic parameters typically requires that a large sample of individuals be individually-marked and their fates followed. In most cases, maximum-likelihood techniques have to be used to simultaneously estimate apparent survival and recapture probabilities. We have a brief introduction to these techniques in MARK. Depending on the distribution of sampling effort, following marked individuals may also give some idea about rates of emigration and dispersal distances. There are problems dealing with very old individuals, because too few marked animals attain old ages to allow robust parameter estimation. Students are alerted to the limitations of estimating parameters, and encouraged to be critical of input data when assessing published models.

ESTIMATING POPULATION SIZE

The other parameter that needs to be estimated is population size. This requires a defensible definition of a population (geographically, genetically or both). We have a quick refresher of census techniques for mobile and sessile organisms., and consider the difference between sampling error and population fluctuations. In many cases there are simply insufficient data to construct a demographic model. The best we can do is look for trends in population size over time, bearing in mind that changes in the size of a population may occur through changes in its range, density, or both. Simple regression analysis can be used to test for a population trend. However, if a significant trend is not discovered, we need to estimate the power of the test. This is dependent on the length of the data series, the magnitude of the hypothesised rate of change (either linear or exponential) and the coefficient of variation of the initial population estimate. We use Tim Gerodette's programme TRENDS to solve this tricky puzzle. In some instances the precision of the population estimate may be so poor that it is not possible to detect a change in population size until it is too late. Under these circumstances, other management techniques have to be employed to assess the health of a population.

ADDING STOCHASTICITY – POPULATION VULNERABILITY ANALYSIS

Adding stochasticity to demographic model adds a sense of realism by allowing one to explore a range of possible outcomes rather than a single, deterministic outcome. This lends itself to the concept of extinction risk, given that extinction often appears to be a stochastic process. Population viability analysis (PVA) models attempt to assess the probability of a population of a given size becoming extinct within a specified time frame under a defined set of possible future conditions. In conservation, we are often more concerned with exceptional population behaviours rather than the average. The range and distribution of individual variation in demographic performance is especially critical in the dynamics of small populations. Given



the limited time available for this module, we use VORTEX, a package designed to predict extinction risk in small animal populations using an individual-based, stochastic simulation. Students each conduct a PVA based on real data using VORTEX.

SPATIALLY EXPLICIT MODELS

Adding spatial structure adds further realism, but brings with it a heavy price in terms of additional data demands (and concomitant loss of model power). We consider spatially-explicit differences in demographic parameters, resulting in source and sink areas, as well as the concept of meta-populations, with movement between habitat patches. To build a spatially-explicit model, one needs patch-specific survival and fecundity data, as well as information on movement rates, and associated risks of mortality, between patches as a function of age, sex and status.

AN INTRODUCTION TO MODELLING

This module also introduces students to numerical modelling. A model is a simplified representation of an object, and can be explanatory or predictive. In the former case, models help to formalise our understanding of a system and to highlight gaps in our knowledge. Such models deliver qualitative rather than quantitative data, but can still be useful in guiding management actions, in addition to directing future research efforts.

Explanatory models also can be used to build null models and test the significance of patterns observed in nature. Predictive models tend to be more demanding on data, and great caution needs to be exercised in translating results from the simplified model world into the real world. The type of model used depends primarily on the question being asked and, to a lesser extent, the amount of data available. Students are exposed to deterministic and stochastic models, as well as population and individual-based models.

community ecology

Community ecology is a complex subject that fuels much debate in the scientific literature. Frequently, classical theories have proved inadequate to explain patterns observed in nature. The search for paradigms has become confounded by exceptions, and the dream of a unifying theory with global application is far from being realized. Escalating anthropogenic disturbance and exploitation of the natural environment have highlighted the importance of community ecology theory to conservation biologists. There is an ever-increasing emphasis on predicting the ecological consequences of certain actions; such prediction is not possible without an understanding of community dynamics.

This module provides an overview of recent thinking about community structure and dynamics, and of the theoretical and empirical bases that have underpinned modern concepts in the field. The first week of the 2-week module is devoted to theoretical considerations, and the second week is spent in the field examining how these ideas can be translated into problem solving. Underlying the entire module is the theme that defines community ecology, from identifying pattern, to inferring processes and making predictions.

