Course directory 2023.2024

school of biology (FBM-BIO)
master

> Master of Science (MSc) in Behaviour, Evolution and Conservation, Specialisation Computational Ecology and Evolution

UNIL | Université de Lausanne

SUMMARY

NOTICE

This course catalogue was produced using data from the *SylviaAcad* information system of the University of Lausanne. Its database contains all information about courses proposed by the different faculties and their times. This data can also be consulted online at the address :
https://applicationspub.unil.ch/interpub/noauth/php/Ud/index.php.

Web site of the faculty : **http://www.unil.ch/ecoledebiologie/**

Generated on : 11.11.2024

LEGEND

NAME OF THE COURSE

Teacher

Type of course	Status	Hours per week	Teaching language	Hours per year
Semester	Credits			

N: Levels

P: Programme requirements

O: Objective

C: Content

B: Bibliography

I: Additional information

ABBREVIATIONS

TYPE OF COURSE

Attest.	Attestation
C	Course
C/S	Course - seminar
Cp	Camp
E	Exercises
Exc	Excursion
Lg	Guided lecture
S	Seminar
T	Fieldwork
TP	Practical work

STATUS

Fac	Facultative
Obl	Compulsory
Opt	Optional
Fac/Comp/Opt	Facultative, compulsory or optional (according to the study programme)

SEMESTER

Sp	Spring
A	Autumn

UNIL | Université de Lausanne
Ecole de biologie

Master of Science in Behaviour, Evolution and Conservation
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2023-2024

The Master program has a normal duration of 4 semesters and comprises 120 ECTS :

Module 1 : 15 ECTS : Compulsory Courses
Module 2 : 15 ECTS : Practical Project
Module 3 : 40 ECTS : Compulsory Courses (11 ECTS) and Optional Courses (29 ECTS)
Module 4 : 50 ECTS : Personal Research Project

For specialisation Computational Ecology and Evolution (CEE), the student must :

- Obtain **30 ECTS** in the specialisation :
  - Module 1 : 9 ECTS with Computational Compulsory Courses (marked in bordeaux)
  - Module 3 : 9 ECTS with Computational Compulsory Courses (marked in bordeaux) and 12 ECTS with Computational Optional Courses (marked in bordeaux)
- Carry out the First Step Research Project (Module 2) and the Master Research Project (Module 4) in the field of Computational Ecology and Evolution, validated by the head of CEE specialisation

Training objectives are available in its programme regulations.

Specific training objectives: At the end of the course the students will be able to:
• Model population processes.
• Make advanced use of computer and statistical methods in ecology and population biology.
• Use computer programming techniques.

MODULE 1

Compulsory Courses / *Enseignements obligatoires*	Hours per semester C	E	S	PW	Teaching Staff	ECTS	Limited nb of students
Semester 1 (Autumn) / *Semestre 1 (automne)*							
Advanced Python Programming (MSc MLS) *Programmation avancée en Python (MSc MLS)*	10	18	-	-	**Salamin N.**	3	
Data Analysis (MSc MLS) *Analyses de données (MSc MLS)*	8	8	-	-	**Bergmann S.**	3	
Molecular Methods in Ecology and Evolution *Méthodes moléculaires en écologie et évolution*	18	-	-	21	**Sanders I.**, Fumagalli L. Salamin N.	3	
Concepts in Ecology *Concepts en écologie*	6	-	-	-	**Bertelsmeier C.**	2	
Concepts in Evolution *Concepts en évolution*	6	-	-	-	**Schwander T.**	2	
Introduction to Scientific Writing *Introduction à la rédaction scientifique*	7	9	-	-	**Roulin A.**	2	
Master BEC Retreat *Retraite Master BEC*	-	-	-	-	**Kawecki T.**	-	
Introduction to R (optional support) *Introduction à R (mise à niveau optionnelle)*					**Schütz F.**	-	
Total	**55**	**35**	**0**	**21**		**15**	

MODULE 2

Practical Project / *Travail pratique*							
Semester 1 (Autumn) / *Semestre 1 (automne)*							
First Step Research Project *Travail d'initiation à la recherche*	-	-	-	224	**Kawecki T.**	15	
Total						**15**	

Computational courses marked in bordeaux

Abbreviations
C = Course
E = Exercise
S = Seminar
PW = Practical Work

The pandemic has shown us that circumstances beyond our control may require us to make the following adjustments / adaptations to study plans during the semester:

- possibility to switch from one mode of teaching to another (face-to-face <-> distance, synchronous <-> asynchronous, switch to co-modal teaching where it was not initially planned).
- change / modification of evaluation modalities, without inducing derogations from the Study Regulations (oral <-> written, exam <-> validation, individual work <-> group work, practical work <-> theoretical work, face-to-face evaluation <-> online evaluation, etc.)
- alternative or time-shifted modalities for teachings, internships, practical work, fieldworks and camps that could not take place or teachings that could no longer take place in the form initially planned.

Students are invited to consult this document regularly (Study Plan & Evaluation Procedure)

ADVANCED PYTHON PROGRAMMING

Nicolas Salamin

C	Obl/Opt	English	10
A	2/3		

E	Obl/Opt	English	18
A			

N: Master

P: There are not prerequisites for this course.
The students are however expected to be familiar with computers. They should have a good understanding of the functioning of a computer (hardware components, operating system/file system). A basic knowledge of UNIX/LINUX would be good, although it is not essential.
It will be necessary to install the following software on your own laptop:
- python3 with the modules numpy and biopython
- a text editor with syntax highlighting (simple one or IDE)
- for windows user: a terminal environment (e.g. cygwin or MinGW)

C: We will cover the following aspects of programing in Python:
1) basic syntax
2) data types in Python

DATA ANALYSIS

Sven Bergmann

C	Obl/Opt	English	8
A	2/3		

E	Obl/Opt	English	8
A			

N: Master

P: We assume nothing more than the mathematics you would have obtained in your studies when you were 18.

O: In this course the goal is to be able to formulate hypotheses properly, design experiments, whether in the laboratory, in a clinic, or in the filed, that have sufficient power to test these hypotheses, conduct appropriate statistical tests of the data generated, generate clear figures, and interpret the results obtained.

