**Course Title**

GIS and remote sensing for conservation and evolutionary biology

**Course Instructors**

Eleanor Sterling, Mary Blair, andPeter Galante

**Instructor email, phone and office location**

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**Instructor office hours:** by appointment

**Duration:** 10 sessions over 9 weeks – March 4, 11, 25, Apr 1, 8, 15, 22, 27, 29, May 4

**Time:** W 9am – 12 noon (except 2:30-5:30pm on the two sessions on Mondays – Apr 27 and May 4).

**Course Description**:

This course will focus on the application of Geographic Information Systems (GIS) to address questions relating to evolution and biodiversity conservation. Students will gain hands-on experience with multiple GIS software packages and will learn the fundamentals of species distribution modeling and remote sensing. The course will combine lectures and computer lab exercises, and each student will undertake an individual project.

**Credits:** 2 (30 hours of contact and 60 hours of additional assignments)

**Prerequisites**: None

**Learning Objectives**:

* Understand fundamental GIS concepts, including data types, projections, and scale.
* Carry-out basic GIS tasks, including importing/exporting data, georeferencing, overlays, reprojecting, digitizing, and calculating spatial statistics.
* Be familiar with multiple GIS packages, including Quantum GIS and R statistical software.
* Understand the principles of remote sensing.
* Be able to obtain and interpret remote sensing imagery.
* Learn the theory of species distribution modeling (also called ‘ecological niche modeling’)
* Run and evaluate species distribution models using multiple methods (including Maxent)
* Learn use of R for dealing with spatial data and running species distribution models.
* Discover how GIS can be used in a wide range of applications, including in evolutionary biology and conservation:
  + Guiding fieldwork to discover new populations and unknown species
  + Species delimitation
  + Studies of speciation processes
  + Conservation area planning
  + Projecting the impacts of climate change

**Course Bibliography**:

*Books*

Horning, N., J. Robinson, E.J. Sterling, W. Turner, and S. Spector. 2010. *Remote Sensing for Ecology and Conservation: A Handbook of Techniques*. Oxford University Press.

Peterson, A.T., J. Soberon, R.G. Pearson et al. 2011 *Ecological Niches and Geographic Distributions*. Princeton University Press, Monographs in Population Biology.

*Suggested Additional Book*

Guisan, A., Thuiller, W., and N.E. Zimmermann. 2017. *Habitat Suitability and Distribution Models: With Applications in R.* Cambridge University Press.

*Journal Articles:*

Alvarado-Serrano, D.F. and L.L. Knowles. 2014. Ecological niche models in phylogeographic studies: applications, advances and precautions. *Molecular Ecology Resources* 14:233-248.

Blair, M.E., Sterling, E.J., Dusch, M., Raxworthy, C., and R.G. Pearson. 2013. Ecological divergence and speciation in *Eulemur* sister species. *Journal of Evolutionary Biology* 26(8):1790-1801.

Franklin, J., 2013. Species distribution models in conservation biogeography: developments and challenges. *Diversity & Distributions* 19: 1217-1223.

Graham, C.H., S. Ferrier, F. Huettman, C. Moritz & A.T. Peterson. 2004. New developments in museum-based informatics and applications in biodiversity analysis. *Trends in Ecology and Evolution* 19, 497-503.

Guisan, A. et al. 2013. Predicting species distributions for conservation decisions. *Ecology Letters* 16:1424-1435.

Kozak, K.H., C.H. Graham, & J.J. Wiens. 2008. Integrating GIS-based environmental data into evolutionary biology. *Trends in Ecology and Evolution* 23, 141–148.

Merow, C., Smith, M.J., & Silander, J.A. 2013. A practical guide to MaxEnt for modeling species’ distributions: what it does, and why inputs and settings matter. *Ecography* 36: 1058-1069.

Pearson, R.G., Raxworthy, C.J., Nakamura, M. & Peterson, A.T. 2007. Predicting species’ distributions from small numbers of occurrence records: a test case using cryptic geckos in Madagascar. *Journal of Biogeography* 34, 102-117.