THE THEORETICAL BACKGROUND

The theoretical component starts by addressing the factors and forces that structure communities. This theme is developed further through an exploration of community structure and stability, and examining how the way in which pattern is investigated will affect the interpretation of structure and stability, and organization and complexity. We explore food web structure, with particular emphasis on how community connectedness and compartmentalization affect cascades within communities. We consider why surviving interactions within communities are highly non-random and address the questions of whether different communities, containing different species, are functionally convergent.

A factor underlying many elements of conservation biology is scale – this is of paramount importance when considering patterns of species abundances and scales of diversity. We consider how communities are structured in terms of their relative species' abundances, and why. This incorporates species-abundance patterns, Island Biogeography Theory and an investigation of the differences between inventory and differentiation diversity concepts.

Diversity, however, can change over short time scales either as a result of intrinsic processes such as migration, or extrinsic forcing factors such as environmental crunches and climate change. We consider these variations and their implications, and also address the question of whether communities are saturated.

Modern conservation biologists are concerned about rapid changes in species' distribution patterns and the degree to which these are forced by anthropogenic factors. We examine patterns of distribution and endemism and explore why many of these apparently fail to conform to theoretical predictions. This in turn leads to consideration of the factors that drive local or regional variation in species' densities.

To round off the theoretical treatment of community ecology, we revisit two old 'chestnuts' – niches and guilds, and the thorny issue of competition as a force structuring communities. In terms of niches and guilds, we concentrate on how to decide when they are useful as concepts, and in the case of competition, emphasis is placed on distinguishing between intensity and importance.

In most years, the week of theory will include lectures from at least two specialists: in 2008 these included a guest lecture about the forces structuring diversification in bat communities, one which explored the importance of food-web modelling in managing marine ecosystems and a third which addressed the interactions between competition, predation and trophic cascades.

THE FIELD COMPONENT

This is the time for putting theory into practice! By way of example, the following field problems were tackled in recent years.

- Why has a dominant alien marine competitor has failed to remove a competitive subdominant from the shore?
- How does fire influences the interaction between fynbos and forest and how does this affect management decisions?
- Alien plant clearance programmes: why do the 'recovering' plant communities differ so dramatically and does this influence how alien clearance programmes should operate?
- Why is a rare, indigenous bird thriving only in disturbed, alien infested riverine forests?
- What will the Orange Kloof forests (heavily selectively logged by early settlers) look like in 150 years time?

ecosystem & aquatic ecology

INLAND AQUATIC ECOSYSTEMS

This 1-week module serves as an introduction to inland aquatic ecosystems such as rivers, lakes, floodplains and wetlands, and then focuses on rivers because they are the major target of water-resource development. As the end-point of drainage in the landscape, inland water systems have no true boundaries and are highly vulnerable to disturbance occurring anywhere within the landscape. Additionally, because they are the source of most of the world's fresh water, massive landscape-scale modifications of their flow regimes to suit human needs result in widespread and severe degradation of the rivers themselves. In developing countries, hundreds of millions of people are subsistence users of rivers and the development-driven changes generally impact them most whilst the advantages of development are felt elsewhere, such as in cities. As we enter a new era of dam building that is focused on developing countries, improved and more sensitive development and management of the world's rivers is vital, for we are now often losing more than we gain from water developments.

The module covers the nature and functioning of river ecosystems, the impacts of development on them and their subsistence users, and modern moves toward integrated water resource management (IWRM) that incorporate social and ecological issues at the same level of importance as engineering and economic issues.

Students will be introduced to the wide range of disciplines involved in IWRM with explanations of their role: hydrology, hydraulics, geomorphology, sedimentology, water chemistry, bank and channel vegetation, aquatic invertebrates, fish and fisheries, aquatic and water-dependent mammals, water birds, resource economics, macro-economics, sociology, public and livestock health, and intangible cultural and religious issues. Other topics covered include the goods and services provided by rivers, scenario creation, modern Decision Support Systems (DSS) and how to deal with data-poor situations.

Written and other research tasks and discussion groups focus on river and catchment signatures (the unique species composition of aquatic and riparian plant and animal communities in each river); the nature of and threats to a selection of the world's Great Rivers, how to communicate with engineers and political decision makers, and how to approach river management with a conservation perspective.

MARINE SYSTEMS

The science of conservation biology has until recently been concerned almost exclusively with terrestrial biodiversity and landscapes. This is changing rapidly, but the application of terrestrial paradigms and experience in the marine environments is inappropriate. Food web-structure, reproductive systems, dispersal, biogeography, the nature of threats, property rights and human values together dictate a new approach to conservation of the sea.