C: We will cover:
1. Distributions and random variables
2. Variance, covariance and measures of association
3. Constructing statistical tests using distributions
4. Regression
5. Non-linear regression

MOLECULAR METHODS IN ECOLOGY AND EVOLUTION

Luca Fumagalli, Ian Sanders

C	Obl/Opt	English	18
A	3/3.5/5/6		

TP	Obl/Opt	English	42
A			

N: Master

O: The objective of this course is to learn the relevant molecular tools that are currently used in ecology, evolutionary and conservation biology research and understand why and when to apply them.

C: This course covers the reasons why molecular genetics is a necessary tool in many ecology, evolution and conservation biology projects. We study its uses and then look at at selection of techniques, particularly for looking at polymorphism, that are not traditionally taught in molecular cell biology courses. Man of the techniques can only be learnt in the classroom as there is not enough time in a week to practically learn all useful techniques. Therefore, the associated laboratory class cover some of the fast techniques that are useful for studying polymorphisms in populations.

B: The course is mostly based on publications in international journals rather than one specific book. The publications are made available in pdf format at the beginning of the course.

CONCEPTS IN ECOLOGY

Cleo Bertelsmeier

C	Obl		English	6
A	2			

N: Master

CONCEPTS IN EVOLUTION

Tanja Schwander

C	Obl	English	6
A	2		

N: Master

INTRODUCTION TO SCIENTIFIC WRITING

Alexandre Roulin

C	Obl	English	7
A	2		

E	Obl	English	9
A			

N: Master

P: Lecturing and paper writing are in English.

O: This short but intensive block course introduces students to the practice of scientific writing (and aspects related to publishing in peer-reviewed scientific journals). We will discuss questions/topics such as: - Why is it important to publish? - What is good/clear versus bad/unclear (scientific) writing? - How to learn how to write well? - How to structure and write a good scientific manuscript? - The submission, editorial and reviewing process. - How to review someone else's paper? - Plagiarism and publication ethics Publishing is of key importance in scientific research: your job as a scientist is not finished until you have published your results - science is to a very large extent about effectively communicating your results and insights, i.e. what you have learned about how nature works. The ultimate aim of this intensive course is thus to equip students with a solid understanding of how to effectively communicate their research in writing.

C: Course Content

The course includes both lectures and practical exercises in class, distributed over four half-days. The lectures will give a broad and brief overview of different aspects of scientific writing and publishing as well as on plagiarism and publication ethics; however, the major emphasis of the course is on practical work on the part of the students. During the practical parts the students will learn, from scratch, the fundamental structure and essential components of scientific writing, how to write effective outlines/drafts and - most importantly - how to write complete, clear, well-structured papers. These practical exercises will thus require students to do reading and writing assignments, often under a bit of time pressure.

At the beginning the exercises will be worked on by teams of 2-4; towards the end, each student will work individually. Finally, to get a grade for this class, students will have to complete a written report (homework assignment). For each exercise as well as for the written report we will give detailed and individualized feedback. Note that all lecturing and assignment writing are in English.

Detailed Programme

Module 1: Lecture 1: Writing papers: overview of why and how.

We will discuss the following: Overview of class and organizational things (incl. homework assignments). Why is it important to publish? What is good/clear versus bad/unclear (scientific) writing? How to learn how to write well? [We will also briefly touch upon issues of good scientific practice and conduct, and various ethical issues connected to publishing.] Approx. 2 hours.

Module 1: Practical 1. Summarise a paper: title, keywords, abstract.

In groups of 2-3. Read the assigned (stripped down and short) manuscript and come up with a title and with keywords. Then write a short abstract (< 200 words). Approx. 1.5 hours. We will then discuss the solutions you have come up with, and their potential pros and cons, together in class. Approx. 30 mins.

Module 2: Lecture 2: Writing papers: details on structure, drafting, revising.

We will discuss the basics and essentials of writing a scientific paper (and also what not to do!). Specifically, I will explain how a paper should be structured and sub-structured, how to draft a paper (i.e., how to get started), how to build and complete a full manuscript, and then how to improve it by continuous and aggressive revising and re-revising. I will also give you hints and tips for effective writing. Approx. 1.5 hours.

Module 2: Practical 2. Write a paper: your own nano-paper from results.

I will give you some data/results (e.g., data figures/tables/legends/statistical outcomes) to choose from. Form teams of 3-4 people. Ask yourself: What do the results/tables/figures/analyses show and mean? Then prepare a very short nano-paper (2 pages max), including: Title, Abstract, Introduction, Materials and Methods, Results, Discussion and Conclusion (there are some other components in a paper that we will skip for the sake of this exercise). Each component should be between 1 and 3-4 sentences maximum. Approx. 2 hours. We will then discuss your solutions and their potential pros and cons together in class; Approx. 30 mins. We will then give you detailed feedback on your papers by e-mail after the course.

Module 3: Lecture 3: Publishing papers: understanding the whole process.

We will briefly recapitulate what we have discussed and learned so far, and then focus on the 'final' stages of writing a paper and submitting it to a journal. Approx. 1 hour

Module 3: Practical 3: Review a paper: critically assess a manuscript.

What distinguishes a good from a bad manuscript? Now you are the reviewer! Being a critical reviewer will help you to learn to distinguish between good and bad writing and thus help you to improve your own scientific writing. You will be given a short, stripped-down manuscript. Team up in groups of 2-3. Read both manuscripts critically, then make pro and contra lists for both manuscripts. Briefly explain why you would accept/reject (or reach some other decision) the manuscript for publication (

FIRST STEP PROJECT

Richard Benton, Marie-Christine Broillet, Antoine Guisan, Tadeusz Kawecki, Laurent Lehmann, Sanjiv Luther

TP	Obl	English	224
A	15		

TP	Obl	English	280
A	15		

TP	Obl	English	250
S	14/25		

TP	Obl	English	224
A	15		

TP	Obl	English	224
A	15		

TP	Obl	English	224
A	15		

N: Master

P: Practicals performed during the bachelor (molecular biology, genetics, biochemistry, bioinformatics)

O: - An initiation to the work of a scientist
- Conduct experimental work in research lab (wet bench or in silico)
- Interpretation of research results
- Implement basic principles in experimental design (e.g. include the appropriate controls, statistical significance of the results etc...)
- Present your experimental work in a written report which will be organized like a typical research article (intruduction, results, discussion, materials and methods)
- present your work orally (seminar style)

C: Perform laboratory work for about 12 weeks during the time when the student does not follow theoretical classes. This research project will typically be performed under the guidance of a PhD student or a post-doc from the host laboratory.