Pearson, R.G. & Raxworthy, C.J. 2009. The evolution of local endemism in Madagascar: watershed vs. climatic gradient hypotheses evaluated by null biogeographic models. *Evolution*, 63, 959-967.

Phillips, S.J., Anderson, R.P. & Schapire, R.E. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190, 231-259.

Raxworthy, C.J., C. Ingram, N. Rabibisoa & R.G. Pearson. 2007. Applications of ecological niche modeling for species delimitation: a review and empirical evaluation using day Geckos (*Phelsuma*) from Madagascar. *Systematic Biology* 56, 907–923.

Rose, R.A., *et al.* 2015. Ten ways remote sensing can contribute to conservation. *Conservation Biology*, Online Early. DOI: 10.1111.cobi.12397

Stanton, J.C., Shoemaker, K.T., Pearson, R.G. & H.R. Akcakaya. 2015. Warning times for species extinctions due to climate change. *Global Change Biology* 21, 1066-77.

*Web resources:*

*We will provide additional resources specific to each session in the weekly project tasks documents.*

Species distribution modeling: YouTube videos of training course by Dr. Richard Pearson <https://www.youtube.com/playlist?list=PLKYTvTbXFuChaoF-L-1e9RzCagdLPQcCU>

Remote Sensing: <http://www.amnh.org/our-research/center-for-biodiversity-conservation/biodiversity-informatics/remote-sensing-guides>

Biodiversity Informatics Training Resources: <http://biodiversity-informatics-training.org/>

Environmental Computing in R http://environmentalcomputing.net

*Software:*

Quantum GIS (freeware: <http://www.qgis.org/en/site/>)

R (freeware: <http://www.r-project.org/>)

R studio (freeware – companion software for R, highly recommended for first time users: https://www.rstudio.com/)

Maxent (freeware: https://biodiversityinformatics.amnh.org/open\_source/maxent/)

Java (freeware: https://www.java.com/en/download/)

ENMTools (freeware: <http://enmtools.blogspot.com/>)

*Other software resources of interest (not required):*

Free software for map editing: Inkscape - <https://inkscape.org/>, gimp - <https://www.gimp.org/>

*Wallace* software for species distribution modeling workflows: <https://wallaceecomod.github.io/>

**How to obtain class materials:**

We have set up a web site from which you can download materials for the class:

<https://pgalante.github.io/RGGS_GIS/>

Password is “password”

We will post all materials for the course here, including large datasets for use during the labs. Materials for each session will be available by the evening preceding each class. Please download all materials *prior* to class to ensure that class time is used effectively.

**Evaluation Basis:**

Students will undertake an individual project that will be graded based on a final paper (50%) and presentation (30%). Weekly lab exercises will also be assessed (20%).

*Final Exam/Project Description***:**

Each student will undertake an individual project. Each class will introduce new methods and approaches that the students will apply to their own project as between-class assignments. In this way, students will progressively build their own project over the duration of the course, giving the opportunity to apply the techniques learned to an example of interest. The following general progression will apply to projects: 1. Obtain and import species’ occurrence records (may be the student’s own data, or obtained from a database such a GBIF); 2. Obtain and manipulate environmental layers (e.g., change resolution, project and clip climate and remote sensing layers); 3. Run and evaluate species distribution models (e.g., Maxent); 4. Present mapped results and discuss applications (applications may include finding unknown areas of endemism, reserve planning, etc.). Students will submit a final paper and present to the class on their individual project. Final presentations will be on the last day of class, May 4. Final papers will be due on May 6, giving students time to incorporate comments from the final presentations.

**Statement on Academic Integrity**: Each graduate student bears the responsibility to observe traditional canons of scholarly discourse, scientific research, and academic honesty. Plagiarism, cheating, and fraud in research will not be tolerated. Accordingly it is expected that students work individually unless specifically instructed to work in groups. The full Academic Integrity policy is in the student handbook*.*

**Course Evaluations**: Each student is required to complete an anonymous course evaluation at the end of the term. The course evaluation is a tool for faculty and administrators to improve the student learning experience.