Human-induced extinction of marine species is extremely rare. Is this statement correct, and if so, why? The criteria used to list species as threatened or critical differ between land and sea. Fishing is regarded as the greatest threat to marine biodiversity. Fisheries management and marine conservation should be synonymous, but in practice the underlying philosophies differ widely. How are they being reconciled? There is widespread evidence of severe depletion of fish stocks by fishermen. Boom and bust is the norm for almost every fishery. Why are these trends universal, even where fishery management and marine science is well-funded? The cessation of fishing and marine protected areas are argued by many to hold the answer to stock recovery, but such remedies are difficult to implement and may have unexpected and undesirable consequences.

This module investigates the ecology of marine organisms, particularly those targeted by fisheries. Debates between fishery managers and conservationists usually hinge on the interpretation of poor data with low statistical power, and sophisticated mathematical and statistical models. Conservationists are frustrated by the lack of progress in the application of effective conservation measures. This module examines some the social, economic and political processes that have led to the deplorable state of many marine ecosystems, and considers alternatives.

There has been a massive recent push for the application of Marine Protected Areas. This conservation strategy has gained many localised successes, mostly in coastal waters, but their application in offshore environments and the high seas remains problematic. In addition, there is much disagreement over the value of such areas to fisheries. This module considers the processes by which marine protected area sites are selected and designed, and considers the circumstances in which they may be useful. Other forms of regulation are also considered, including the controversial practice of re-stocking.

Fish farming is seen by many as a relief for wild stocks, and an answer to the insatiable demand for seafood. Salmon has changed from a king's delicacy to the chicken of the sea. We look at the ecological, social and economic realities of replacing wild caught fish with farmed products.

conservation genetics

The subject of Conservation Genetics merges a number of biological disciplines including ecology, molecular biology, mathematical modeling and evolutionary systematics. It is both a theoretical and an applied science; theoretical approaches include those of classic Population Genetics, the emerging theories of Phylogeography, and Phylogenetic Systematics.

Population genetics is concerned with the application of genetic principles, such as Mendel's laws, to entire populations and attempts to understand evolutionary mechanisms at this level. An application is found in conservation biology which is ultimately concerned with maintaining the evolutionary

potential of species, not simply the preservation of reasonable numbers of individuals. To achieve this we need to know the amount and distribution of genetic variation in a species or population and, more importantly, to understand the underlying processes generating such patterns.

Classical population genetics, whether theoretical or empirical, focuses on the analysis of gene frequencies. Additionally, analysis of non-nuclear genes (mitochondrial or chloroplast), non-selected portions of the genome (DNA fingerprinting) and the determination of direct DNA sequences have brought the fields of population genetics and molecular systematics closer together. The emerging field of phylogeography provides a platform for analysing DNA sequence data within a spatio-temporal framework, while molecular systematics informs our understanding of the evolution of animal and plant lineages; in so doing these approaches help determine 'units of conservation'; these can be populations, species, ecotypes, morphotypes etc. This module covers the essentials of both evolutionary and molecular genetics with the emphasis on the relevance of each component to species in the wild. Attention is also given to investigating adaptive genetic variation, quantitative genetics and the inheritance of measurable morphological traits (especially fitness).

THEORETICAL AND STATISTICAL ASPECTS

Conservation genetics aims to derive strategies for the long-term maintenance of the genetic variability of species, since genetic variability is intimately linked to both the relative fitness of each individual and the long-term adaptability and evolutionary potential of the population. Understanding the basis for this variability (and hence fitness) requires knowledge of the inheritance of genes, gene frequencies in populations, how selection acts on the genome and the way these aspects are described by the Hardy-Weinberg Equilibrium model.

MOLECULAR EVOLUTION

Since many of the most effective techniques for measuring and quantifying genetic variability are biochemical, an understanding of the molecular basis of genetics and evolution is required. This consists of the structure of the eukaryotic genome and of the genetic material (DNA) itself. In addition, some details of the DNA of sub-cellular organelles such as mitochondria and chloroplasts (since they are often the easiest to study in practice) must be considered. The various types of mutational events are discussed to show how the genome and the organism evolve, and to explain concepts such as that of neutral evolution (which describes changes in the genotype that have insignificant consequential changes in the phenotype), adaptive evolution and the so-called molecular clock (whether molecular changes in DNA occur, on average, at a constant rate).

COMPUTER MODELLING OF POPULATION GENETIC DATA

There are few better ways to gain understanding and insight into conceptual problems than through interactive computer modelling. A number of computer-based programs in population and molecular genetics are demonstrated to participants. These will provide exercises blending both theoretical and practical aspects of population and molecular genetics.

