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CUR Focus

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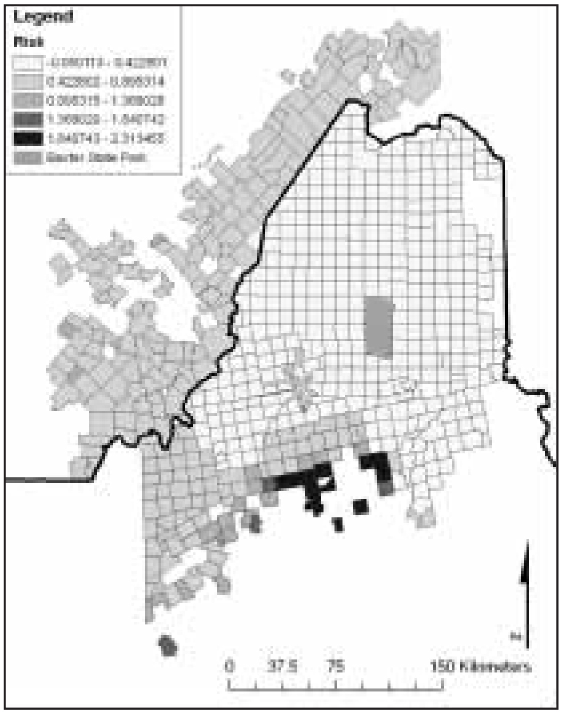
Tigers, Wolves, and Moose, Oh My: Challenges and Opportunities for Promoting Undergraduate Research in Environmental Studies with GIS

The tiger *(Panthera tigris)* and gray wolf *(Canis lupus)* are interesting but challenging animals to study. These species are wide-ranging, elusive, dangerous, and in the case of tigers, their forest home in Asia is about 10,000 miles from the nearest U.S. college. Although undergraduate students have long been interested in these charismatic mammals, few carry out original research involving these species, in part because of these difficulties. However, students at Colby College in central Maine are playing an integral role in "real world" tiger and wolf research and conservation efforts by using Geographic Information Systems (GIS) to expand the understanding of their habitat, conservation needs, and potential for conflict between these animals and humans. The growing student interest at Colby in using GIS to study these and other challenging environmental issues mirrors changes occurring in curricula of other departments and programs nationally that are recognizing the benefits of using GIS to promote spatial literacy (Newcombe, 2006; Sinton & Lund, 2007).



A vector map created by Brendan Carroll ('06) as part of his senior honors research in Environmental Policy. This map shows the results of a model of relative risk for wolf-human conflict in townships within northern Maine and southern Quebec province. For his analysis, Carroll first selected townships where road density was less than 0.7 km/km2, a threshold identified in other studies as a major predictor of wolf suitability. He then applied a regression equation based on the published literature to five landscape variables (pasture/hayfield, deer density, coniferous forest, cropland, open water, and wetlands) to identify areas of high human-wildlife conflict. Dark colors represent townships with high risk of human-wolf conflict. This map was created using ArcGIS 9.1.

Colby College recognizes the benefits of undergraduate research for student learning (see Wenzel, 1997; Kardash, 2000; Lopatto, 2003; Seymour, Hunter, Laursen, & DeAntoni, 2004; CUR & NCUR, 2005). Frequently, student research experiences help to define career plans and may generate interest in graduate study (Hathaway, Nagda, & Gregerman, 2002; Lopatto, 2003). Consequently, Colby strives to engage as many students as possible in significant research (e.g., Nyhus, Cole, Firmage & Yeterian, 2002; www.colby.edu/sturesearch/ressymposium).

In this paper we describe how Colby College has made the curricular changes and major investments in laboratory space, hardware, software, and personnel necessary to expand GIS capacity to support undergraduate research across the campus. We illustrate how students in the Environmental Studies (ES) Program are using GIS to demonstrate the range of opportunities for student engagement with this technology. We conclude with a discussion of the challenges we faced in building this program, and the lessons we learned in overcoming these challenges.

