Remote Sensing in Ecology and Conservation
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INTERDISCIPLINARY PERSPECTIVES

Bridging disciplines with training in remote sensing for animal movement: an attendee perspective

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Abstract

Remote sensing and animal movement datasets are increasingly used to answer key questions in ecology and conservation. Collecting and accessing this data is becoming ever cheaper and easier, but limited analytical expertise limits its wider use. Working at the interface between these two disciplines is challenging as there are no standard techniques for handling the complex spatial data, so specific and in-depth training is required. Higher education programs rarely cover remote sensing for animal movement, so external courses play a major role in training newcomers and creating a more unified global community. We conducted an online survey to investigate the views of previous attendees of four training courses that involve remote sensing and animal location data. These courses provided subject-specific knowledge, practical and coding skills, networking, collaboration opportunities, insightful discussions and transferable research skills. Our survey highlighted the importance of real-world examples, practical sessions, time for participants to work with their own data, preparatory material and open source software. Despite the value of interdisciplinary training in remote sensing and animal movement, it reaches few ecology and conservation practitioners outside of academia. We advocate more funding for underrepresented participants to attend existing course and the development of new courses.

Introduction

Observing the changing status of the planet is key to understanding and predicting animal distributions (O'Connor et al. 2015; Skidmore et al. 2015). With increased habitat loss, invasive species, climate change and overexploitation, it is imperative that future conservationists understand how these changes may affect species (Mace and Purvis 2008). Advances in remote sensing technology are rapidly providing new variables and higher resolution data, which could be harnessed to address key questions in ecology and conservation (Rose et al. 2014). For example, Landsat data can identify habitat degradation caused by grazing (Karnieli et al. 2013), and sea surface temperature patterns explain seabird foraging behavior (Scales et al. 2014). Similarly, animal movement is an emerging field driven by rapid developments in technology, specifically miniaturized bio-loggers, which are sensors attached to animals to record their behavior (Ropert-Coudert and Wilson 2005). Satellite imagery, in particular, is becoming increasingly important for investigating animal movement patterns (Pettorelli et al. 2014a, 2016; Wikelski et al. 2007).

The importance of earth observation for ecology and conservation was postulated over a decade ago (Roughgarden et al. 1991; Kerr and Ostrovsky 2003; Nagendra 2001; Turner et al. 2003), but various challenges still limit its application (Pettorelli et al. 2014a). Among obstacles such as data access (Turner et al. 2015) and software availability (Rocchini and Neteler 2012), the data generated by remote sensing and animal tracking technology is not straightforward to handle. Remote sensing and animal tracking data are spatially and temporally autocorrelated, and therefore cannot be analyzed using standard statistical methods (Legendre 1993; Dray et al. 2010). A key challenge is to keep up with the rapid development of analytical approaches (Nathan et al. 2008), which has led to a lack of standard methods as many similar tools have been developed without a cohesive strategy (Nathan 2008). Additionally, datasets from both fields are becoming rapidly large and more complex. The spatial and temporal resolution of satellite images is increasing and new technology, including multispectral imaging, hyperspectral imaging, RADAR and LiDAR, allow additional variables to be measured (Pettorelli et al. 2014a; He et al. 2015). Bio-logging devices are recording at a higher frequency and for longer, as well as logging additional measurements such as acceleration, temperature and sound. Furthermore, devices are becoming smaller and cheaper, allowing more species and individuals to be tagged (Ropert-Coudert and Wilson 2005; Wilson et al. 2008). Skills in analysis, coding and data management are needed to overcome the challenges posed by such complex data. Moreover, standard approaches using open access methods allow for better comparison between studies and facilitate collaboration (Hampton et al. 2013), and open access datasets allow different methods to be directly compared using the same data.