PRACTICAL APPLICATIONS OF POPULATION GENETICS

Whereas mutation is the ultimate source of all genetic variation, many other factors determine the distribution and maintenance of this variation. These factors include sexual reproduction, natural selection (and unnatural in captive populations), migration, and genetic drift in isolated populations. Population bottlenecks may contribute to inbreeding, with consequent implications for fitness (inbreeding depression).

The counterpart to this is outbreeding depression which can occur as a consequence of moving individuals into the ranges of other populations of their species and also by mixing captive populations from different sources. Both have significant implications for conservation management, especially in the use of concepts such as effective population size and population viability.

disturbance & restoration ecology

This two-week module is very practical and participatory. It comprises three sections – theory, fieldwork and a written assignment.

The 4-day theoretical introduction covers concepts and theories in the disciplines of disturbance ecology and restoration ecology through a mixture of lectures, discussions and student seminars based on key papers. The concept of disturbance includes events that disrupt ecosystem, community, or population structures and change resources, substratum availability or the physical environment. Both natural and anthropogenic disturbances and disturbance regimes are considered, together with their roles in evolution of life-history traits, the structuring of plant and animal populations and communities, and their influences on ecosystem functioning. Ecological restoration is the process of assisting the recovery of biodiversity and/or functions of an ecosystem that has been degraded, damaged, or destroyed. Restoration is linked with disturbance ecology through its focus on damaged environments and through the use of management interventions to restore species, populations or functions.

During the 4-day field trip, hypotheses relating to the applications of disturbance in conservation management and restoration are tested. The field data are then analysed and a scientific paper prepared for assessment. Skills developed or strengthened include the design of field experiments, use of a variety of methods for quantifying disturbance, vegetation cover, plant population structure and habitat heterogeneity, data and metadata compilation, critical review of published literature, presentation and evaluation of mini-lectures and the art of scientific writing.

An understanding of disturbance and restoration ecology is essential for a career in ecological impact assessment, habitat and population management, ecological restoration and rehabilitation, conservation planning, or protected area design. Predicting the effects of management interventions such as burning, fire exclusion, culling, bush clearing, selective harvesting, livestock reductions, and species introductions requires a knowledge of disturbance ecology theory as well as the knowledge gained through practical experience.

invasive species

The view of Charles Elton that undisturbed native communities are not susceptible to invasion by introduced species has blinkered scientists to the realities of a very serious conservation problem. Empirical studies have shown repeatedly that this dogma is fallacious and that, as a corollary, the phenomenon has major implications for preserving biodiversity. Now that the intellectual stalemate surrounding the topic has been broken, it is apparent that the scientific understanding of alien invasions is inadequate to meet the challenges posed. Recent syntheses and some novel research have allowed significant theoretical advances to be made. These are sufficient to increase markedly the effectiveness of current programmes aimed at controlling invasives. This module updates the level of current ecological understanding of invasions and invasive species.

INVASIBILITY AND ITS CORRELATES/CAUSES

Abiotic determinants of the differential susceptibility of communities to invasion include disturbance regimes and patterns of habitat distribution within biomes. Biotic determinants of the success of invaders include ecological release due to the absence of host-specific parasites, diseases, predators and, for plants, herbivores found in the original range; availability of appropriate pollinators and dispersers for plants; the presence of generalist predators and the level of competition present in the invaded community. The greater susceptibility of island communities to invasion, compared to mainland ones, has long been noted. Does this lead to valid generalizations about the community structure of invaded communities?

INVASIVENESS AND ITS CORRELATES/CAUSES

So far it has proved impossible to make well-founded predictions about which species will prove successful invaders and where. This means that probabilistic techniques have to be used. One approach is to try and match the invader's natural range characteristics with those of the area under consideration. Bioclimatic characters may be important here. Lifestyle characteristics may also be used but, so far, attempted generalizations have broken down too often. Are there biogeographic and taxonomic patterns in invasiveness of species?

IMPACTS OF INVASIONS

The impacts of invasions can be assessed on four geographical scales: global, regional, biome and local. They also may be classified ecologically. One of the problems in such classifications is the time lag between arrival, first appearance of invasiveness and appearance of noticeable effects. It is clearly desirable to quantify invasive impacts, and techniques for doing so are discussed. It is possible to make some valid generalizations on invasive impacts, with particular reference to those related to biogeography, community structure and the prior evolutionary experience of invaded communities or ecosystems.

