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Bottom-up resource limitation: the ecosystem energy balance predicts the quality of nutrition in a herbivore prey population

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Published in:
Remote sensing for conservation: uses, prospects and challenges

Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
Fernandez, N., Garcia, M., Gil, E., Serrano, E., & Delibes, M. (2014). Bottom-up resource limitation: the ecosystem energy balance predicts the quality of nutrition in a herbivore prey population. In N. Pettorelli (Ed.), *Remote sensing for conservation: uses, prospects and challenges: Abstracts* (pp. 21-21). Zoological Society of London.

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symposium

ZOOLOGICAL SOCIETY OF LONDON
REGENTS PARK, LONDON, NW1 4RY

22 and 23 May 2014

REMOTE SENSING FOR CONSERVATION: USES, PROSPECTS AND CHALLENGES

Photos: www.earth-observation.org ; visibleearth.nasa.gov

ABSTRACTS

Organised by

**Nathalie Pettorelli, Zoological Society of London;
Martin Wegmann, University of Wurzburg & DLR;
Woody Turner, NASA**

8.30 REGISTRATION OPENS

8.55 **Welcome**

Nathalie Pettorelli, Zoological Society of London, UK
Email: nathalie.pettorelli@ioz.ac.uk

9.00 **Keynote: What don't we know? Thinking about the missing information**

Jonathan Baillie, Zoological Society of London, UK
Email: jonathan.baillie@zsl.org

We are currently in the dark ages of conservation where society has little understanding of the species and ecosystems with which we share the planet, our impact on them and the implications for humanity if they are destroyed. With rapid advances in technology we are now entering an era where we will be able to effectively monitor both biodiversity and drivers of biodiversity loss. This information will completely transform the field of conservation as it will clearly define our impact on other forms of life and make it easier to explore the relationship between biodiversity and human wellbeing. It will also allow the conservation movement to truly identify the success or failure of interventions. In this new era, our destruction of biodiversity will be transparent and the implications relatively well understood.

9.30 **Keynote: Remote Sensing for Conservation: New Directions**

Woody Turner, NASA, USA
Email: woody.turner@nasa.gov

How can remote sensing scientists and conservation biologists synchronize efforts to benefit conservation, making remote sensing a standard tool in the conservation toolkit? Doing terrestrial or aquatic conservation with remote sensing forces us to address the challenge of scale. The relatively coarse spatial scales of remote sensing pixels have traditionally limited the perceived utility of remote sensing in the ecological sciences. The answer to this challenge of scale lies in the integration of different types of observations at different spatial scales. In particular, we need to integrate environmental remote sensing at continental, regional, and landscape/seascape scales with ecosystem, organismal, and genomic biodiversity observations. This requires translators. Typically, these are common reference frames in space and time, provided by geographic information systems and observations with georeferenced time-stamped metadata, and qualitative and quantitative models expressing our knowledge of how remotely-sensed environmental parameters relate to biological data. Today, we have common reference frames and many useful models. We also have time series of some key environmental parameters from remote sensing (e.g., climate and land/ocean surface conditions). What we often lack are time series of biodiversity data. The good news is that a plethora of new observations are available for capturing elements of biodiversity through time. In fact, these new observation systems are ushering in an era of near-ubiquitous remote sensing. Drones, camera traps, sound recordings, cell phone apps, and new small satellites are among the tools providing an ever-growing amount of fine-scale biodiversity imagery. The remaining challenge is to develop frameworks, partly technical IT networks, but also—and just as important—social frameworks in which remote sensing technologists and conservation biologists can work together to use these new tools for the preservation of life on Earth. Getting started on building such a social framework is a key goal of this symposium.

10.00 ***POSTER SESSION (TEA/COFFEE)***

SESSION I: SATELLITES TO MONITOR PRESSURES ON BIODIVERSITY

Chair: Allison Leidner, NASA Earth Science Division

10.30 **Oil in the Sahara: mapping anthropogenic threats to Saharan biodiversity from space**

Thomas Rabeil, Sahara Conservation Fund, France
Email: thomas.rabeil@saharaconservation.org

Clare Duncan[1], Daniela Kretz[1,2], Martin Wegmann[3,4], Thomas Rabeil[5] & Nathalie Pettorelli[1]
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Deserts are among the most poorly monitored and understood biomes in the world, with evidence suggesting that their biodiversity is declining fast. Oil exploration and exploitation can constitute an important threat to fragmented and remnant desert biodiversity, yet little is known about where and how intensively such developments are taking place. This lack of information hinders local efforts to adequately buffer and protect desert wildlife against encroachment from anthropogenic activity. Here, we investigate the use of freely available satellite imagery for the detection of features associated with oil exploration in the African Sahelo-Saharan region. We demonstrate how texture analyses combined with Landsat data can be employed to detect ground-validated exploration sites in Algeria and Niger. Our results show that site detection via supervised image classification and prediction is generally accurate. One surprising outcome of our analyses is the relatively high level of site omission errors in Niger (43%), which appears to be due to non-detection of potentially small-scale, temporary exploration activity: we believe the repeated implementation of our framework could reduce the severity of potential methodological limitations. Overall, our study provides a methodological basis for the mapping of anthropogenic threats associated with oil exploitation that can be conducted across desert regions.