Despite the value of remote sensing in ecology and conservation, and the numerous challenges in its application, there is little training that bridges the gap between these disciplines (Pettorelli et al. 2014a). These topics are rarely covered in higher education programs (Pettorelli et al. 2014b), due to the small number of lecturers within biological science departments with such expertise. Furthermore, research institutions, universities and funding bodies rarely facilitate interdisciplinary research or teaching between departments (Cech and Rubin 2004). As such, there is a strong need to train newcomers including postgraduate students, postdoctoral researchers and ecology or conservation practitioners (Wegmann et al. 2016). Furthermore, courses have a key role in establishing connections between communities and encouraging consistent methods (Pettorelli et al. 2014a).

This interdisciplinary perspective has three main aims. Firstly, to outline the multiple benefits of attending specialist training in remote sensing and animal movement. Secondly, to demonstrate the challenges faced by those running courses, and provide information from an attendee viewpoint to aid the planning of future courses. Finally, to encourage the training of a larger number and wider diversity of users in this rapidly developing research area. We surveyed previous attendees of relevant training courses to assess their needs and preferences, and having attended the AniMove Animal Movement Analysis for Conservation in 2014 or 2015, we are equipped to present a student perspective.

Materials and Methods

Few interdisciplinary courses covering remote sensing for ecology and conservation are available (Pettorelli et al. 2014a,b), especially in relation to animal movement. We conducted an online survey of people who had previously attended a 5- or 10-day training course that involved using remote sensing and animal movement data (surveyplanet.com/56aa68df1fb2579657c33e50). We used open questions to ask what the course's main benefits and drawbacks were, and multiple choice questions to capture more detail. Between 9 March and 25 April 2016, we received 49 responses relating to four courses, which varied in the amount of animal movement material covered (Table 1).

Value of attending training courses

Training courses in remote sensing and animal movement are highly valued by participants; 98% would recommend the course they attended. We identified a number of key benefits of training courses. Firstly, new skills and

Table 1. Survey responses by course and year (1 person attended both the AniMove and CAnMove course).

Course title and host organization	2009–13	2014	2015	2016	Total
Spatial analysis of ecological data using R, PR statistics	–	1	10	9	20
Animal movement analysis for ecology & conservation, AniMove	2	6	8	–	16
ECO 304 animal movement ecology, University of Zurich	–	–	8	–	8
Ecology of migration, CAnMove, Lund University	3	–	3	–	6

knowledge acquired through the course curriculum. Secondly, a broader exposure to different approaches and problem solving through discussions with tutors and other attendees. And finally, career ideas and opportunities for networking and starting collaborative projects.

New skills and knowledge

Attendees reported improved coding and practical skills, as well as transferable research and communication skills (Fig. 1). As these courses deal with rapidly developing research areas without standard techniques (Nathan 2008; Nathan et al. 2008), providing attendees with the latest technical and computational tools is key. Learning state-of-the-art methods was the most commonly stated main benefit in response to our open question (14 participants), which is particularly important in such a fast-moving field, where published articles or books may not yet be available. Additionally, participants found it useful to learn about current methodological debates and priority areas for future development. The courses generally covered the main area of the attendees' research, and resulted in new analyses within attendees' own projects (Fig. 1). For example, Figure 2 illustrates the application of remote sensing and animal movement analysis skills learnt on the AniMove course to a participant's own data. The environmental correlates of the home range of sheep were investigated using satellite imagery and the Normalized Difference Vegetation Index in combination with dynamic Brownian Bridge Movement Models of home range from Global Positioning System (GPS) tracking (Kranstauber et al. 2012). In the era of big data, research groups and employers highly value skills in handling large datasets and analyzing complex patterns (Hampton et al. 2013).

Besides the direct acquisition of theoretical and technical knowledge, more informal discussions between the course teachers and participants proved to be highly enriching and were specifically stated as a main benefit by six respondents. Meeting both the teachers and the other attendees was beneficial to all course participants, with meeting teachers benefitting more people in relation to their studies or research and meeting other attendees benefitting more people with respect to personal aspects such as comparing lifestyles (Fig. 3). In discussions, attendees dealt with common concerns from different points of view, leading to the emergence of new ideas and approaches. Moreover, resolving specific problems is easier in diverse groups, as solutions may arise from different disciplines or people who have previously overcome similar obstacles. Additionally, explaining projects to others with relevant knowledge is a good way to clarify ideas and improve communication skills, which is particularly valuable when such opportunities are not available at home institutions.