ECOLOGICAL BASES FOR CONTROL

In dealing with biological invasions, the first point to attack is countering the effects of the invader's ecological 'release' from competitors, predators, parasites and pathogens. This is where biological control, properly managed, is invaluable. It may be possible to manipulate the structure of the native community to make it less susceptible to invasion. One way of doing this is to restore the disturbance regime within which the community evolved. Global climatic change may hinder this aim. Clearly, it is necessary to study invaders both demographically and ecologically to ascertain where the weakest points are in the life cycle. Successful control programmes are usually characterized by integrated attacks at several weak points.

MODELLING INVASIONS AND THEIR CONTROL

The use of models greatly improves understanding of invasions and how to deal with them, whether they are models of the invasion process or ones explaining invasive success. Demographic models are virtually essential for predicting the impacts of alternative control methods such as biocontrol, disturbance regime manipulations and integrated control.

INTERDISCIPLINARY CORE

complex systems

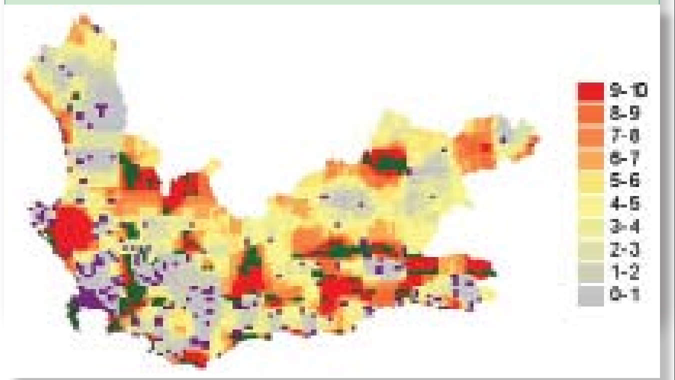
This one-week module offers an introduction to the study of complex systems. Complexity presents a challenge for many traditional approaches to understanding and managing ecosystems. At the same time, it highlights the importance of people in management and the need for approaches that take into account not only the ecological aspects of conservation problems but also their human and societal aspects. The contents of the module are based loosely around the recent edited volume, Complexity Theory for a Sustainable Future (Norberg and Cumming, 2008). Conservation-relevant complexity theory is considered in four transdisciplinary categories: asymmetries, networks, information processing, and cross-cutting problems such as scale and management. Asymmetries refer to systematic arrangements of system elements and range from gradients in landscapes through biodiversity to inequalities in livelihoods and differences in power. Networks include ecological interactions, social interactions, physical connections such as roads and railways, and information networks such as radio and the internet. Information processing in simple terms refers to what occurs between input and output, or between stimulus and response. In ecosystems it can include such things as the mechanisms by which forest communities adapt to fragmentation or weeds evolve resistance to herbicides; and in societies, it can include decision making and other political processes that influence responses to crises or opportunities. Lastly, questions about the role of system history, constraints, path dependencies and scale arise in each of these different realms and influence empirical results and the conclusions that are drawn from them about complex systems. The module includes explicit discussions of higher-order system properties such as resilience and vulnerability, and illustrates how the growing field of complexity theory provides a logical conceptual foundation for conservation biology.

landscape ecology

This four-week module covers key concepts, skills and methods, and conservation-related applications of landscape ecology and associated disciplines. The conceptual content focuses on ways of thinking about spatial variation in the biophysical and anthropogenic environments, and its role as both a cause and a consequence of variation in ecosystems. Key topics include scale, hierarchy theory, pattern-process linkages, landscape functionality, and adaptive management.

The skills and methods component of the course aims to introduce students to the tools that they will need in order to undertake spatial analyses of conservation-related problems. The focus is on working in a GIS (Geographic Information System) environment and getting useful, synthetic information out of spatially explicit data sets. Most of the training in this area is undertaken through hands-on exercises that include interpreting aerial photographs, completing simple

Irreplaceability index for areas of the Western Cape, as calculated by CB students Hannah Thomas, Jeremy Sheldon, Lindy McGregor, and Dimby Raharinjanahary. Green indicates current protected areas; urban centres are shaded purple; and different shades of red or grey indicate irreplaceability.



operations in a GIS environment, working with remotely sensed data, calculating patch metrics, and spatial statistics. Students then apply some of these skills by working in groups to develop a rudimentary conservation plan for the Western Cape, using CLUZ and MARXAN to prioritize areas.