11.00 **The NDVI and its potential to track pressures and their impact on biodiversity**

Nathalie Pettorelli, Institute of Zoology, Zoological Society of London, UK
Email: Nathalie.pettorelli@ioz.ac.uk

Over the last few decades, theoretical and applied ecology have increasingly relied on the wealth of opportunities and information provided by new technological developments, as exemplified by animal tracking devices such as GPS, camera traps, or increased computational speed for sophisticated analyses such as Bayesian analyses. The Normalised Difference Vegetation Index (NDVI) is among those technological advances useful for ecology. The NDVI is a satellite-based index that has been shown to be highly correlated with plant canopy absorbed photosynthetically active radiation, photosynthetic capacity, net primary production, leaf area index, fraction of absorbed photosynthetically active radiation, carbon assimilation, and evapotranspiration. NDVI data can provide valuable information about temporal and spatial changes in vegetation distribution, productivity, and dynamics; allowing monitoring of habitat degradation and fragmentation, or assessment of the ecological effects of climatic disasters such as drought or fire. NDVI has also provided ecologists with a promising way to couple vegetation with animal distribution, abundance, movement, survival, reproductive parameters, or population dynamics. The NDVI opens the possibility of addressing questions on scales inaccessible to ground-based methods alone as it is mostly freely available, with global coverage across several decades, and high temporal resolution. With this talk I aim to provide an overview of the principles and possible applications of the Normalised Difference Vegetation Index (NDVI) in ecology and conservation, with a focus on its potential to track pressures and their impacts on biodiversity.

11.30 **Combining land cover change and fragmentation analyses to track habitat degradation**

Martin Wegmann, CEOS Biodiversity, DLR, Department of Remote Sensing, Wuerzburg, Germany
Email: martin.wegmann@uni-wuerzburg.de

Martin Wegmann, Moreno Di Marco, Zoltan Szantoi, Nathalie Pettorelli

Land cover change is occurring globally and is monitored by governmental and non-governmental agencies with remote sensing expertise. Deriving actual land cover statistics and land cover change information is highly relevant for decision makers and conservation practitioners. Analyses based on remote sensing are often driven by data availability, technical advances and capabilities and perspectives. However ecological requirements are frequently bypassed, making it difficult to evaluate the ecological effects of land cover change on habitats. In this interdisciplinary study we combine remote sensing technologies with ecological analysis of habitat fragmentation to evaluate the ecological effects of land cover change in African protected areas. Using information on habitat requirements for mammal species and land cover classification based on medium spatial resolution satellite imagery, we derive ecological relevant information on land cover change over time with respect to its effects on species. Several spatial pattern analyses are conducted on a landscape and protected area scale. The results provide valuable information not only about the total amount of land cover in the study area, but also about their spatial arrangements and, in combination with ecological data, also about their ecological value(s). This study shows the importance to approach land cover studies from an interdisciplinary perspective. Even relatively minor losses of natural land cover (i.e. loss of species habitat) can have large effect on the level of landscape connectivity perceived by species. Analyzing these effects is only possible with in-depth knowledge of the species ecology such as their sensitivity to disturbance or their movement patterns in combination with ecological relevant remote sensing land cover data. Data from remote sensing agencies are necessary to be analyzed jointly with scientists in conservation, biodiversity, or ecology to develop relevant environmental information. Depending on the aim and available ecological information the development of new interdisciplinary remote sensing products do provide complementary needed information for value added land cover information.

12.00 **The Global Urban Footprint – a new worldwide human settlements layer to assess anthropogenic disturbances**

Thomas Esch, German Aerospace centre (DLR), Germany
Email: thomas.esch@dlr.de

T. Esch[a], M. Marconcini[a], A. Felbier[a], W. Heldens[a], A. Roth[a], M. Wegmann[b]
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Half of the human population is already living in urban environments and the sprawl of man-made infrastructure into the natural and cultivated urban hinterland is expected to continuously progress in the future. Hence, it is a vital challenge to conservation biology and environmental management to i) understand the complexity, cross-linking and increasing dynamics of the global urbanization patterns, and ii) to meet the rapidly growing need for sustainable urban, peri-urban and rural development by implementing effective instruments for the observation, analysis and control of urban sprawl. Here it is important to note that the process of urbanization has to be considered as a spatial continuum ranging from urban to rural settlements that frequently shows a fuzzy transition and complex interdependency between the built-up area and the adjacent cultivated or natural landscape. A promising approach to monitor the status and development of human settlements is the analysis of Earth observation (EO) imagery. However, considering human settlements layers (HSL) for developing countries, the capability of existing data sets to accurately delineate small and scattered towns and villages is quite limited. Therefore, recent EO-based initiatives have started with the aim to provide more accurate HSL based on high resolution EO imagery – one of them being the Global Urban Footprint (GUF) project of the German Aerospace Center (DLR). In the context of the GUF initiative a fully-operational processing system for the detection and delineation of built-up areas from radar imagery collected by the German TanDEM-X (TerraSAR-X add-on for digital elevation measurement) mission in the years

2011-2013 has been developed that finally provides a binary settlement mask (raster file) indicating built-up and non-built-up areas in a spatial resolution of 12 m. Moreover, we introduce and demonstrate a technique that uses the globally available GUF settlement mask to facilitate an effective large-scale (continental, global) spatial and structural characterization of human settlements properties and patterns based on spatial network analysis. The results achieved indicate the high potential of the developed approaches to quantitatively and qualitatively describe the settlement pattern at a very high spatial precision from the local up to a continental level. We could also demonstrate the capabilities of the GUF layer and spatial analysis techniques to describe landscape fragmentation and related predictions of human disturbances to habitats. Hence, the presented data sets and methods can help to improve the ecological understanding of the drivers affecting changes in the biodiversity patterns.