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MODULE 3

Courses / *Enseignements* *	Hours per semester C	E	S	PW	Teaching Staff	ECTS	Limited nb of students
Compulsory Course / *Enseignement obligatoire*							
Semesters 2 to 4 (Spring / Autumn) / *Semestres 2 à 4 (printemps / automne)*	Hours per total						
Seminars of the Department of Ecology and Evolution *Séminaires du Département Ecologie et Evolution*	-	-	10	-	**Kawecki T.**	2	
Subtotal / *Sous-total*	0	0	10	0		2	
Computational Compulsory Courses / *Enseignements computationnels obligatoires*							
Semester 3 (Autumn) / *Semestre 3 (automne)*							
Advanced Data Analysis (MSc MLS) *Analyses de données : niveau avancé (MSc MLS)*	8	8	-	-	**Ciriello G.**	3	
Population Genetics and Dynamics *Génétique et dynamique des populations*	9	20	-	-	**Goudet J.**	4	
Spatial Analysis and GIS in Ecology *Analyses spatiales et SIG en écologie*	7	10	-	-	**Guisan A.**	2	
Subtotal / *Sous-total*	24	38	0	0		9	
Computational Optional Courses / *Enseignements computationnels optionnels* *							
Semester 2 or 4 (Spring) / *Semestre 2 ou 4 (printemps)*							
Advanced Population Genetics (MSc MLS) *Génétique des populations avancée (MSc MLS)*	14	6	-	-	**Malaspinas A.-S.**	3	20
Bioinformatic Algorithms (MSc MLS) *Algorithmes de bioinformatique (MSc MLS)*	19	20	-	-	**Dessimoz C.**, Gfeller D.	4	
Microbiome Analysis (MSc MLS) *Analyse du microbiome (MSc MLS)*	8	16	-	-	**van der Meer J.**, Bertelli Lombardo C.	2	
Phylogeny and Comparative Methods *Phylogénie et méthodes comparatives*	14	14	-	-	**Salamin N.**	4	
Sex, Ageing and Foraging Theory *Théories et modèles de l'évolution de la reproduction sexuée, la sénescence et la consommation de ressources*	9	-	-	9	**Mullon C.**	2	
Spatial Modelling of Species and Biodiversity *Modélisation spatiale des espèces et de la biodiversité*	14	14	-	-	**Guisan A.**	4	
The Evolution of Cooperation : from Genes to Learning and Culture *L'évolution de la coopération : des gènes à l'apprentissage et la culture*	22	-	-	-	**Lehmann L.**	3	
Semester 3 (Autumn) / *Semestre 3 (automne)*							
Machine Learning for Earth and Environmental Sciences (GSE) *Apprentissage automatique pour les sciences de la terre et de l'environnement (GSE)*	56 C/PW				**Beucler T.**	5	
Optional Courses / *Enseignements optionnels* *							
Semester 2 or 4 (Spring) / *Semestre 2 ou 4 (printemps)*							
Applied Ecology *Ecologie appliquée*	14	-	-	36	**Pellet J.**	4	
Behaviour, Economics and Evolution Lecture Series (HEC) *Séminaires BEE*	10	-	10	50	**Lehmann L.**, Santos-Pinto L.	6	
Co-evolution, Mutualism, Parasitism *Co-évolution, mutualisme, parasitisme*	14	-	-	-	**Sanders I.**	2	
Current Problems in Conservation Biology *Problèmes actuels en biologie de la conservation*	14	14	-	-	**Wedekind C.**	4	10
Ecology of the Fishes of Switzerland *Ecologie des poissons de Suisse*	7	-	-	10	**Rubin J.-F.**	2	
Honeybee Ecology, Evolution and Conservation *Ecologie des abeilles, évolution et conservation*	14	-	-	-	**Dietemann V.**	2	
Integrated course Mountain Ecosystems *Cours intégré écosystèmes de montagne*	28	-	-	-	**Guisan A.**	3	
Interfaculty Seminar on the Environment (most in French, GSE) *Séminaire interfacultaire en environnement*	-	-	14	-	**Guisan A.**	2	
Scientific Communication - Scientific Hands-on Workshop Module (in French only) *Médiation scientifique - module atelier scientifique*	14	14	-	-	**Kaufmann A., Reymond P.,** Ducoulombier D., Trouilloud S., Ythier M.	4	8
Semester 3 (Autumn) / *Semestre 3 (automne)*							
Animal Communication and Parasitism *Communication animale et parasitisme*	14	-	-	-	**Christe P.**, Roulin A.	2	
Anthropogenic Effects on Wild Animals : Mechanisms and Fitness Consequences *Effets anthropogènes sur les animaux sauvages : Mécanismes et conséquences sur la fitness*	14	-	-	-	**Bize P.**	2	
Biological Invasions *Invasions biologiques*	14	-	-	-	**Bertelsmeier C.**	2	
Molecular Mechanisms of Evolution (MSc MLS) *Mécanismes moléculaires de l'évolution (MSc MLS)*	3	12	-	-	**Benton R.**, Geldner N.	2	
Phylogeography *Phylogéographie*	7	10	-	-	**Fumagalli L.**	2	
Plant and Animal Domestication : from History to Molecular Mechanisms (MSc MLS) *Domestication des animaux et des plantes : de l'histoire aux mécanismes moléculaires (MSc MLS)*	12	12	-	-	**Soyk S.**	3	

Computational courses marked in bordeaux

* - Before choosing an optional course, please check the "programme requirement" (prerequisites for the course) in the course description

- Students can choose optional courses not included in this study plan for a max. of 4 ECTS. They can also obtain a maximum of 6 ECTS for a professional internship outside of Unil. Both are subject to prior approval of the head of the Master and will require a sufficient proof of completion

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Courses / *Enseignements* *	Hours per semester C	E	S	PW	Teaching Staff	ECTS	Limited nb of students
Optional Courses / *Enseignements optionnels* *							
Optional Field Courses / *Etudes de terrain optionnelles* *(Financial contribution by the student required)*							
Drivers of Invertebrate Biodiversity along Altitudinal Gradients (Field course in the Alps) *Facteurs déterminant la biodiversité des invertébrés le long de gradients altitudinaux (stage de terrain dans les Alpes)*	6	-	-	80	**Schwander T.**	6	20
Ecology and Evolution of the Mediterranean Flora *Ecologie et évolution de la flore méditerranéenne*	-	-	-	48	**Pannell J.**	4	14
Integrated Practical Work Mountain Ecosystems in the Alps ** *Travaux pratiques intégrés écosystèmes de montagne dans les Alpes*	-	-	-	52	**Guisan A.**	4	
Total						**40**	