The applications component of the course takes conceptual and methodological approaches and applies them to real-world conservation problems. These lectures and discussions cover such topics as predicting species occurrences, alternative approaches to conservation planning, difficulties in applying landscape ecology ideas to freshwater and marine ecosystems, the conservation of migratory species, and scenario planning.

In general, the landscape ecology module introduces students to the analysis of broad-scale problems. While the focus is on conservation-related topics, broad-scale analysis inevitably introduces a wide range of other material; lectures touch on a variety of other disciplines and include ideas from economics, sociology, geography, and physics. It is intended that students who have completed the module will have sufficient background to approach regional conservation problems and planning efforts with a basic grounding in theory, the ability to work with spatial data, and a healthy degree of skepticism.

climate change and conservation

Climate change, compounded by land-use change and other global problems, is one of the gravest environmental change drivers causing biodiversity loss and changing species distributions and abundances. This 1-week module provides an introductory overview of key concepts, methods and principles for the development of conservation approaches to help give most biodiversity "a fighting chance to survive the first (and maybe the last) few centuries of the Anthropocene era."

Climate change impacts on, and vulnerability of, biodiversity are the emphasis of the module. We also focus on ways in which humans can maximize biodiversity's capacity to adapt to climate change through conservation action, spatial planning and other means. Adaptation to climate change is an emerging field of conservation biology, in which few hard and fast rules have been rigorously tested. The urgency of the situation demands the wise use of flexible, dynamic conservation approaches based on sound ecological and evolutionary principles and a big-picture view of human development and species evolution. The module is thus very interdisciplinary, drawing on physiological tolerances, biogeography, systematic conservation planning, ecosystem management, evolution, genetics and behavioural ecology – as well as applied sociology, scenario planning, environmental policy and the nature of society and human behavioural change.

We expect that students completing the module will be able to start to weigh up different scenarios for climate change impacts at different scales and propose concrete, on-the-ground management and policy approaches to minimizing biodiversity loss in very uncertain and difficult times.

resource ecology

Enhancing the economic well-being of humans need not result in environmental degradation. Improved economic conditions, social upliftment and empowerment of stakeholders are essential for conservation needs to become priorities in developing countries. At the same time, conservation requires that natural resources are valued correctly. Long-term, environmental costs typically are excluded from present commodity prices; they have to be accounted for either by incorporating them into the pricing structure or by offsetting costs using taxes and/or subsidies. Similarly, decisions regarding many potential developments hinge on their economic viability. To compare the option of conserving an area with that of development, the true value of conserved areas has to be assessed. Until recently, only the direct values of conservation areas (e.g. tourism, timber extraction, etc.) were considered. Indirect values also have to be considered. These include factors such as improved quality of life, maintenance of key ecosystem functions, recreational, educational and scientific values, the existence value of flagship species, and the option value of retaining an area in its natural state. Incorporating these values into the equation, and given the relatively small input cost of the non-development option, conservation often makes economic sense.

SUSTAINABLE DEVELOPMENT

If the goal of resource management is to achieve the highest possible level of human well-being over the long term, then a policy designed to advance this goal could be termed sustainable development. The South African Department of Environment Affairs' 1993 policy document on Environmental Management embraces such a policy, to which there are two major components:

- Economic development is concerned with the management of man-made and environmental capital to satisfy human needs and aspirations;
- Sustainability is concerned with the management of man-made and environmental capital to maintain the capability of satisfying the needs and aspirations of both future and present generations.

No topic receives more attention in discussions of environmental management than 'sustainable development'. Is sustainability a well-defined concept? Is it an appropriate goal for management? Are limitations to achieving sustainability based on a lack of ecological knowledge of what needs to be done, or are they sociological in origin? These are all questions currently under debate.

CONTROLS & INCENTIVES

One approach to controlling environmental pollution and over-exploitation of resources is to set standards or prescribe certain actions. Direct controls may be effective in implementing policy, and usually are set by the government. Unfortunately, governments often have inadequate information to establish cost-effective controls, and blanket regulations mandating specific control measures are inefficient as each case is unique. Monitoring and enforcement of regulations can also be expensive and unpopular.

Another method of influencing the utilization of natural resources is through applying economic incentives. Economic incentives attempt to correct market signals which lead to environmentally damaging activities, and have ad-

vantages over regulatory approaches. Economic incentives attach a cost to the damaging activity. This cost is related to damages suffered as a consequence of the externalities resulting from the acting party's environmental utilization, and should result in environmental quality meeting the goals set by the environmental authorities. There are many different economic incentives suited to various situations, for example: pollution charges, subsidies, marketable permits, compensation, environmental bonds.