12.30 LUNCH

13.30 **Monitoring fires from space**

Diane Davies, NASA LANCE Operations Manager, Sigma Space Corporation /Trigg Davies Consulting Ltd, USA
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Monitoring fires from space is not new. NASA's MODIS sensor, onboard the Terra and Aqua Earth Observing System satellites have been providing global fire observations since 2000 and 2002 respectively. But not all fires are detected, and not all hotspots detected are fires – so what do we need to know to make satellite-derived fire information useful for conservation? A basic understanding of how fires are observed, which fires will be detected as well as what it means on the ground. NASA's Fire Information for Resource Management System (FIRMS/GFIMS) was originally developed to get MODIS (MODerate resolution Imaging Spectroradiometer)-derived active fire/hotspot information directly in to the hands of protected area managers. FIRMS provides: fire locations in formats that can easily be ingested in to a Geographic Information System (GIS) or Google Earth-type application; web mapping tools to view, query and download fire locations; and an email alert service, which notifies users of fires in or around their area of interest. This talk will provide a brief overview MODIS-derived fire products useful for conservation as well as describing FIRMS, now part of NASA's Land Atmosphere Near real-time Capability for EOS; some caveats that should be considered when using these data; and examples of how MODIS-derived fire information are being used for conservation. There will also be a brief overview of VIIRS (Visible Infrared Imaging Radiometer Suite), onboard the Suomi National Polar-orbiting Partnership (NPP) satellite – which is expected to provide continuity after MODIS.

14.00 **Detecting and monitoring threats to marine biodiversity**

Frank Muller-Karger, University of South Florida, USA
Email: carib@usf.edu

Coastal and marine ecosystems are showing the impact of climate change and increased human use of resources. In particular, continental shelves and coastal ocean waters support numerous industries in areas as diverse as tourism and recreation, energy extraction, fisheries, transportation, and applications of marine bio-molecules. A proactive effort to understand how the diversity of these regions is changing is needed to inform mitigation and adaption policy, so that nations around the globe can more effectively monitor their Exclusive Economic Zones (EEZ). Yet we currently have no standardized metrics for assessing changes in ecological function in the coastal ocean. A coordinated, international monitoring effort based on scientific insight and technological inventiveness will be required to establish biodiversity baselines and to continuously evaluate change of biological resources in these economically and ecologically valuable regions. The tools to start these large-scale assessments are available today. Some examples help illustrate efforts to use remote sensing observations to map coral ecosystems, evaluate stressful conditions due to changes in temperature in the ocean, and characterize changing biological resources over large spatial scales.

Specifically:

1) The Global Millennium Coral Reef Map, developed with NASA support using over 1,200 Landsat images, is available through the UNEP WCMC (http://data.unep-wcmc.org/datasets/13). It provides users with a simple GIS-format basemap of geomorphological features useful to understand the spatial distribution of resources in shallow coral environments. Our next steps need to include developing the technology to map habitats using higher spatial resolution imagery, such as from DigitalGlobe's World-View 2 (2 meter resolution) and other such sensors.

2) Global assessments of coral reef stress due to high temperature events are deployed operationally by the Coral Reef Watch program (http://coralreefwatch.noaa.gov; US NOAA NESDIS); we can now use these products to evaluate changes in biodiversity of coral reef communities over the past two decades. These products are an example of the applicability of global satellite data products to understand local impacts of large-scale change.

3) Oceanic-scale ecosystem monitoring: Various complementary ocean remote sensing datasets are now available to evaluate physical and biological environmental parameters from local to global scales. These include global time series of temperature, wind, ocean currents, salinity, and ocean color observations. Experimental products help assess primary productivity and phytoplankton functional group distributions in the world's oceans based on satellite ocean color data. As hyperspectral satellite sensors are developed, we will be able to combine these into new dynamic assessments of phytoplankton size classes, functional types, and ecosystem function. We will be able to monitor 'seascapes', similar to how we evaluate terrestrial 'landscapes'. Monitoring seascapes over time will help understand how marine ecosystems are changing. An important focus needs to be the Exclusive Economic Zones of coastal nations.

These examples show that we are ready to develop and implement an operational Marine Biodiversity Observation Network. Particular emphasis on monitoring lower trophic levels seems relevant, since these organisms form the base of the marine food web, play critical roles in global biogeochemistry, and are highly sensitive to ecosystem perturbations both at the bottom and at the top of the trophic structure. Such a system will help protect the livelihoods of coastal communities in the context of the goals of the Future Earth program and of the Intergovernmental Platform on Biodiversity and Ecosystem Services.

14.30 **Benefits of hyperspectral remote sensing for tracking plant invasions**

Kate He, Murray State University, USA
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Biological invasions are viewed as a significant component of global change and have become a serious threat to natural ecosystems. Concerns for the implications and consequences of successful invasions have stimulated a considerable amount of research aimed at understanding the mechanisms of invasion and providing guidelines for control and management efforts. In this paper, we aim to report what remote sensing can offer for invasion ecologists and review recent progress made in plant invasion research using hyperspectral remote sensing. We review the utility of hyperspectral remote sensing for detecting, mapping, and predicting the spatial spread of invasive species. A range of topics are discussed, including the tradeoff between spatial and spectral resolutions and classification accuracy, the benefits of using time series to incorporate phenology in mapping species distribution, the potential of biochemical and physiological properties in hyperspectral spectral reflectance for tracking ecosystem changes caused by invasions, and the capacity of hyperspectral data as a valuable input for quantitative models developed for assessing the future spread of invasive species. We found that hyperspectral remote sensing holds great promise for invasion research. Spectral information provided by hyperspectral sensors can detect invaders at the species level across a range of community and ecosystem types. Furthermore, hyperspectral data can be used to assess habitat suitability and model the future spread of invasive species, thus providing timely information for invasion risk analysis. Our review suggests that hyperspectral remote sensing can effectively provide a baseline of invasive species distributions for future monitoring and control efforts. The information collected by sensors on the spatial distribution of invasive species can help land managers to make long-term constructive conservation plans for protecting and maintaining natural ecosystems.