* - Before choosing an optional course, please check the "programme requirement" (prerequisites for the course) in the course description
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** Taking Integrated Course Mountain Ecosystems is a prerequisite to follow Integrated Practical Work Mountain Ecosystems in the Alps

MODULE 4

Personal Research Project / *Projet de recherche personnel*	Hours per semester C	E	S	PW		ECTS
Semesters 2 to 4 (Spring / Autumn) / *Semestres 2 à 4 (printemps / automne)*						
Write a Review *Rédaction d'une revue*	4	2	-	-	Kawecki T., Director of the Master Research Project	5
Master Research Project CEE *Travail de Master CEE*					Director of the Master Research Project	45
Total						**50**

SEMINARS OF THE DEPARTMENT OF ECOLOGY AND EVOLUTION

Tadeusz Kawecki

S	Obl/Opt		English	10
A S	2			

N: Master

P: All seminars and discussions are in English

O: Learn about the current research of other groups and meet international experts.

C: International experts present their research and answer to questions in public.

ADVANCED DATA ANALYSIS

Giovanni Ciriello

C	Obl/Opt	English	8
A	2.5/3		

E	Obl/Opt	English	8
A			

N: Master

P: You must have attended the first data analysis course, or convince me that you are competent at basic statistical analyses.

O: This course follow-up on the Data Analysis course to introduce advanced statistical and algorithmic approaches tailored to the analysis of high-dimensional data.

C: In this course we will cover:
1. Penalized regression models
2. Clustering analyses
3. Dimensionality reduction techniques
4. Introduction to deep learning

POPULATION GENETICS AND DYNAMICS

Jérôme Goudet

C	Obl/Opt	English	9
A	1.5/4		

E	Obl/Opt	English	20
A			

N: Master

P: A good grasp of the principles of population genetics and population dynamics (i.e. at least an introductory course in both)

O: Gain an understanding of how genetics and genomics interact with demographic and selective processes, with a particular emphasis on inbreeding depression and genetic rescue
website:
http://www2.unil.ch/popgen/teaching/PGD21

C: In the first part of the course, selected papers from the recent literature are presented by students and discussed in a journal club format.
In the second part, in groups of 2-3 students you will use computer simulations and the quantiNemo program to investigate questions such as:
-When and how can a small population purge deleterious alleles?
-How can we quantify Inbreeding Depression?
-is neutral diversity a good proxy for the health status of a population?

I: http://www2.unil.ch/popgen/teaching/PGD21/

SPATIAL ANALYSIS AND GIS IN ECOLOGY

Antoine Guisan

E	Obl/Opt	English	10
A			

C	Obl/Opt	English	7
A	1.5/2		

N: Master

P: Basics in statistics and ecology

O: Teaching students the basics of GIS and remote sensing, as well as the main spatial methods available in spatial ecology.

C: 1. Introduction to GIS
2. Introduction to remote sensing
3. Raster analyses
4. Neighbourhood analyses
5. Spatial interpolation
6. Detection of spatial structures and patterns

B: Wadsworth, R. & Treweek, J. 1999. Geographical Information Systems for Ecology
Caloz, R. & Collet, C. 2002. Précis de télédetection, vol. 3. Presses Univ. du Québec
Turner, Gardner, O'Neill 2001. Landscape Ecology in Theory and Practice: Patterns and Process. Springer
Dale, Birks, Wiens 2000. Spatial Pattern Analysis in Plant Ecology. Cambridge University Press.
Klopatek, J.M. & Gardner, R.H. 1999. Landscape Ecological Analysis: isuues and applications. Springer.
Hunsaker, C.T., Goodchild, M.F., Friedl, M.A. and Case, T.J. (Eds). 2001. Spatial uncertainty in ecology. Springer.
Hansson, L., Fahrig, L. and Merriam, G. 1995. Mosaic Landscapes and Ecological Processes. Chapman & Hall.

I: http://www.unil.ch/ecospat

ADVANCED POPULATION GENETICS

Anna Sapfo Malaspinas

C	Opt	English	14
S	3		

E	Opt	English	6
S			

N: Master

B: Textbooks and relevant articles:
Mark Stoneking, An introduction to Molecular Anthropology
John Wakeley, Coalescent theory, an introduction
Nielsen, R. et al. Tracing the peopling of the world through genomics. Nature 541, 302-310 (2017).
Novembre, J. et al. Genes mirror geography within Europe. Nature 456, 98-101 (2008).
Green, R. E. et al. A complete Neandertal mitochondrial genome sequence determined by high-throughput sequencing. Cell 134, 416-426 (2008).
Nordborg, M. On the probability of Neanderthal ancestry. Am J Hum Genet 63, 1237-1240 (1998) (theoretical paper)
Green, R. E. et al. A Draft Sequence of the Neandertal Genome. Science 328, 710-722 (2010)

BIOINFORMATIC ALGORITHMS

Christophe Dessimoz

C	Opt	English	19
S	3/4		

E	Opt	English	20
S			

N: Master

P: The course assumes familiarity with basic programming concepts (variable and function declaration, arrays, for-loops, conditional statements, etc.). Algorithms are introduced from a practical angle so the mathematical formalism is kept at a minimum.

O: The course aims at improving the student's programming skills by gaining a deep understanding of some of the key algorithms in bioinformatics, with a special emphasis on sequence and graph algorithms. Students will learn widely applicable concepts, such as asymptotic time complexity, binary search, dynamic programming, hashing. Practicals and home assignments are essential parts of the course. The language of the course is Python, though the concepts covered in the course are applicable to all computer languages.
More info, including dates, rooms, and link to Moodle page:
https://lab.dessimoz.org/teaching/bioinfalgo/

MICROBIOME ANALYSIS

Jan Roelof van der Meer

C	Opt	French	8
S	1.5/2		

E	Opt	French	16
S			

N: Master

P: None. Practicals will involve working with R.