How Students Learn to Use GIS for Research at Colby

Colby recognizes the value of GIS in teaching and identifies GIS infusion into the academic program as an important College goal in its current strategic plan. The ES Program has been a campus leader in recognizing the role GIS can play in supporting undergraduate research. The Program is committed to expanding the use of GIS throughout the ES curriculum and several of our courses have already been reorganized to incorporate GIS training to support this initiative.

However, at small colleges like Colby that lack a Department of Geography where GIS training typically occurs, helping students to develop the GIS skills necessary to complete GIS research projects can be a challenge. To help overcome this problem, we have developed a range of approaches that introduce our students to this technology and prepare them for more advanced research using GIS.

Courses with team research projects and GIS components. Enrollment in existing core courses within the ES curriculum introduces a large number of students to GIS. For example, students are exposed to GIS through a series of laboratory exercises in the required Advanced and Applied Ecology course offered through the Department of Biology. GIS and remote sensing training in earlier courses prepare students for using these tools in their capstone research projects during their senior year. For more than a decade, the Environmental Science capstone course has had a required GIS component for its semester-long research project (Firmage & Cole, 1999; Nyhus, Cole, Firmage & Lehmann, 2002; Nyhus et al., 2007). The relatively new Environmental Policy capstone course now uses GIS in most years as well.

One noteworthy approach that we have used successfully to increase student research opportunities is the use of team research projects. Students are introduced to this approach in our introductory course, Environment and Society (Firmage, Tietenberg & Cole, 2005). This approach extends through a number of intermediate-level courses to the capstone courses (Firmage & Cole, 1999). The team research model allows students to work together, to learn useful collaboration skills, and to create new knowledge. This model also enables students of differing abilities and skill levels to participate in a research experience, and enables the faculty to offer research experiences to a larger number of students than would be possible using the traditional research models. Each student in a team completes specific research that contributes to the larger project. Benefits of the team research model include providing students with an intense research experience, developing various research skills, introducing students to team approaches to research problems, and building solidarity with other students in the major program (Firmage et al., 2005). These team research projects are often expanded to become independent studies, honors projects, or summer internships.

Projects involving GIS use are particularly suited to these team activities. We are now expanding opportunities for team research by enabling students in two different courses to collaborate on research projects. Students in the Introduction to GIS and Remote Sensing course are collaborating with students in the Environmental Justice course to produce maps as part of their environmental justice research projects. This collaboration provides the students in the GIS course with projects that are relevant to their field of interest as they learn the use of GIS tools. It also helps to introduce students in the Environmental Justice course to the power of GIS and to expand their research capability.

Specialized GIS courses. The ES Program began offering the Introduction to GIS and Remote Sensing course annually three years ago as a result of receiving a new faculty position. This new position emphasizing GIS teaching was the result of a long-range plan by the College to develop GIS capacity on campus. In this course, students learn about both "visual" and "analytical" GIS concepts, and receive intensive hands-on experience with GIS software. Students are required to complete independent research projects, which are often used as springboards for future independent research projects. Students present their maps and research at the year-end research symposium and on-line using both static maps and an internet map server (e.g., see www.colby.edu/environ/courses/ES212/aom06). A course in GIS will remain an important component of training for students wishing to conduct more advanced projects because it introduces students to fundamental theory and concepts of Geographic Information *Science*. For example, students taking formal coursework receive more background in the use and misuse of projections, cartographic concepts, remote sensing, and more advanced analytical concepts and software tools than they would from shorter modules in other courses.