15.00 POSTER SESSION (TEA/COFFEE)

SESSION II: SATELLITES TO MONITOR THE STATE OF BIODIVERSITY

Chair: Jennifer Swenson, Duke University

15.30 **Measuring and monitoring changes in land cover**

Lucy Bastin, Aston University, UK
Email: l.bastin@aston.ac.uk

Land use change and habitat degradation must be monitored and measured in order to identify risks and to plan for conservation in the context of increasing population and development pressures. Historically, remotely-sensed data has been an ideal tool for this purpose, combined with expert knowledge and ground truth to train classifiers and to distinguish true patterns and trends from natural variations and errors in classification. The variety of remotely-sensed data is increasing at a spectacular rate, with new suites of sensors offering potentially huge quantities of timely data at a high resolution. Models for interpreting and classifying the data are also advancing, and in some cases are moving from the office or desktop to the Web, allowing models (for example, multispectral classifiers or topographic correction algorithms) to be shared, published and composed into flexible workflows that can be used to carry out truly reproducible science. At the same time, the explosion in citizen science and user-generated content seems very suitable for validation of land use and land cover maps against photographs, textual reports and truly scientific classifications from members of the public. The potential for combining these resources to map the state of the earth and predict environmental outcomes is huge, but there are several challenges, which include: finding useful inputs from a variety of heterogeneous information; ensuring that data and tools will work together; assessing the trustworthiness of data and results; and documenting workflow and provenance. We present some example solutions to these challenges which follow the principles of GEOSS*. Feedback mechanisms can allow users to rate and report on datasets and resources. Interoperability is illustrated with examples of Web-based landcover validation tools which are based on free and open-source software and standards, and support expert / community reporting. A variety of tools are available to gauge and handle uncertainty, and to convey its impact to decision makers, and there are important initiatives underway to standardise the way that the lineage of a dataset can be recorded. We show how these tools can be used to increase the usability of earth observation data by local stakeholders and experts, and can assist in ensuring the best possible recording of landcover change.

16.00 **Remote sensing and the management of rare ecosystems: mangroves as a study case**

Temilola Fatoyinbo, NASA, USA
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Mangrove forests are important ecosystems that provide a number of ecological, social and economic benefits. They provide critical habitat and nursery grounds, play key roles in biogeochemical and hydrological cycling, regulate water quality, reduce shoreline erosion, provide coastal protection from extreme events, and support large numbers of economic activities. These ecosystems only cover less than 1% of the Earth's terrestrial surface, yet, they are amongst the highest carbon storing and exporting ecosystems globally. Despite these known benefits, mangroves have been greatly destroyed and degraded by humans. Current estimates of the loss of original mangrove forests are as high as 60%. The main drivers of mangrove decline are anthropogenic in nature, with shrimp farming, urban development, changes in water management and felling for local use as prime causes. In addition to the direct human influence, mangroves are greatly impacted by extreme weather events such as severe storms and tsunamis, sea-level rise and other direct consequences of climate change. Recent advancements in remote sensing technology have permitted the mapping and monitoring of mangrove ecosystems in 2 and 3 dimensions, on a regional to global scale. This talk will focus on leveraging the development of cutting-edge remote sensing technology for applied mapping and of mangrove ecosystem structure and distribution. In particular, we will discuss using Interferometric SAR and LiDAR data to derive mangrove height and biomass on a global scale and the implications for the conservation and biodiversity science community.

16.30 **Counting animals from above: technical advances to monitor populations from flying platforms**

Peter Reinartz, German Aerospace centre (DLR), Germany
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Peter Reinartz[1], Martin Wegmann[2]
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The development of Earth Observation (EO) data in the past decades has increased the applicability to detect small scale features such as big animals or flocks. Recent studies show that EO can be applied for mapping animals but still a large gap exists to apply EO in automatic animal detection and counting for conservation. However many advances have been made in other related fields such as car or human detection and tracking and these methods provide a high potential for conservation. But identifying and differentiating a variety of animal species requires higher resolution imagery than provided by space borne remote sensing. Here we present the general potential to detect and count features using aerial photography and furthermore outline its applicability for animal detection. The evaluation of very high resolution optical remote sensing data, acquired from airborne platforms, allows detailed analysis of the covered areas. In recent years innovative applications have been boosted through new image processing techniques, especially in the field of computer vision and through faster processing capabilities. Single objects like vehicles, humans and animals can be detected, counted and tracked and their density and even their patterns and dynamic behaviour can be studied and quantitatively analysed. The German Aerospace Center (DLR) has developed a camera system (3K-Camera-System) together with a real-time, on-board, image data processing system and data down link capabilities. These systems are used for applications in the field of traffic and people as well as disaster monitoring in urban or rural environments. Technical properties of the system and real-world applications are presented. Currently the detection, counting and tracking of the animal "homo sapiens" is aimed at, with a focus on detecting humans, estimating their number in crowds and analysing their movement direction and speed. For this a probabilistic framework of local features in the image whose spectral reflectance differs from the surrounding region is applied, followed by a mean shift segmentation to obtain probability density functions (pdf). Finally, graph theory is used to detect segments which should represent people or small groups of people. Counting is also performed for larger and dense groups, using the pdf as well as estimations in a transformed colour space.

All these approaches have been developed primarily for car and human detection but can be adjusted to animal detection and counting. Applying such algorithms shows that these methods perform appropriate even on low resolution and bad quality images found on the internet. We demonstrate the performance to detect animals in a variety of different images of birds and mammals. The feasibility to detect animals with the proposed approach using aerial images of varying quality and viewing angles from several different terrestrial ecosystems is shown in preliminary results with no fine tuning of the developed algorithm. Irrespective of a missing adjustment the algorithms demonstrate that they can successfully detect (and count) animals. Based on these promising first results, a replicable and objective method for estimating animal abundance might be established for monitoring e.g. populations in national parks. However all approaches are limited by the ecology and behaviour of the targeted animals. Such approaches will only perform appropriate if for example no vegetation hampers the detection and the animals are not highly mobile, otherwise population estimates might be error prone. The methodology still requires estimations of error and uncertainties to be incorporated in order to provide reliable animal counts for conservation and moreover depend very much on the image background e.g. soil or grassland, as well as on other features of the image data.