O: The goal of this class is to give an overview of different host-related and environmental microbiomes, of theory on microbiome development and community growth, and to explain a number of regular microbiome analysis tools. This really cool class will involve different teachers and collaborators working within the National Centre of Competence in Research on Microbiomes. It will consist both of frontal presentations, questions and discussion sessions, and practical work.
Teachers are: Senka Causevic , Maxime Batsch , Julian Garneau, Julien Luneau , Joanito Liberti , Alan Pacheco (ETHZ), Jordan Vacheron , Massimo Amicone, Jeanne Tamarelle , Claire Bertelli , Sedreh Nassirnia, Alessia Carrara, Carmen Chen, Elena Montenegro, Yangji Choi, Elindi de Coning, Jan Roelof van der Meer, Melanie Stäubli (ETHZ), Isaline Guex

C: Content is still open to last-minute changes, but will likely consist of the following lectures:
- General overview on microbiomes: what are they, how do they function?
- Diversity analysis techniques
- High-througput functional techniques
- Meta-omics techniques
- The soil microbiome
- The rhizosphere microbiome
- The plant leaf microbiome
- The human and animal gut microbiome
- Gut-brain axis

The following practicals are being prepared:
- soil microbiome diversity
- metatranscriptomic data analysis
- community modeling

B: Course material will be uploaded on Moodle shortly before the classes.

PHYLOGENY AND COMPARATIVE METHODS

Nicolas Salamin

C	Opt	English	14
S	3/4		

E	Opt	English	14
S			

N: Master

P: none

O: Phylogenetic reconstruction methods and their application in evolutionary biology. To know and understand phylogenetic reconstruction methods in order to test the processes leading to genes and organisms evolution.

C: The subjects will be presented during lectures as well as practicals.
I. Reconstruction methods
- What is a phylogenetic tree and how to interpret it?
- Tree reconstruction:
a) optimisation criteria and models of evolution
b) search for the optimum tree
c) Bayesian methods
- Can we trust the inferred tree?
II. Uses for phylogenetic trees
- Detecting positive selection in a coding gene
- Testing coevolution and cospeciation
- Macroevolution:
a) dating evolutionary events
b) tempo and mode of evolution
c) testing for key innovations
- Phylogeny and conservation

B: Felsenstein, J. 2003. Inferring phylogenies. Sinauer Associates.
Page, R. 2003. Tangled trees: Phylogeny, cospeciation, and coevolution. University of Chicago Press.
Purvis, A., Gittleman, J.L. and Brooks, T. 2005. Phylogeny and conservation. Cambridge University Press.
Swofford, D.L., Olsen, G.K., Waddell, P.J. and Hillis, D.M. 1996. Phylogeny reconstruction. Pages 407-514 In Molecular Systematics (D.M. Hillis, C. Moritz, B.K. Mable, eds.). Sinauer Associates.
Yang, Z.H. 2006. Computational Molecular Evolution. Oxford University Press.

I: http://www.unil.ch/phylo/teaching/pmc.html

SEX, AGEING AND FORAGING THEORY

Charles Mullon

TP	Opt	English	9
S			

C	Opt	English	9
S	1.5/2		

N: Master

P: Ability to program in R or other languages.

O: Introduction to theoretical principles and modelling approaches to fundamental problems in evolutionary ecology.

Understand the biological factors that influence the evolution of ageing, sex, and resource consumption.

Learn to conceptualise a biological problem and analyse it quantiatively.

Introduction to individual-based simulations.

C: We explore the evolution of sexual reproduction, ageing and resource consumption, through three big questions:

<p id="yui_3_17_2_1_1674222015810_171">1. Why do we age? <p id="yui_3_17_2_1_1674222015810_199">2. Why do we reproduce sexually?
3. How should we consume resources?

We look at these questions through mathematical and computational modelling. In addition to core concepts of evolutionary ecology, students thus learn how to formalize a theoretical model, implement it in a computer program (e.g. R, C or Python) and analyse its output.

SPATIAL MODELLING OF SPECIES AND BIODIVERSITY

Antoine Guisan

C	Opt	English	14
S	3/4		

E	Opt	English	14
S			

N: Master

P: If possible, course 'Spatial Analyses & GIS' (ANSPAT) in 1st semester of the Master (not strictly required).

O: Species distribution models (SDMs) are increasingly important in ecology and conservation biology. This course proposes an introduction to these models and related concepts and methods. Overview of the main steps of model building. Advantages and limitations. Applications to various domains (climate change, invasions, rare species, ...).

C: Chap. 1. Introduction to species' niche & distributions, and related models. Theory and principles behind these models. Competition and disperal limitations. Types of response variables, main predictive modelling approaches, field sampling design, from predicting species distributions to predicting communities.
Chap. 2. Model calibration. Presence-only versus presence-absence data, statistical theory and methods for presence-only data, regressions and classifications for presence-absence, ensemble modelling and forecasting.
Chap. 3. Model evaluation. Internal versus external evaluation. Data and metrics for evaluation. Crossvalidation, jackknife, bootstrap, uncertainties.
Chap. 4. Assumptions behind these models. Pseudo-equilibrium, niche conservatism, niche completeness, realized niche, and other postulates.

B: Guisan, A. & Zimmermann, N.E. (2000). Predictive habitat distribution models in ecology. Ecological Modelling 135(2-3): 147-186.
Guisan A, Thuiller W (2005) Predicting species distribution: offering more than simple habitat models. Ecology Letters, 8, 993-1009.
Guisan et al. (2013) Predicting species distributions for conservation decisions. Ecology Letters 16: 1424-1435.

I: http://www.unil.ch/ecospat

THE EVOLUTION OF COOPERATION : FROM GENES TO LEARNING AND CULTURE

Laurent Lehmann

C	Obl/Opt	English	22
S	3		

N: Master

O: What makes us such a unique species, able to cooperate in large-scale societies, organize social interactions, and dominate ecologically the Earth? The main goal of this course is to provide the foundations of social evolution, which consists of two main ingredients in humans: cooperation and cumulative cultural evolution. On one side, the course will thus focus on studying the main forces favoring and maintaining cooperation (mutually beneficial interactions, altruism) and conflict (cheating, malevolence, warfare) in group-structured populations. On the other side, we will study the forces behind cultural evolution, where behavior in interactions depends on genetic determinants, social learning, and individual learning ("gene-culture coevolution"). This will allow discussing the major steps in human social organization evolution, from primate autarky to division of labor in large-scale societies.