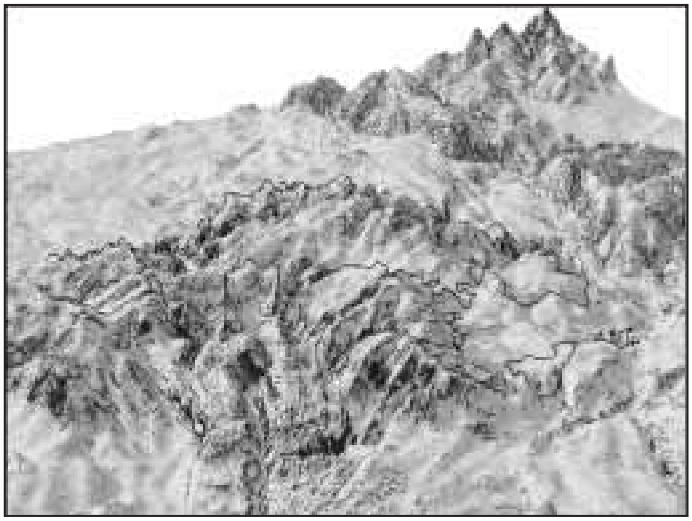
Informal non-credit learning. Some students develop GIS skills independently or by working with a faculty or staff mentor. Opportunities for extra-curricular GIS training are increasing at Colby. Through a consortium of other Maine colleges and universities, Colby students and faculty/staff have the opportunity to take on-line courses through ESRI's Virtual Campus. Increasingly, other GIS on-line training modules are becoming available as well, such as those developed by the National Institute for Technology and Liberal Education (NITLE) Latitude Initiative (http://gis.nitle.org/resources/GIST.htm). Efforts to expand GIS across the Colby campus have included in-house workshops and tutorials funded by internal and external grants. With the recent hire of a dedicated, campus-wide technology specialist with GIS skills, we expect that these workshops will become an increasingly important component of GIS training on campus for students and faculty interested in integrating a spatial dimension into their research projects.

Student Research Examples with GIS

Students who use GIS in their research activities have a variety of backgrounds and experiences with this technology. Some students are relative newcomers to GIS and they are able to create basic, but effective, descriptive vector maps; other students are experienced GIS users who create sophisticated predictive models using raster-based GIS and statistics. The following cases illustrate the diversity of GIS research activities conducted by students in the ES program.

At an elementary level, students in several non-GIS courses have created basic vector maps using GIS to support their course research projects. Three years ago, for example, students in the senior Environmental Policy Seminar capstone course created a report, *The State of Maine 2004: An Environmental Assessment* (www.colby.edu/environ/ES493/stateofmaine2004/). Each student was required to complete one map to complement their contribution to this report. The course did not have a laboratory component so the GIS efforts were limited. Nevertheless, the students were able to create meaningful maps. Jessica Beetz ('05), for example, created a cartographically simple but instructive map showing patterns of land ownership as part of her study on sustainable forestry in the state. In the 2005 iteration of this course, a laboratory session was added, in part, to enable students to have more in-class opportunities to learn and use GIS to support elementary quantitative analyses. Senior environmental science students with little or no prior GIS training have been creating sophisticated maps for years in the environmental science capstone course (Nyhus et al., 2002a; Nyhus et al., 2007).

A growing number of ES students have the GIS skills to conduct GIS projects on their own, typically as part of independent study or senior honors research. When Environmental Policy major Brendan Carroll ('05) investigated the transboundary implications of possible wolf reintroduction and recovery in Maine, he used GIS skills he gained in an earlier course to develop a spatial model of wolf depredation risk in Maine and Quebec Province. This analysis was based on previous models of wolf habitat suitability in Maine and wolf-livestock depredation models for Wisconsin and Minnesota. He first estimated the extent of wolf habitat in the study area using a road density threshold. He then combined GIS and linear regression to relate the risk of wolf-human conflict for a township or equivalent area to five different landscape characteristics. His maps show townships where there is a high risk of human-wolf conflicts. With this GIS and statistical model, Carroll was able to focus on the relevant policy implications of his findings. For example, the risk of conflict was greater in Canada than in Maine, suggesting the importance of US policy makers discussing any plans for reintroduction with their Canadian counterparts.



An example of GIS data manipulation by students collaborating with a faculty member. This figure shows the boundary of a protected area in China (black line) overlain on a 3-dimensional digital elevation model showing areas of high slope (dark) and low slope (light). The student researchers digitized the protected area boundary from paper maps and created a digital terrain model by modifying Shuttle Radar Topography Mission (SRTM) elevation data using Inverse Distance Weighting (IDW) interpolation to fill in areas of missing data. Figure was created using ArcGIS 9.1 with Spatial Analyst and 3-D Analyst extensions.