As a first draft, the approach highlights how technical innovations in remote sensing could provide valuable information for conservation management. Finally important questions and challenges are raised for discussion on how this methodology and also alternative camera systems could be used to monitor populations from ground based and flying platforms in different environments and under diverse conditions.

17.00 POSTER SESSION with cash bar. Symposium end of day one (18.30)

19.00 SYMPOSIUM DINNER – tickets to be booked in advance

SESSION II: SATELLITES TO MONITOR THE STATE OF BIODIVERSITY

Chair: Emily Lines, University College London

9.00 **LiDAR as a tool to monitor biodiversity**

Thomas Nauss, Philipps-Universitat Marburg, Germany
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The development of effective conservation management requires accurate information on the spatial distribution of biodiversity. However, biodiversity data can be expensive to collect and is often limited by the availability of appropriate taxonomic expertise. Therefore field sampling is inefficient for visualizing spatial patterns of biodiversity across large extents with a sufficiently fine grain. Recent developments in remote sensing sample ecological relevant information across large extents with a fascinating fine grain that allow to model biodiversity. We will give a short and user-friendly introduction to the methodology of LiDAR (Light detection and ranging) and we will present examples of the possibilities to model biodiversity using variables derived from LiDAR information. LiDAR information can provide fascinating details of the vegetation structure. LiDAR surveys are also cost-effective and cost just 5% of the cost of field sampling, when area was taken into consideration. We show that it is possible to model occurrence and abundance of species as well as of communities using these data on vegetation structure. However, the performance of models differs considerably between species, communities as well as between methods used to collect the field data for ground-truthing. Furthermore for species data the performance of models using LiDAR is correlated to the performance using other sets of independent data. Thereby the performance of the models shows a phylogenetic signal. In the future we need more efforts to predict the performance of models by using natural history information of species as well as by using ecological information about the processes structuring communities.

9.30 **Predicting vertebrate movement from space to better inform landscape management planning**

Kamran Safi, Max Plank Institute, Germany
Email: ksafi@orn.mpg.de

Studying animal movement is key element in international efforts for conserving biological diversity in the face of increasing fragmentation and landscape level human alterations, even in the remotest of all places. Without understanding the proximate and ultimate mechanisms involved in the various aspects of animal movement in the environmental context it happens, it will be essentially impossible to understand, and ideally anticipate, population dynamics, speciation processes or the effect of human alteration on species extinction processes, particularly, but not exclusively, for migratory species. Here, I present a global study on migratory pathways that were modelled from 16 different species encompassing movement data of several hundred individual birds. This study exemplifies how empirical data on specific behaviour such as migration can be combined with remote sensing information to map at continental levels important areas of a period during the animals' lifetime where they are highly susceptible to landscape level alterations. This study is the first quantitative model of migratory behaviour and could be used not only to highlight important areas, but due to the nature of modelling movement, can be used to quantify potential impact on specific populations in a quantitatively explicit way.

10.00 **Unveiling wild animal populations' secrets using satellite data**

Peter Fretwell, British Antarctic Survey
Email: ptf@bas.ac.uk

Wildlife populations in Antarctica are often poorly quantified often due to the remote and inhospitable nature of the environment, which makes sites inaccessible or expensive to monitor. All vertebrate life on the continent is dependent on the Southern Ocean for food and over the last few decades this ocean has become subject to regional climate-change and a growing commercial fishery that pose a potential threat to many of the animals living here. Baseline population estimates and accurate monitoring are urgently needed to understand which species in which areas may be at risk. One solution to this problem has been the use of Very High Resolution (VHR) satellite imagery. As the resolution of satellite data has increased, finer and finer detail has become visible, and we have now breached a threshold where individual animals can be seen. This technology has facilitated the ability to find, estimate and monitor populations of wildlife and in some cases has revealed new behaviour and adaptations to environmental change. The use of this VHR satellite imagery has been pioneered in Antarctica where there is no obscuring vegetation and the lack of terrestrial predators means that the mammals and birds have little need for camouflage and have a high visual contrast with their surrounding environment. Here we discuss several scientific breakthroughs using this technology, including the ability to find emperor penguins colonies and estimate their population using VHR satellites which has led to the first synoptic, comprehensive survey of a species from space. We also discuss new techniques to find and count other bird species including pygoscelis penguins and (by using the unique spectral signature of their guano) flying seabirds. Finally we showcase ongoing efforts to use VHR satellite imagery to identify and automatically count cetaceans in the Southern Ocean, including recent satellite studies on elephant seals, ice seals and baleen whales such as southern right, blue and humpbacks.

10.30 POSTER SESSION (TEA/COFFEE)

SESSION III: SATELLITES TO INFORM RESPONSES TO THE CURRENT BIODIVERSITY CRISIS

11.00 **Using remote sensing to inform conservation priorities**

Graeme Buchanan, RSPB, UK
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It is established that the funding available to conservation falls well short of the amount needed to address the current extinction crisis. Consequently, conservationists need to target funding to where it is most needed. To set priorities, the conservation community needs information on what is where and how is or might be changing. While in situ field data is invaluable, remote sensing can provide a valuable tool for delivering this information, filling the gap left where conventional in situ monitoring is lacking, or unfeasible to collect. This talk considers how remote sensing data can be used to set conservation priorities for sites and species (relevant to Aichi targets 11 and 12). In particular, the talk considers the use of remote sensing data to assess species distributions and changes in suitable habitat, and loss of natural land cover on sites, and the benefits of better access to not just remote sensing data, but tools to derive these products.