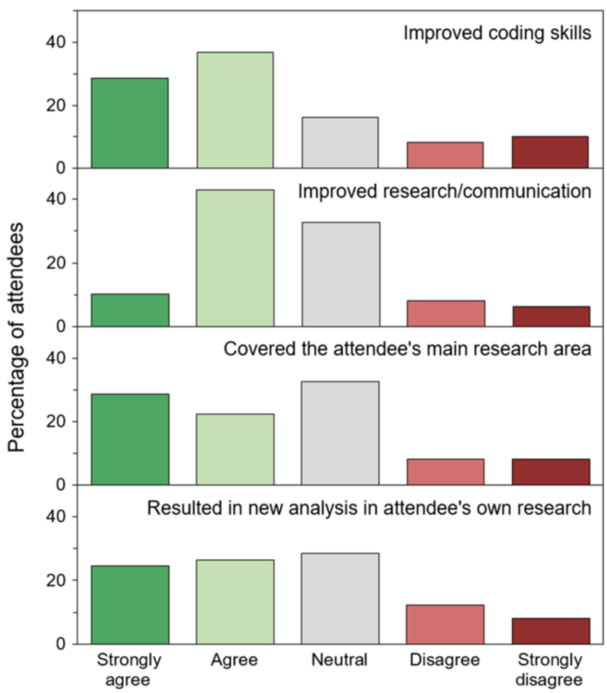

Figure 1. Survey responses from the 49 participants relating to the benefits of attending courses on a Likert scale. Answers to each question total 100%.

Networking and collaboration

Courses create networks of researchers and promote future synergies between both teachers and attendees. When our survey asked an open question on what the main benefits of the course were, 11 attendees mentioned the opportunity to make useful contacts and develop a network, and three mentioned meeting collaborators. Teachers and other attendees provided a similar number of participants with benefits relating to networking, career ideas and potential employment (Fig. 3). Interdisciplinary collaborations between remote sensing researchers and ecologists enhance the potential of both disciplines (Pettorelli et al. 2016, 2014b). Survey respondents reported three collaborations that arose from courses, including the development of a method for predicting birth events in moose, deer and elk from GPS collar data (E. Fuller, pers. comm. 2016), and a study of cougar movement in the Southern Yellowstone Ecosystem (A. Kusler, pers. comm. 2016). A further 13 attendees were planning collaborations with attendees or tutors after meeting through a course (Fig. 3). We expect more collaborations stemming from these courses to develop as 78% responses were registered less than a year and 18% less than a month after the courses.