C: The course will be composed of five main parts and more focused on human behavior than the "Ecology and Evolution" class on which it builds:
(1) Cooperation and conflict in well-mixed populations. Here, we will study the evolution of cooperation (and cheating) in well-mixed population (no division into groups). We will study the standard one-shot social dilemmas illustrating the tension between self-interest and group-interest, like the prisoner's dilemma and the stag-hunt game. We will then investigate various settings of repeated interactions, where reputation dynamics between individuals are crucial to sustain long-term relationships.
(2) Cooperation and conflict in group-structured population. Here, we will study the forces shaping cooperation when interactions occur in group-structured populations (the rule in humans), and where the localization of the social interactions generates in the same time novel incentives to cooperate and novel incentives for spiteful behavior. We will also consider conflicts between groups and study warfare in small-scale hunter-gather societies.
(3) Social learning and gene-culture coevolutionary theory. Here, we will study the main modes of social learning ("cultural transmission"), which underlies cumulative cultural evolution that is the main determinant of the human lineage ecological success. We will also study gene-culture coevolution and how social learning impacts the dynamics of cooperation within groups.
(4) Individual learning and preferences. Here, we will discuss the main modes of individual learning that allow individuals to learn information about the relevant behavior to express on their own (e.g., trial-and error learning and related decision heuristics, maximizing behavior). We will investigate the conditions under which evolution may and may not lead individuals to become equipped with goal functions ("utility maximization behavior").
(5) Major transition from small to large-scale societies. Here, we will discuss the main evolutionary steps that took the human lineage in a 6 million year long co-evolutionary gene-culture ride from self reliant primate social organizations ("autarky") to large scale societies with extreme division of labor ("catallaxy"). This transition involved a zizag path from dominance, to egalitarianism, to inequality again.

MACHINE LEARNING FOR EARTH AND ENVIRONMENTAL SCIENCES

Tom Beucler

C/TP	Opt	English	48
A	5		

N: Master

P: - Basic knowledge of Python

- Interest in Earth and environmental sciences

O: Full English syllabus (with links) at https://wp.unil.ch/dawn/teaching/#ML_EES.
In this 8-week hands-on course, we will introduce common ML algorithms in the context of their application in environmental science and engineering. By the end of this course, you should be able to:

1. Name common ML algorithms (listed in Section 2 of the syllabus) and summarize their advantages and limitations, especially in the context of environmental science,

2. Implement them in Python (mostly using the Numpy, Scikit-Learn, Keras, and Tensorflow libraries in Google Collab notebooks),

3. Know from experience which algorithms are most appropriate for environmental applications you are passionate about (e.g., your Masters thesis).

C: Last updated on August 28, 2022; please consult https://wp.unil.ch/dawn/teaching/#ML_EES and select the appropriate semester for the most up-to-date information.

- Week 1-2: Linear/Logistic Regression for Classification/Regression & Statistical Forecasting
- Week 2-3: Decision Trees/Random Forests/SVMs & Environmental Risk Analysis
- Week 3-4: Unsupervised Learning for Clustering/Dimensionality Reduction & Environmental Complexity
- Week 4-5: Artificial Neural Networks & Surrogate Modeling
- Week 5-6: Generative Modeling: From Uncertainty Quantification to Stochastic Downscaling
- Week 6-7: Convolutional Neural Networks & Remote Sensing
- Week 7: First In-Class Presentation
- Week 7-8: Graph Neural Networks & Interconnected Systems
- Week 8-9: Explainable Artificial Intelligence & Understanding/Communicating Predictions
- Week 9-10: Hybrid Modeling & Knowledge-Guided Learning
- Week 10-12: Office Hours for Final Projects, In-Class Peer-Review and In-Class Presentations

Possible overview of student-chosen related topics not covered in class that may be relevant to final projects: Bayesian inference, Causal discovery, Data ethics, Recurrent Neural Networks, Reinforcement Learning, Symbolic Regression.

In-class peer review: Each class member submits the draft of their final project for review and reviews 3 drafts from peers.

B: 1. "Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, 2nd Edition" by Aurélien Géron (https://www.oreilly.com/library/view/hands-on-machine-learning/9781492032632/)
2. "Deep Learning with Python, 2nd Edition" by Francois Chollet (https://www.manning.com/books/deep-learning-with-python)

I: https://wp.unil.ch/dawn/teaching/#ML_EES

APPLIED ECOLOGY

Jérôme Pellet

C	Opt	English	14
S	3/4		

TP	Opt	English	36
S			

N: Master

P: BSc level in biology, including ecology

O: Applied ecology is a young crisis discipline undergoing a major effectiveness revolution. In most situations, urgent action is necessary, even in the absence of reliable information. How do we gather sound ecological information? How do we use it to plan natural communities conservation? In the process of answering these questions, wildlife ecologists often realize that research and practice are just two sides of the same coin.
After this lecture, students are able to understand the underlying concept of evidence-based conservation and adaptive management. They have applied the concepts in several different conservation settings.

C: The goal of the course is to teach students some of the skills they will need as evidence-based conservationists. Practical examples will be drawn from various ecosystems, communities and species. The course will revolve around the stages of adaptive management:
monitoring ecological resources, monitoring occupancy and abundance
research syntheses (systematic reviews and meta-analyses)
ecological triage (systematic conservation planning and red lists)
natural communities conservation planning and legislative context.
Field-based case studies will provide students an opportunity to apply and discuss some of the principles illustrated in the course. Practical work will include meeting with practitioners, discussing and analyzing their approach and methods through the prism of adaptive management.
« There is no such thing as a special category of science called applied science; there is science and its applications, which are related to one another as the fruit is related to the tree that has borne it. » Louis Pasteur

BEHAVIOUR, ECONOMICS AND EVOLUTION LECTURE SERIES

Laurent Lehmann

C	Obl/Opt	English	10
S	6		

S	Obl/Opt	English	10
S			

TP	Obl/Opt	English	50
S			

N: Master

CO-EVOLUTION, MUTUALISM AND PARASITISM

Ian Sanders

C	Opt	English	14
S	1.5/2		

N: Master

P: Must understand english and be prepared to give presentations

O: To understand the evolutionary consequences of organisms living together in mutualism or parasitism and how to investigate it experimentally

C: The course comprises some introductory talks given by me about concepts in co-evolution and theoretical frameworks for studying co-evolution. Afterwards, students give presentations on chosen key publications in this field and the group discusses these subjects after the presentations.

B: : All bibliography is made availble in pdf format before the course begins. For an example of the publications discussed you can find last years publications in my docunil public folder.

CURRENT PROBLEMS IN CONSERVATION BIOLOGY

Claus Wedekind

C	Opt	English	14
S	3/4		

E	Opt	English	14
S			

N: Master

P: Lectures, discussions, and proposal writing in English.