11.30 **Effectiveness of African protected areas for the conservation of large mammals**

Carlo Rondinini, University of Rome, Italy
Email: carlo.rondinini@gmail.com

Although conservation intervention has reversed the decline of some species, conservation success is outweighed by a disproportionate number of species moving towards extinction. African large mammals have lost most of their populations in the last 40 years, even inside protected areas (PAs), and have faced an overall increase in extinction risk. At the same time, the African PA network is mitigating habitat loss for forest species. Here I present two studies that combine satellite imagery and data on mammal distribution and biology to elucidate the effectiveness of African PAs for the conservation of large mammals.

In the first study, the extinction risk of African mammals is modelled by applying machine learning techniques to a set of independent variables belonging to four classes: species distribution state, human pressures, conservation response, and species biology. We derived information on distribution state and human pressure from satellite-borne imagery. Variables in all four classes were identified as important predictors of extinction risk, and coverage by PAs played a prominent role. Interactions were observed among variables in different classes (e.g. level of protection, human threats, species range size). The model was 90% accurate in classifying extinction risk status of species.

In the second study, the role of PAs in maintaining connectivity for large mammals in Africa was assessed. The African PA network has the potential to act as a set of functionally interconnected patches that conserve meta-populations of mammal species, but individual PAs are vulnerable to change, which may disrupt connectivity and increase extinction risk. Individual PAs have different roles in maintaining connectivity, depending on their size and location. We measured their contribution to network connectivity (irreplaceability) for carnivores and ungulates and combined it with a measure of vulnerability based on a 30-year trend in remotely sensed vegetation cover (Normalized Difference Vegetation Index). Highly irreplaceable PAs occurred mainly in southern and eastern Africa. Vegetation cover change was generally faster outside than inside PAs and particularly so in Southern Africa. The extent of change increased with the distance from PAs. About 5% of highly irreplaceable PAs experienced a faster vegetation cover loss than their surroundings, thus requiring particular conservation attention.

Overall, PAs have a measurable effect on the conservation of large mammals in Africa, although they alone are insufficient to stop population declines and the race towards extinction. In a continent experiencing fast conversion of natural habitat, PAs can play a key role in maintaining connectivity for area-demanding species like the African large mammals, provided that effective action is taken to prevent degradation and loss of the natural habitats they host.

12.00 **Remote sensing for sustainable landscapes**

Andrew Skidmore, Faculty ITC, University Twente, The Netherlands
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How can remote sensing measure and monitor the sustainability of landscapes? In this presentation, the concepts of essential biodiversity variables (EBVs) and plant traits are explored in the context of monitoring landscape sustainability. Firstly, what are the characteristics of sustainability for resource conservation? And secondly, how can hypertemporal and hyperspectral remote sensing be used to measure such characteristics of sustainability for both production (food, bio-energy) as well as the conservation of species and biodiversity. Maintaining food and tree product yields while minimizing soil erosion and water pollution are important indicators of a landscape in balance with agricultural and forestry activities; these parameters can be routinely derived from remote sensing. Some examples of successfully applying remote sensing to monitor the fragmentation of landscapes include use of indicator species (liverworts, wolves and elephants), as well as tracking of barnacle geese and crested ibis. Species distribution models based on hypertemporal remote sensing allow the response of species under climate change scenarios to be projected.

12.30 ***LUNCH***

Chair: Harriet Allen, University of Cambridge

13.30 **Remote sensing and the development of blue carbon initiatives**

Emily Pidgeon, Conservation International, USA
Email: epidgeon@conservation.org

The coastal ecosystems of mangroves, salt marshes, and seagrass meadows are now recognized for their significant capacity to sequester and store carbon, in addition to the numerous other valuable ecosystem services they provide. However, these “blue carbon” ecosystems are being lost at an average rate of 2% per year resulting in CO2 emissions at globally relevant quantities. Accounting for the blue carbon sequestered in coastal systems has the potential to be a significant tool in promoting and sustainably financing marine management and conservation in coastal areas. Recent updates to the IPCC recommendations on carbon accounting in wetlands now provide explicit guidance to countries on including coastal wetlands in national carbon inventories. Simultaneously, there is a strong interest in financing site-scale wetland conservation and restoration. However, implementing such projects will require systematic, repeatable and large scale assessment and monitoring of coastal ecosystems. It is necessary to be able to map the extent, change and carbon content of these systems. Until recently, remote sensing techniques have had limited capacity to resolve ecosystems at the land-ocean interface, particularly including seagrasses and other submerged habitats. Recent developments, however, have seen global to local scale mapping of mangroves, including estimates of change. Building on these efforts, it is now possible to map salt marshes using publically available data. Large-scale, repeatable mapping of seagrasses is still experimental but success has been achieved at local scales. These approaches are already in use directly supporting conservation and management of coastal areas. Developing techniques for mapping carbon in coastal ecosystems is the next challenge for blue carbon conservation and management. Estimates of above ground biomass carbon are being produced for mangrove areas using remote sensing techniques. However, the soil carbon is the largest carbon pool in all blue carbon ecosystems, varying between 50 and 95% of the carbon in the ecosystem. There are currently no techniques that allow for largescale monitoring of soil carbon in blue carbon ecosystems. Increased interest in coastal carbon, however, has motivated an expansion of in situ carbon assessments that should, in combination with remote sensing mapping techniques, make modeling of blue carbon viable.

14.00 ***Satellites and the implementation of REDD+: a case study from Indonesia***

Edward Mitchard, University of Edinburgh; Mandar Trivedi, ZSL; Murray Collins, University of Edinburgh
Email: edward.mitchard@ed.ac.uk

Every vision of REDD+ implementation has a robust Measurement, Reporting & Verification (MRV) system at its core, with investor/donor confidence and ultimately payments coming directly from this system. The majority of tropical countries have had some support in developing MRV systems from UN-REDD, the Forest Carbon Partnership Facility, or other donor sources, and therefore many such systems exist of various levels of sophistication. Similarly the plethora of voluntary sector REDD+ projects that have sprung up over the past few years also have developed monitoring systems, acting as pilots for national systems as they fulfil many of the same functions at a smaller scale.