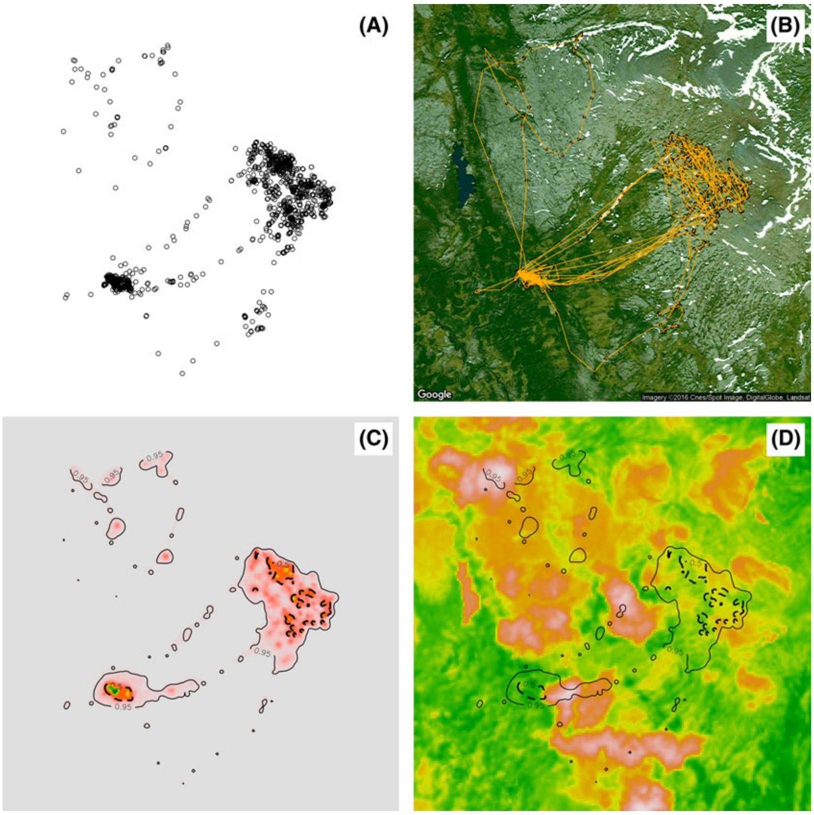

Figure 2. Hourly GPS from one sheep *Ovis aries* in Spekedalen, Norway, 23rd Jun to 3rd Sep 2013. (A) Locations plotted in R. (B) Track plotted onto Google satellite map using the 'ggmap' R package. (C) A dynamic Brownian Bridge Movement Model (dBBMM) to estimate the home range with 50 and 95% contours, created using the 'move' R package. (D) The dBBMM contours plotted onto an NDVI raster calculated from Landsat 8 surface reflectance and spectral indices data.

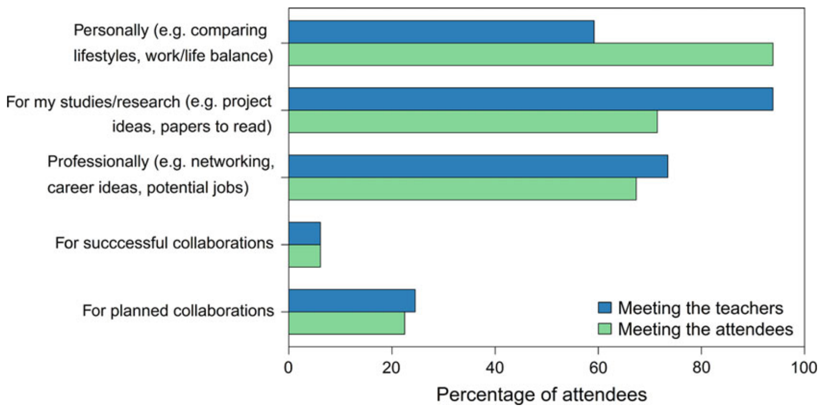

Figure 3. The percentage of the 49 attendees who found that meeting the teachers and other attendees was beneficial for each reason given in a multiple choice question.

Guidance for course organizers

Our open question asking 'What were the course's main benefits?' revealed numerous preferences of course attendees, and they reflect particular highlights as the question required free style answers. Small numbers of responses containing matching opinions are expected and opinions may be shared by participants who did not specifically expressed them. Twelve attendees praised the teaching and six particularly valued a group of specialists with diverse experience. Three participants appreciated the use of real-world data in lectures, and seven mentioned that practical examples were particularly useful, with three who would have liked more of this element. Learning to apply statistical methods to spatial datasets was also suggested. Participants want to finish a course with the ability to carry out a complete workflow, including data collection, processing, error checking, visualization, analysis and publication quality figures.