O: Introduction into
- some important problems of conservation biology
- funding opportunities for conservation projects
- the planning, writing, and reviewing of grant proposals in the context of the course

Own ideas shall be developed, presented and discussed in class.

C: Some current research topics within the field of conservation biology will be further introduced in lectures, potentially also guest lectures, and discussions in class. Each student then develops an own idea of a research project within these topics. After an introduction into funding agencies and the planning and writing of grant proposals, each student (or groups of two) write(s) up an own proposal and present(s) it to the class. The proposals of colleagues will then be peer-reviewed after an introduction into peer-reviewing of grant proposals.
Class size restricted to 10 students.

ECOLOGY OF THE FISHES OF SWITZERLAND

Jean-François Rubin

C	Opt	English	7
S	1.5/2		

TP	Opt	English	10
S			

N: Master

P: none

O: Recognize the different habitats and species
Know the biology of the principal species
Identify the problems linked to the management of these habitats and species

C: Generalities on water
Lakes
Watercourses
Plankton and plants
Systematic of fish
Anatomy of fish
The fish of Switzerland

HONEYBEE ECOLOGY, EVOLUTION AND CONSERVATION

Vincent Dietemann

C	Opt	English	14
S	1.5/2		

N: Master

P: none

O: At the end of this series of courses, students will be able to describe the complexity of social organisation in honey bees. They will have acquired advanced knowledge of the mechanisms underlying the ability of honeybees to adapt to natural and human-induced changes, as well as the limits to this ability to adapt. In the light of this knowledge, students will be able to analyse, evaluate and critique the quality of information available in the media and scientific literature on this highly socio-economic organism. This critical sense can also be extended to other themes and organisms. Through the proposed examination, students will practice writing clear and succinct answers to questions that require the collation and logical organisation of information from multiple sources.

C: Since honeybees are economically important insects, they have been studied early in history and the knowledge we possess about them is greater than for any other social insect species. Our understanding of the honeybee reveals the complex organisation reached by insects when they form societies. This series of lectures will present some aspects of this complexity that will be replaced within its evolutionary context. Various aspects of honeybee ecology and evolution, including geophylogeny, biology, reproduction at individual and colony level, division of labour, communication, pathogens will be presented. As the honey bee is an insect of high economic value, we will also look at the socio-economic aspects that influence its biology and evolution.

After a general introduction of this model species describing the diversity and biogeography of the taxon, we will dissect the communication abilities of European honeybees and compare it with related Asian species. We will see how this communication is used to organise foraging tasks sustaining colony growth. Honeybee health is a current concern and we will review the pathogens affecting them and comment the role of humans in their spread and control in an evolutionary context. Since honeybee stocks and wild populations are experiencing decreases in some regions of the world, we will see what economical losses could occur and some conservation projects to invert the trend will be put in context.

B: Seeley T, 1985. Honeybee Ecology. Princeton University Press.
Seeley T, 1995. The wisdom of the hive. Harvard University Press.
Moritz RFA, Southwick EE, 1992. Bees are superorganisms. Spiringer Verlag
Oldroyd B, Wongsiri S, 2006. Asian Honey Bees. Harvard University Press.
Koeniger N, Koeniger G, Tingek S, 2010.Honey Bees of Borneo. Natural History Publications
Winston ML, 1987. The Biology of the honey bee. Harvard University press.

INTEGRATED COURSE MOUNTAIN ECOSYSTEMS

Antoine Guisan

C	Obl/Opt	English	28
S	1.5/3		

N: Master

P: none

O: To obtain a multidisciplinary knowledge basis on aspects of ecology & evolution of mountain ecosystems

C: General introduction to mountain environments Adaptations to marginal environments Reproductive systems along elevation Patterns of micro-organisms along elevation Biological invasions in mountains Impact of climate change on mountain biota - field observations and experiments Impact of climate change on mountain biota - spatial modelling Human-wild fauna conflicts in mountain regions

B: Donnée séparément pour chaque leçon.

I: Planning détaillé donné sur moodle aux étudiant.e.s inscrit.

INTERFACULTY SEMINAR ON THE ENVIRONMENT

Antoine Guisan, Pierre-Louis Rey

S	Opt	French	18
S	2		

N: Master

P: None

O: To give students a deep understanding of an environmental issue, animated for the most part through contributions from external visitors to UNIL.

C: Conferences are in french.

B: Précisé par les intervenant.e.s de semaine en semaine

I: https://www.unil.ch/gse/sie

SCIENTIFIC COMMUNICATION - SCIENTIFIC HANDS-ON WORKSHOP MODULE

Alain Kaufmann, Philippe Reymond

C	Opt	French	14
S	3/4		

E	Opt	French	14
S			

N: Master

ANIMAL COMMUNICATION AND PARASITISM

Philippe Christe

C	Opt	English	14
A	1.5/2		

N: Master

P: None

O: Across the animal kingdom, individuals of the same species differ in their propensity to take risks, and explore new environments, and to be active, aggressive or sociable. Individual differences in behaviour that are consistent through time and across contexts are coined 'personalities', 'behavioural syndromes' or 'temperaments'. The terminology of personality is not a mere fashionable label of something usually studied by behavioural ecologists, but useful to conceptualize the common phenomenon that individuals differ markedly and consistently in their behavioural phenotypes across ecological and social contexts. The notion of personality implies that suites of behaviours are correlated within individuals and hence individuals are less flexible than would be expected under optimality models. In this course, I propose to study personality from an evolutionary point of view and also the evolution of language.

C: This lecture is interactive and illustrated by recent research articles.
7h will be given by A. Roulin and 7h by P. Christe

B: Réale, D., Reader, S.M., Sol, D., McDougall, P.T. & Dingemanse, N.J. (2007). Integrating animal temperament within ecology and evolution. Biol. Rev., 82, 291-318.
Sih, A., Bell, A.M., Johnson, J.C. & Ziemba, R.E. (2004). Behavioral syndromes: an integrative overview. Q. Rev. Biol., 79, 241-277.
Journaux scientifiques figurant sur internet (http://perunil.unil.ch/perunil/periodiques/).

I: Aucune

ANTHROPOGENIC EFFECTS ON WILD ANIMALS : MECHANISMS AND FITNESS CONSEQUENCES

C	Opt		French	14
A	2			

N: Master

MOLECULAR MECHANISMS OF EVOLUTION

Richard Benton

C	Opt	English	3
A	1.5/2		

E	Opt	English	12
A			

N: Master

P: Students should have a solid background in molecular genetics and developmental/cell biology.