Alexandra Jospé ('06) prepared for her honors project slightly differently. As a junior, she completed a simple project that mapped the location of moose-vehicle collisions in Maine to fulfill an assignment for the Introduction to GIS and Remote Sensing course. Intrigued by the idea of making predictive models that might be useful to state biologists, she focused her year-long honor's research on developing a spatially explicit human-wildlife conflict model of moose-vehicle collisions in Maine using more sophisticated GIS tools. She identified landscape and road variables that were statistically significant predictors of vehicle collisions. She did this by comparing six years of actual collision data with a corresponding number of "dummy" variables. She was then able to incorporate these variables into a logistic regression model to develop a "risk surface" using GIS to predict the locations where future collisions would likely occur.

Other ES students complete GIS research as part of independent study projects or through summer internships. Kevin Fritze ('07) was hooked on GIS use after completing the introductory GIS course and vigorously pursued additional opportunities to use his new expertise and to expand his GIS skills. He completed a summer internship devoted to developing maps for a local land trust. Then as an intern in Washington D.C. in the spring of his junior year and a subsequent summer internship, he worked on GIS projects at the Environmental Protection

Colby Environmental Policy major Brendan Carroll ('05) working on a GIS base map of southern China.

Agency and the Department of Interior. Greg LaShoto ('07), a summer GIS research assistant at Colby, collaborated with a faculty member and the Natural Resources Council of Maine to develop a map illustrating how catastrophic sea level rise resulting from global warming could affect Maine's coast.

Finally, some students collaborate on GIS projects with faculty. For example, one faculty member is collaborating with an international team of researchers and the Government of China on a project to restore the critically endangered South China tiger (*P.t. amoyensis*) to the wild. Using documents and digital data obtained from Chinese authorities, ES students are using GIS to identify locations where appropriate habitat and other landscape characteristics might enable the successful reintroduction of the South China tiger. ES students have developed preliminary base maps not previously existing in China for use in field surveys and helped to develop tiger habitat suitability analyses. Participating in research opportunities like this one energizes students by giving them the opportunity to apply their advanced technical GIS expertise to a real world problem and provide new knowledge to Chinese authorities who did not have the resources needed to conduct these analyses.

One measure of the effectiveness of these efforts is the number of ES students who have presented award winning GIS posters and talks at off campus meetings. Another measure is the number of our graduates who have gone on to use their GIS training in jobs and at graduate programs across the country. For example, Phoebe Lehmann Zarnetski ('01) developed an early interest in GIS through the ES program. She and other students co-authored a research poster using GIS to show areas of high erosion potential in a local watershed. Their poster won the Maine Water Conference Best Poster award in 2001. Phoebe went on to expand her GIS skills in graduate school and won the prestigious Ecological Society of America's E. Lucy Braun Award for best poster at the national meetings in 2005. Alex Jospé was hired by The Nature Conservancy as a GIS analyst after graduation based on her undergraduate GIS research project.

Challenges and Responses to Building Capacity to Support GIS Research

Ultimately, support for undergraduate GIS research begins far upstream from the student sitting in front of a computer screen studying tiger restoration, wolf-human conflict, or the possible impacts of sea level rise. In building GIS research capacity in our Environmental Studies Program and across the campus we have faced several challenges and learned several lessons. We present them here in the hope that they will be helpful to faculty, staff, and administrators at other colleges and universities seeking to incorporate the use of GIS and remote sensing into their undergraduate research programs.

First, our "early GIS adopters" recognized over a decade ago that GIS could promote spatial learning as well as research and collaboration. Student GIS research in a regularly-taught course at Colby began in the capstone Environmental Science course to facilitate analysis of land use patterns and their potential impacts on lake watersheds (Firmage & Cole, 1999; Nyhus et al., 2002b). David Firmage and Russ Cole, the two faculty teaching this course, also recognized that they lacked the time and expertise necessary to invest in extensively revamping the curriculum to facilitate the use of new GIS software on their own, and that promoting a major investment in resources was needed over the long-term from the College to incorporate GIS into the curriculum successfully.