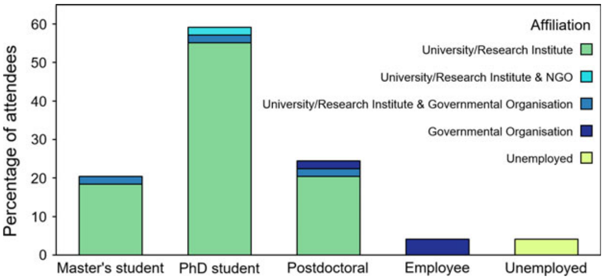

Figure 4. The position and affiliations of the 49 survey participants at the time of the course that they attended.

Course intensity

When asked what the main drawbacks of the course were, the most common response stated by 14 participants from all courses was that the course was too intensive or too short to cover the material. Attendees needed more time to go through practical exercises and use their own data, especially given the computational run time of some techniques. Planning and conducting courses for heterogeneous groups ranging from master's students to postdoctoral researchers is a challenging task. This leads to diverging requirements; our survey found that 16% of the participants strongly agreed and 12% agreed with the statement 'The course was too advanced', while 33% disagreed and 8% strongly disagreed. This is especially relevant for coding, which can be a major obstacle. A solution suggested in four responses is to provide more preparatory material before the course. We expand that to include example data formats for students to match their own data to in advance. Additionally, more explicit guidelines would allow those considering attending a course to better assess whether their skill level would allow them to get the most out of the course, and, if required, obtain more experience before the course. A small number of students per tutor is also important when individuals have differing levels of experience, as it allows for more questions. Running longer courses would reduce intensity and allow more material to be covered, but we recognize that longer courses are more costly and logistically challenging. Intensive courses may therefore be unavoidable given the constraints and complexity of the field. Having separate courses for different types of users could also reduce these problems.

Use of participants' own data

While simple datasets are required for teaching new methods, our survey showed that 94% of participants want to also have sessions for investigating their own data. Although this takes up time that could have been used to deliver more teaching material, attendees found working with their own data during the course was extremely productive as experts were available to solve problems quickly. AniMove course participants had 5 days working with their own data, and many found this very constructive. Attendees may go to a course specifically to learn how to handle their own data, rather than to learn general concepts and techniques, which is likely as most attendees were postgraduate students and postdoctoral researchers (Fig. 4). It may also be easier to understand concepts and their applicability in relation to familiar data.

Software

Spatial analysis and visualization requires specialist software, and while many participants have experience with commercial software through institutional licenses, open source software is on the rise in ecology and conservation (Pettorelli et al. 2014a). Open source software is key to maximizing the future application of taught material by ensuring that students have unlimited access after the course. All attendees wanted to learn methods using open source software, such as R (R Core Team 2016) and QGIS (QGIS 2016), with only 18% wanting to also learn commercial software, such as ArcGIS (ESRI, Redlands, CA, USA). R in particular, provides a range of packages for remote sensing and movement analysis, such as 'RStoolbox' (Leutner and Horning 2016), 'move' (Kranstauber and Smolla 2016), and the 'adehabitat' packages (Calenge 2006). Open source also promotes the development of new methods, aids research outside of academia and facilitates collaboration (Rocchini and Neteler 2012; Neteler et al. 2012).

A major challenge is the use of different operating systems and software versions, as even minor differences can cause errors and disrupt practical sessions. To minimize disruption, courses could provide more installation and update information in advance, including the required R packages. Course organizers could reduce time spent troubleshooting by using a pre-configured virtual environment containing all the required course material, software and R packages (e.g. http://live.osgeo.org/en/index.html). The adapted virtual machine could then be imported and used seamlessly on any platform a participant may bring (e.g. www.virtualbox.org). However, we recognize that new software or operating systems might increase the complexity for organizers, and it is important to ensure that participants can repeat taught techniques after the course.

Recommendation summary

The most worthwhile training incorporates the coverage of theory, multiple analytical techniques, practical coding methods, data management and time to work with participants' own data. Logistical and financial constraints on course length mean that these courses become very intensive, so organizers could optimize time in the course by providing more preparatory material, guidelines on the preferred level of coding skills required, installation instructions and having small numbers of students per teacher.