All MRV systems we have seen, as well as systems used by voluntary sector subnational REDD projects, use satellite data both to estimate past rates of deforestation and to map and monitor current forest extent. A smaller number additionally use satellite data to map forest degradation, though many projects and country-wide systems currently do not consider degradation processes. Some projects are additional investigating the use of satellite data to directly map aboveground carbon stocks, rather than just changes in forest area and type, but this remains largely experimental.
MRV systems differ greatly in the type of remote sensing data used. Many use medium-high resolution optical data (Landsat typically supplemented by SPOT, ASTER, CBERS and others, between 10 and 30 m resolution), the most famous being the PRODES system operated by Brazil. Such optical data is widely available for no or low cost, is relatively easy to analyse and interpret, can easily detect large-scale deforestation, and archives date back to the 1970’s. Operational forest change datasets are now being produced, and are archived and distributed by the Global Forest Watch consortium, which could reduce the costs associated with ingesting such data into MRV systems. However, there are difficulties in its use related to cloud cover and the detection of small-scale deforestation and degradation, which preclude the use of such optical data for some areas of the tropics, and limit its use elsewhere. We

give examples demonstrating where it works well, and explore examples from Indonesia and central Africa where standard optical data is not suitable.

Some monitoring systems for REDD+ have developed using Synthetic Aperture Radar (SAR) data. This is less readily available than optical data, and has higher processing costs, but has the benefit of seeing through clouds and penetrating through the forest canopy, thus potentially having the ability to detect forest degradation. We show an example from a ZSL project in Berback national park in Sumatra where L-band radar data has been used with great success to map small-scale deforestation, and compare this to optical data (where clouds allow!)

In the final part of this presentation we will look to the future, in particular to the sensors that will be operating in the 2020's when REDD+ will hopefully become operational. In all likelihood no sensors used by MRV systems now will still be operational in the 2020's, but the large satellites that will be flying have already been commissioned. It is clear that the need for optical data will be covered, if not by a successor to Landsat 8 then by the EU-funded Sentinel 2 satellites; and that long-wavelength SAR data will in all likelihood not be operationally available, but shorter wavelength C-band SAR will be provided by the EU-funded Sentinel 1.

14.30 **DOPA, a Digital Observatory for Protected Areas using earth Observations**

Grégoire Dubois, European Commission - Joint Research Centre
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The Digital Observatory for Protected Areas (DOPA) is conceived as a set of distributed Critical Biodiversity Informatics Infrastructures (databases, web modelling services, broadcasting services, ...) combined with interoperable web services to provide a large variety of end-users including park managers, decision-makers and researchers with means to assess, monitor and possibly forecast the state and pressure of protected areas at local, regional and global scale.

In particular, the DOPA aims to:

- provide the best available material (data, indicators, models) agreed on by contributing institutions which can serve for establishing baselines for research and reporting (i.e. Protected Planet Report, National Biodiversity Strategies and Action Plans, …);
- provide free analytical tools to support the discovery, access, exchange and execution of web services (databases and modelling) designed to generate the best available material but also for research purposes, decision making and capacity building activities for conservation;
- provide an interoperable and, as much as possible, open source framework to allow institutions to get their own means to assess, monitor and forecast the state and pressure of protected areas and help these to further engage with the organizations hosting critical biodiversity informatics infrastructures.

End-users of DOPA will quickly realize that earth observations are used directly or indirectly in almost all indicators proposed in DOPA Explorer Beta, a first web interface to the underlying web services. DOPA Explorer Beta currently provides simple means to explore around 9,000 marine and terrestrial protected areas that are greater than 150 km^2, identify those with most unique ecosystems and species, and assess the pressures they are exposed to because of human development. It is the purpose of this presentation to discuss the main components of the DOPA that are using earth observations, namely the eStation and eMarine which are receiving, processing, analysing and disseminating key environmental parameters derived from remotely sensed data over the terrestrial and marine environments. eHabitat is another web modeling service of the DOPA which uses products of the eStation and eMarine to characterize the uniqueness of the ecosystems found in protected areas as well as their connectivity with the surrounding ecosystems. Used in conjunction with climate change and/or land use change scenarios, eHabitat can further be used for ecological forecasting and be integrated in more complex processing chains.
More information on DOPA and its underlying services can be found at http://dopa.jrc.ec.europa.eu/

15.00 POSTER SESSION (TEA/COFFEE)

Chair: Noëlle Kümpel, Zoological Society of London

15.30 **Identifying the top 10 conservation questions that can be informed by remote sensing**

Robert Rose, WCS, USA
Email: rrose@wcs.org

Remote sensing plays a vital role in helping the conservation community monitor threats to the planet's ecological systems. With rapid advancements in remote sensing technology and increasing rates of ecosystem degradation, there is a need to both help the conservation community best use remote sensing to address the most critical environmental challenges and help the remote sensing community better understand what imagery and tools would most contribute to conservation activities. With support from NASA, the Wildlife Conservation Society organized a workshop that brought together 32 leaders from the conservation and remote sensing communities, representing the academic, government and NGO sectors, in order to address these needs. The goals of the workshop were to: identify the 10 highest priority conservation challenges that could be resolved using remote sensing technologies; renew relationships within the community to address these challenges; and outline a process to re-energize a conservation remote sensing working group. During the workshop, the 300+ challenges were narrowed down to the top ten. In addition, workshop participants outlined a plan to develop a conservation remote sensing working group. This session will review the process used to conjure the initial questions and distill the list to 10, present the results, and discuss the implications of making the list broadly available to the conservation, remote sensing and donor communities.