As one step in this process, with a grant from the National Science Foundation, the ES Program hired a two-year postdoctoral teaching and research fellow with GIS background who could simultaneously provide technical support while freeing up the faculty time needed to develop these new ideas into a sustainable program (Nyhus et al., 2002a; Nyhus, Cole, Firmage & Yeterian, 2004). Ultimately, this approach led to enhanced faculty and administrative recognition of the potential benefits for GIS use on campus, the need to provide more formal support for GIS in the curriculum, and the need to hire new faculty and staff with GIS background.

Second, the College has invested carefully and efficiently in the infrastructure necessary to provide faculty and staff with the hardware and space resources necessary to support GIS. GIS research often involves long periods of intensive work that is not easily done in multipurpose laboratories and classrooms. From a small beginning in one dedicated space with three Macintosh computers, MacGIS software, a small digitizing tablet, a scanner, and a color printer, we now have several teaching and public computer clusters where students can access GIS software on advanced PCs. By starting with a small, dedicated GIS laboratory, we were able to begin using GIS without a large financial commitment. These efforts became an effective "proof of concept" that became the foundation for more ambitious and expensive investment in laboratory space, such as a dedicated GIS laboratory funded by the Oak Foundation in the Diamond Building, a new home for social sciences and interdisciplinary studies that opened in early 2007.

This "start small" strategy also enabled us to establish a good working relationship with our Information Technology department and to develop a mutual understanding of the support needs necessary for the broad use of GIS and remote sensing technology on campus. This support includes providing appropriate computer and supporting hardware (e.g., workstations, servers, scanners, printers, plotters) as well as implementing standardized hardware acquisition and allocation strategies with frequent updates necessary to sustain GIS once it has been introduced to the campus.

Third, GIS software can be tremendously expensive. Our earliest efforts used freeware and a few licensed copies of ArcView 3.2. We then obtained an in-kind grant of software from ESRI for a full ArcGIS laboratory kit. Today, as part of a consortium with other Maine schools, we have achieved financial efficiencies through consortium-wide software licenses and have sought and received additional support from national organizations such as NITLE. These efforts helped to expand GIS access from the specialized laboratories of the early adopters to the faculty at large who might otherwise not have the inclination to explore the possibilities of using GIS for themselves and their students.

Fourth, libraries are a tremendous resource for supporting undergraduate GIS research. The College GIS Web pages have been maintained by the Science Librarian since 2004 to help students and faculty identify data sources, and to provide a common interdisciplinary GIS Web presence for the campus. In 2006, the Library initiated a campus institutional repository—a digital archival space to collect research projects created by Colby faculty and students. GIS projects from classes and independent research are being submitted to the repository and because of this new initiative will be accessible for on and off campus viewing.

Finally, the College has invested in support and training for faculty, staff, and students because it recognized the significant time commitment required on the part of the faculty and staff to become familiar with GIS applications and their use. This support has included sending faculty, staff, and teaching assistants to training workshops hosted by both ESRI, Inc. and NITLE, hosting on-campus workshops, and making available other information about GIS resources. The College also realized that it was unable to provide significant support for faculty and students using GIS without a GIS specialist in the Information Technology Services Department and funded the appropriate position.

Conclusion

Undergraduate research incorporating GIS and remote sensing has come a long way at Colby. Starting with a small number of students taught by two faculty members in one course in the Environmental Studies Program, GIS has become a common research tool used by many students and staff in many courses and a large and growing number of research projects. By starting with a vision—in our case the importance of learning GIS for our students—we were able to engage administrative interest and demonstrate the potential benefits of GIS to our academic program. These activities led to the inclusion of a GIS initiative in the current campus-wide strategic plan. The Dean of the Faculty, President and ultimately the Board of Trustees were able to effectively mobilize internal and external funds to support GIS and remote sensing on campus. By recognizing early the value of this new technology and the emerging GIS and remote sensing career opportunities for students, the College was willing to provide the support for grant writing and fund raising as well as other administrative aid including the approval of a new faculty position for GIS instruction, approval of a new staff position for GIS support, funding the construction of a GIS laboratory, financial support for intensive GIS training courses, and increased funding for the necessary GIS hardware and software.

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