O: To explore our current understanding of the molecular mechanisms underlying phenotypic differences between species, using examples from animals and plants.
What are the specific genetic loci underlying divergence of traits?
- how do you identify these loci and prove they are responsible?
What are the functional changes in these loci?
- what kinds of changes are possible?
What is the origin of the functional variation in natural populations?
- how do the properties of populations influence evolution?
Are there common principles in how evolution works across species and across traits?
- if so, why? If not, why not?

C: Four primary research articles (which will be made available on MyUNIL) will be read in advance by the students and discussed in detail during the course, spanning the larger scientific context and the experimental approaches used.

PHYLOGEOGRAPHY

Luca Fumagalli

C	Opt	English	7
A	1.5/2		

E	Opt	English	10
A			

N: Master

O: 1) Course
Study of the historical processes (population expansions, bottlenecks, vicariance and migration) responsible for the current geographic distribution of genealogical lineages.
2) TPs
Analysis and interpretation of phylogeographic data with the help of several softwares.

C: 1) Phylogeography: definition and historical backgrounds
2) Animal and plant molecular markers
3) Distribution area
4) Gene tree/species tree
5) Molecular clocks
6) Coalescence
7) Mismatch distribution
8) Phylogenetic trees and networks
9) Phylogeographic patterns
10) Comparative phylogeography
11) Phylogeography and conservation
12) Phylogeography and genomics.

B: Avise JC. 2000. Phylogeography. Harvard University Press.

PLANT AND ANIMAL DOMESTICATION : FROM HISTORY TO MOLECULAR MECHANISMS

Sebastian Soyk

E	Opt	English	12
A			

C	Opt	English	12
A	3		

N: Master

P: Bachelor-level knowledge in genetics, genomics, molecular biology, and/or development is recommended. Having passed one or more bachelor level lectures in genetics, genomics, or developmental biology is of advantage.

O: The course "Plant and animal domestication: From history to molecular mechanisms" aims at delivering a profound knowledge of the history and key traits of plant and animal domestication, as well as an in-depth understanding of the genetic architecture and molecular mechanisms that were modified by human selection.
In addition, the course will enable you to improve your presentation skills (by orally presenting a scientific publication about this topic) and communication skills (by efficiently discussing scientific questions with your fellow students).

C: The content of the course will be delivered through (1) lectures, (2) group work, and (3) student presentations. Sessions will start with ~45 min lectures followed by Q&As. Afterwards, students will discuss original research articles that are related to the lecture content for ~45 min in subgroups. Finally, the students will present the main findings of the research articles and discuss the content in the group. Grading will be based on contribution to the discussions and the presentations.

The content of the course includes:

- a brief history of agriculture and domestication

- genetic basis underlying the diversity in species

- methods in genetics, genomics, and molecular biology to identify major domestication traits

- genetic and molecular basis of domestication traits in plants (e.g. fruit flavor in tomato, latitude adaptation in soybean, etc.), animals (e.g. tameness in rabbits and altitude adaptation in yak, etc.), and microbes (e.g. loss of toxicity in molds and metabolic adapations in yeasts, etc.)

- approaches in genome editing and biotechnology for de-novo domestication and improvement of plants and animals

DRIVERS OF INVERTEBRATE BIODIVERSITY ALONG ALTITUDINAL GRADIENTS

Tanja Schwander

T	Opt	English	80
S			

C	Opt	English	6
S	3/6		

N: Master

P: Program requirement: Financial participation required by the student (approximately 480.-)

O: During this field course, we study different invertebrate taxa (mainly insects and gastropods) to understand the factors driving biodiversity and community composition, as well as the evolution of different life cycles under diverse ecological conditions in the Swiss Alps/Prealps.

C: Course content: - Introductory lectures - Excursions and group field work: analysis of community composition and biodiversity in various habitats - Personal experiments (experimental design, data collection & analysis, presentation of results) - Discussion of scientific papers

ECOLOGY AND EVOLUTION OF THE MEDITERRANEAN FLORA

John Pannell

T	Opt	French	48
S	2/4		

N: Master

P: Financial participation required by the student.

INTEGRATED PRACTICAL WORK MOUNTAIN ECOSYSTEMS IN THE ALPS

Antoine Guisan

T	Obl/Opt	English	52
S	3/4		

N: Master

P: Having followed the integrated course "Mountain Ecosystems"

O: The objectives are four-fold:
- be able to carry out a small research project from beginning to end.
- Learn to work in interdisciplinary team: groups of 5 students from the FBM and FGSE (if possible at least one FGSE student per group).
- be able to efficiently and elegantly communicate your scientific findings (oral and written).
- learn how to carry ecological field work.

C: Two field retreats in Arolla (VS) - usually in May (2 days) and July (4.5 days)
First retreat to design a project and write a proposal
Second retreat to conduct the project in the field, and write a final report ("paper style")
Instructions on the two retreats' programs and the expected proposal and final report on moodle.
Bibliography:
Differents species identification field guides.
Bowman, W. D., and T. R. Seastedt, editors. 2001. Structure and Function of an Alpine Ecosystem : Niwot Ridge, Colorado. Oxford University Press Inc New York.
Nagy, l., and G. g. 2009. The biology of alpine habitats. Oxford University Press, Oxford.
Körner, C. 2003. Alpine plant life: Functional plant ecology of high mountain ecosystem. 2nd Edition edition. Springer, New York.
Ozenda, P. 1985. La végétation de la chaîne alpine dans l'espace montagnard européen. Masson, Paris.

B: Différents guides d'identification d'espèce sur le terrain.
Bowman, W. D., and T. R. Seastedt, editors. 2001. Structure and Function of an Alpine Ecosystem : Niwot Ridge, Colorado. Oxford University Press Inc New York.
Nagy, l., and G. g. 2009. The biology of alpine habitats. Oxford University Press, Oxford.
Körner, C. 2003. Alpine plant life: Functional plant ecology of high mountain ecosystem. 2nd Edition edition. Springer, New York.
Ozenda, P. 1985. La végétation de la chaîne alpine dans l'espace montagnard européen. Masson, Paris.

I: Info détaillées sur moodle pour étudiant.e.s inscrit.e.s

WRITE A REVIEW

Tadeusz Kawecki

C	Obl	French	4
S	5		

E	Obl	French	2
S			

N: Master