Reaching a wider diversity of participants

Our ability to monitor animal movements and environmental change is improving as technological advances facilitate the collection of large high-resolution datasets (He et al. 2015; Ropert-Coudert and Wilson 2005; Hampton et al. 2013). Generating these datasets is becoming easier and cheaper, but analytical skills are lagging behind (Pettorelli et al. 2014a). We call for more training in this field and for the training to reach a wider diversity of participants, particularly ecologists and conservationists outside of academia, and researchers from developing countries. A course with a diverse group of attendees and tutors of different positions, affiliations, nationalities, research themes and experience was seen as highly beneficial in five responses to the open question on the main course benefits. For one course, a poor ratio of 0 female to 8 male teachers was also mentioned. Women are underrepresented in science, and even though biological science has a more equal ratio up until postgraduate level, there is still a long way to go (Blickenstaff 2005; Cronin and Roger 1999). Given the importance of diversity, we encourage appointing a more balanced ratio of female and male teachers.

Attendee affiliation

Training ecologists and conservationists contributes to Target 19 of the Aichi Biodiversity Targets by enhancing implementation through capacity building (O'Connor et al. 2015), but training in remote sensing for animal movement is reaching few practitioners outside academia. We found that 90% of course participants were affiliated with universities or research institutes, and only 9% of those were jointly affiliated with NGOs or governmental organizations (Fig. 4). Many knowledge gaps are filled through collaborations between remote sensing experts and ecologists or conservationists (Pettorelli et al. 2014b). But to keep up with the rate of animal movement data collection, practitioners will need the analytical tools to complete projects autonomously. Training targeted specifically at conservation practitioners may be the best way to achieve wider participation (Buchanan et al. 2015; Wegmann et al. 2016).

Course costs and travel

Financial cost and travel are key factors preventing the attendance of conservation practitioners and students; six participants mentioned course cost as a main drawback in response to the open question. People were willing to spend a median of 600 USD (mean of 708 USD) on a 5-day course, but travel and accommodation can be prohibitively expensive, due to the small number of courses worldwide. This issue is particularly important for attendees from developing countries, where funding is limited and conservation need is great (Waldron et al. 2013; Bruner et al. 2004). Two responses mentioned that serious jet lag made the course more difficult, which can only be solved by having courses within more time zones. Furthermore, learning in a non-native language was challenging for some, and despite an international student base, to the best of our knowledge, there are no similar courses taught in a language other than English. As such, more courses and more funding options for attending existing courses is key to maximizing the potential of remote sensing in ecology and conservation. We urge postgraduate supervisors, non-governmental organizations and employers to consider this type of training in budgets. We also encourage research council, institutes and universities to provide awards or scholarships for course attendance and organization.

Summary and Conclusions

Remote sensing is becoming an increasingly important tool for ecology and conservation. However, completing projects that span the disciplines of remote sensing and animal movement is challenging due to large datasets, lack of standard analytical techniques, limited coverage in standard curriculums and small communities within institutions. Training can bridge the gap by bringing newcomers up to date and forming a more cohesive network. We show that courses are highly valued by previous attendees and provide subject-specific knowledge, practical and coding skills, as well as opportunities for networking and collaboration, clarifying research ideas and gaining generic research and communication skills. We stress the importance of interdisciplinary training in increasing the application of remote sensing in conservation and ecology.

Here, we provide recommendations for three groups: those considering attending a course, course organizers, and those who may allocate funding for students or employees to attend courses. Firstly, we advise attendees to learn about general coding and statistics in advance, as courses in this field tend to be intensive. Secondly, we recommended that course organizers: use real-world examples in lectures; include many practical sessions; incorporate time for participants to investigate their own data; provide more preparatory material; and teach with only open source software. We also suggest that courses are taught by a diverse group of teachers, with different expertise and a more equal gender balance. Finally, we advocate more funding for underrepresented participants to attend existing courses and for new courses to be developed.

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