*Other general statements****:***

Labs will be undertaken using student’s laptops. Therefore, each student must bring a laptop along to each session. Laptops should have Quantum GIS software and R statistical software installed. Instructors will circulate details for obtaining and installing this software after course registration is complete including details on installation specifics for Mac OSX versus Windows and other OS laptops. Windows users should also make sure they have 64x java installed. Let us know if you have a version of Windows older than Windows 8 or if you use Linux.

**Calendar of Topics**

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| **DATE** | **Lecture Topic** | **Lab Topic** | **ASSIGNED READINGS AND PROJECT TASKS** |
| Session 1  March 4 | Introduction to GIS   * Vector and raster data * Projections * Species’ occurrence records (e.g., GPS receivers and GBIF) * Georeferencing (e.g., Geolocate)   Plan for the course, including individual projects | Familiarity with QGIS interface and functions   * Obtain and import species occurrence records * Vector outlines * Attribute tables * Editing * Summary statistics * Cartography | *Reading:* Graham et al. 2004.  *Project:* Identify question, study region and taxonomic focus; obtain species’ occurrence records; prepare short project proposal (for instructor approval) |
| Session 2  March 11 | Environmental layers in GIS   * Raster datasets: climate, topography, geology, etc. * Scale (extent vs. resolution) * File formats * Spatial interpolation   Uses of environmental data | Obtaining and displaying environmental layers in QGIS   * Resampling * Reprojecting * Raster calculator | *Reading:* Kozak et al. 2008.  *Project:* Obtain environmental layers for study region; resample, reproject and clip layers. |
| Session 3  March 25 | Introduction to Remote Sensing   * Types of sensors * Types of products * Applications | Obtaining and interpreting remote sensing data   * Locating and downloading data * Image interpretation and classification | *Reading:* Horning et al. 2009, Chapter 4.; Rose et al. 2015  *Project:* Obtain and format remote sensing data for study region |
| Session 4  Apr 1 | Introduction to Species Distribution Modeling   * Niche theory * Geographical versus environmental space * Model algorithms * Applications and interpretation | Species distribution modeling with Maxent   * Using the Maxent software * Projecting models to new regions and time slices | *Reading:* Up to page 28 (Sections 1-4) of “Pearson\_SDMGuide.PDF”;  Phillips et al. 2006.  *Projects:* Run a Maxent model for project study region and taxa. |
| Session 5  Apr 8 | Evaluating species distribution models   * Generating test data * Setting decision thresholds * Statistical tests of model performance (e.g., AUC) * Background Selection | Species distribution modeling in R   * Using the dismo package in R * Generating and interpreting evaluation statistics | *Reading:* Pages 28-39 (Sections 5) of “Pearson\_SDMGuide.PDF”: Pearson et al. 2007; Merow et al 2013;  *Project:* Run models in R for chosen study region and taxa; generate evaluation statistics |
| Session 6  Apr 15 | Applications of GIS in conservation biology   * Quantifying land cover change and remaining habitat * Systematic conservation planning | Exercise on spatial analysis using a series of GIS tools for conservation planning. | *Reading:*Franklin 2013; Guisan et al. 2013; Stanton et al. 2015  *Projects:* Undertake analyses to address question set out in project proposal |
| Session 7  Apr 22 | Applications of GIS in evolutionary biology, including:   * Species delimitation * Studies of speciation processes * Phylogeography | Exercise on comparing modeled niche overlap of different species or populations | Reading: Blair et al. 2013; AlvaradoSerrano & Knowles 2014; Pearson & Raxworthy 2009; Raxworthy et al. 2007. *Project*: Prepare final report and presentation. |
| Session 8  Apr 27 | Review | Time to work on individual projects | *Reading:* papers specifically relevant for your project  *Projects:* Prepare final report and presentation. |
| Session 9  Apr 29 | Review | Time to work on individual projects | *Reading:* papers specifically relevant for your project  *Projects:* Prepare final report and presentation. |
| Session 10  May 4 | Overview and discussion | Student presentations of individual projects | *Projects:* Finish final report, which is due May 6. |