EVALUATING PROPOSED RESOURCE USES

A major challenge in environmental utilization is to find an acceptable yardstick for evaluating the costs and benefits of alternate uses for a particular resource. Money is the most obvious and widely used measuring rod in free-market economies, because prices provide low-cost information as to the value people attach to goods and services. However, price signals indicate the value of only those goods and services which can be owned and consciously traded for something else. In addition, people often do not perceive the links between their production or consumption of some commodity and the damage inflicted on the environment. Evaluation techniques should thus be comprehensive in scope, systematic in approach, and explicit in their appraisal of all possible outcomes associated with alternative uses of the resource. Several techniques for estimating the true values of resources are outlined and their relative merits are considered.

societies and natural resources

> The purpose of this module is to expose students to some of the social and political issues, concepts and understandings that are crucial for addressing biodiversity conservation. It is obviously not expected that biologists become experts in social science, but awareness and a basic understanding of the complexity of the challenges faced by conservation and an appreciation of where social scientists, within an interdisciplinary framework, can play a role is essential for good research and practice.

Conserving biological diversity involves much more than just an understanding of the ecology and biology of plant and animal species and their interactions. Gone are the days when conservation professionals could afford the luxury of focussing solely on the ecological dynamics of protected areas, safe behind fences from the rest of the world (or so they thought). The contemporary challenges in conservation, as we continue to lose biodiversity at a rapid rate, are enormous and extremely complex, and so, by implication include political, social, economic and even moral and ethical dimensions.

Over the last 10-20 years, there have been substantial shifts in conservation thinking and practice. The interactions and interrelationships between society and biodiversity have slowly achieved greater prominence. Increasingly, it is recognised that local people are integral to any conservation efforts both inside and outside of parks. With respect to the latter, it is now widely accepted that conservation of the world's ecosystems cannot be achieved through a system of protected areas alone. Consequently, we are seeing the growing emergence of broad-scale, integrated landscape approaches of which local communities form very much part. International protocols and agreements have compelled conservation professionals to think more laterally about the links between biodiversity, development and poverty alleviation, particularly given the co-occurrence of the majority of biodiversity hot spots and some of the most impoverished societies in the world. The recent Millennium Ecosystem Assessment (MA), for example, explored the links between ecosystem services (goods and services from ecosystems that provide benefits to humankind) and human well-being on a worldwide scale. The high degree of interdependence between primarily poor rural people and biodiversity is now well documented and irrefutable.

The first half of the module focuses on the links between natural resources or ecosystem services and people, particularly the poor. The concepts of poverty, vulnerability, human wellbeing and livelihoods are explored. The contribution that biodiversity makes to local livelihoods and its role in reducing or mitigating poverty and vulnerability is investigated, drawing on specific case studies. The implications of these linkages for the conservation, or conversely the degradation, of ecosystems and biodiversity are highlighted and related back to the impacts on human well-being and poverty alleviation. The importance of local ecological knowledge and how it can be incorporated into conservation efforts and plans and used to complement scientific knowledge is considered, again through the use of examples. Finally, students will explore current debates, controversies and discourse at the 'conservation-development/poverty' nexus through readings and formal debate.

Recognising the dependence of poor people on biodiversity, the second half of the module focuses on the institutions, formal and informal, that are critical in governing access to, use and sustainable management of natural resources. In the past, many ecological studies of biodiversity ignored social aspects of their case. More recently, many natural science studies have begun to acknowledge the importance of governance and the need for crafting sound institutions. However, a disturbingly high percentage of these studies conclude with a call for good governance or improved institutions with little discussion of what this means. The second half of this module aims to provide a foundation to rectify this shortcoming. The class will begin to answer questions about what defines good governance and how we can think about designing institutions to achieve these results.

Drawing heavily on Common-pool Resource (CPR) management, this section of the course attempts three goals. First, it steps through a variety of rigorous social science techniques which build on the resource economics module and the local-level case studies of the first half of this module. This provides exposure to the fields of political ecology, game theory, social science laboratory experimentation, and field work in social-ecological systems. Each of these draws on theories of CPR management. Second, recent work on the robustness of social-ecological systems links back to earlier discussions of resilience. We examine some of the similarities between the two concepts, look at important differences, and see if we gain further insight from the addition. The final goal of the course is to study the policy process. While this will be a high-level overview, the policy process steps through the stages of policy formation in an intuitive way and clarifies the politics behind policy.

decision analysis for conservation biology

Making decisions such as choosing one species survival plan over another, or which areas to conserve, is an integral part of conservation biology. In the process of making that decision, several goals or objectives usually need to be considered, including biology, economics, social and political considerations. Moreover, decisions often have to be made with incomplete knowledge and inaccurate data. This module introduces key methodical approaches that have been developed to help resolve complex decision-making processes, and explores the philosophy of decision-making in the context of conservation biology.

ANALYSIS OF THE DECISION-MAKING PROCESS

A set of heuristics is needed to ensure that the decision-making process reaches an adequate and acceptable solution. The first step is to identify what it is desired to do (i.e. the 'goal' or goals). There can be no sensible resolution of a problem until all parties can agree on a common goal or prioritized set of goals, which must be stated explicitly. The next consideration is to define all alternative courses of action, including exploring the null option of doing nothing. Are there insufficient resources or other constraints precluding some of the potential alternatives? Other important features of the decision-making process include inclusiveness (all relevant parties must be

consulted) and transparency (all aspects of the process must be open for public scrutiny). An impartial facilitator, a structured decision process and well-defined feedback mechanisms also help avoid conflict between parties.

DECISION TREES

Historically, decision trees have been the favoured approach in reaching decisions in conservation biology. They address problems with a single goal and known likelihoods of different events occurring. In practice, the use of decision trees requires assigning probability values to alternative events. The assessment of these values is difficult, especially when dealing with events with very low probability of occurring; humans are notoriously poor estimators of low risk events. Another problem is that decision trees provide the best average solution, with no consideration of the range of possible outcomes. This is often inappropriate in conservation biology, where, without the luxury of multiple trials, it is essential to assess the range of risks associated with specific scenarios on a single trial basis.

OTHER DECISION-MAKING TECHNIQUES

Decision trees address problems which have discrete alternative solutions. Policy options that are continuous (e.g. how much shall we do and when shall we do it to optimize returns?) can be addressed with linear programming, which optimizes a single objective function. Where there are multiple management objectives, goal programming can be used to maximize the achievement of conflicting goals. However, simplistic resolutions of these types of mathematical functions can lead to ill-considered decisions, as has been shown in alien plant priority rankings. Other approaches have to be employed to test the robustness of the decision analysis process.

When the problem structuring phases have generated a set of alternatives, and a set of criteria against which these alternatives can be evaluated and compared, techniques of preference modelling can be employed. These include the "Small Multi-Attribute Ranking Technique", which has proven to be useful in stakeholder workshops, and has a sound theoretical foundation.

THE ROLE OF MODELS IN DECISION ANALYSIS

Models are ideal tools for assessing the range of possible outcomes resulting from a number of management options under conditions of uncertainty. They can help develop predictions of what is likely to happen, not only regarding the average response, but more importantly, to identify response extremes, e.g. using Monte Carlo simulations. Determining the limits of possible future responses is essential given the need to err on the side of caution in conservation biology. Sensitivity analyses allow key features of the model to be identified, and thus to test the robustness of decisions. Various rule-based models are introduced to address system-level rather than single-species problems.

SYNTHESIS

The final module reviews highlights of the year's course contents and acts as a time of revision and consolidation. It also offers an opportunity to look forward by asking which conservation issues are currently 'hot' and which issues are likely to become important over the next year. In both cases, the synthesis is guided by the course organisers but largely student-led. Students select topics in consultation with the course organisers, research or revise them, and present their summaries as short presentations to the class.

INFORMATION FOR INTERNATIONAL STUDENTS

All applicants except South Africans and permanent residents of South Africa require:

- A valid passport and study permit. Note that you cannot obtain a study permit from within South Africa.
- Medical insurance.
- Proof of English proficiency if English is not your first language (TOEFL test or equivalent)
- A proven ability to support themselves financially and to settle their fees.

For advice and further details, international applicants are welcome to contact either the FitzPatrick Institute's Departmental Administrator at fitz@uct.ac.za or the University's International Academic Programmes Office (IAPO) at iapo@world.uct.ac.za.

The Conservation Biology course is exempt from International Student fees levied by the University of Cape Town. This is reviewed on an annual basis, but currently international students pay the same fees as South Africans and students from SADC (Southern African Development Community) countries.

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