16.00 **Connecting the dots: earth observations from a user's perspective**

Mike Gill[1], Cristina Secades[2] and Robert Höft[3]
Email: Mike.Gill@ec.gc.ca

[1] Environment Canada, Canadian Wildlife Service, 91780 Alaska Highway, Whitehorse, Yukon, Canada Y1A 5X7
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[3] Secretariat of the Convention on Biological Diversity, 413 Saint Jacques St, suite 800, Montreal, QC, Canada H2Y 1N9

Significant and accelerating advances in remote sensing technology present important and multiple opportunities for improved monitoring of the earth's ecosystems and the biodiversity they support. However, there remains significant separation between the remote sensing and in-situ observation communities along with the broader conservation and national policy-making communities. The tendency to continually upgrade to the latest sensor and perfect methodologies challenges the ability of national governments to support feasible, stable and continuous programs for effectively monitoring biodiversity and their pressures. To date, many innovative global, regional and ecosystem-based monitoring products have been developed using remotely sensed data, but more efforts are needed to apply these products and tools to national decision-making processes. In many cases, nations with the greatest biodiversity (and pressures on them) are the ones least able to adopt new technologies and techniques for monitoring biodiversity and pressures, thereby diminishing the opportunity to apply remote sensing data and blend it with in-situ data to inform effective and timely conservation outcomes, though there are notable exceptions.
Considering these challenges and drawing from national and regional examples, the results of a review on the use of remotely sensed data for monitoring biodiversity change, and with the Aichi Biodiversity Targets in mind, we present the Group on Earth Observations – Biodiversity Observation Network's Essential Biodiversity Variables as a possible framework for bringing these communities of practice towards a more coordinated effort to monitor biodiversity and the pressures on it.

16.30 **Integration as the key to success: bridging gaps between ecological research and remote sensing**

Ned Horning, American Museum of Natural History, USA
Email: horning@amnh.org

Remote sensing is an invaluable tool for ecological research but products available from the remote sensing community do not always adequately address the needs of ecologists. In this presentation I will give examples that show how ecology and remote sensing are tightly linked and will highlight gaps that exist between the ecological and remote sensing communities. I will discuss ways to reduce the gaps and strengthen the bridge between the two disciplines. This isn't a new topic but there has been a recent revived interest in addressing it. The presentation will draw on my more than 30 years of experience working with remotely sensed data with most of that time focused on ecological applications.

17.00 **Remote Sensing for Conservation: Sum up and road ahead**

Martin Wegmann, CEOS Biodiversity, DLR, Department of Remote Sensing, Wuerzburg, Germany

Martin Wegmann, Woody Turner, Nathalie Pettorelli and members of CEOS Biodiversity, CRSnet, GEO BON

The usefulness of remote sensing in conservation has been identified decades ago but examples of actual applications underpinned by fully interdisciplinary approaches are still rare. Space agencies have now recognized the high potential of remote sensing in conservation science, biodiversity research and ecology generally. Importantly, members of the conservation community increasingly acknowledge that collaborations with remote sensing scientists can open new research avenues and benefit conservation efforts on the ground. This symposium, in addition to initial activities of the CEOS Biodiversity group[1] and other initiatives such as CRSnet[2], GEO BON[3], CCI[4] or GOFC-GOLD[5], do provide the foundations for the development of a stronger, more interdisciplinary community that sits comfortably between ecology, conservation biology and remote sensing.

[1] www.remote-sensing-conservation.org/ceos
[2] www.remote-sensing-biodiversity.org/networks/crsnet
[3] www.earthobservations.org/geobon.shtml
[4] www.conservation.cam.ac.uk/resource/working-papers-and-reports/cci-report-what-do-conservation-practitioners-want-remote
[5] www.gofcgold.wur.nl

Close: Nathalie Pettorelli, Zoological Society of London

END OF SYMPOSIUM

POSTER PRESENTATIONS

Deforestation and Rice: Using Remote Sensing and Modeling to Link Patters of Biodiversity Loss with Rice Agriculture in Madagascar

A. H. Armstrong[1] (attending), T.E. Fatoyinbo Agueh[1], R. Fischer[2], and A. Huth[2]
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In the species rich tropics, forest conservation is often eclipsed by anthropogenic disturbance. The combination of multi-temporal remote sensing data, field data and forest growth modeling to quantify carbon stocks and flux is therefore of great importance. In this study, we utilize these methods to (1) improve forest biomass and carbon flux estimates for the study region in Madagascar, and (2) initialize an individual-based growth model that incorporates the anthropogenic factors causing deforestation to project ecosystem response to future environmental change. Our approach combined multi-temporal remote sensing analysis (Landsat 30m 2004-present) and ecological modeling (FORMIX3 growth model) to assess biomass change and to understand how tree growth and forest biodiversity relate to past and present economic variability in Madagascar forests of the eastern Toamasina region. Forest diversity and biomass estimations were calibrated using forest inventory data collected over 3 growing seasons over the study region. This information was then built into the previously parameterized (Armstrong et al., in prep and Fischer et al 2013) Madagascar FORMIX3 Model (see Huth and Ditzer, 2000) by incorporating rice economy, selective logging into the model to control certain species groups (i.e. selective harvest) and fire frequency (encroachment). Our findings showed a significant positive correlation between increasing deforestation rates, biodiversity loss and higher local rice prices due to political regime and international market factors.

The View from Kew - Remotely Sensed Solutions for Plant Sciences and Conservation

Susana Baena*, Justin Moat*, Steve Bachman*, Amanda Cooper, Jenny Williams, Tim Wilkinson*, Robert O'Sullivan*

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All life on Earth depends on plants. They are the basis of ecosystems in which all animals, including humans, live, survive and grow. Kew is furthering plant science and conservation through the use of Remote Sensing to help understanding plant diversity and to guide better conservation practices. We will present our latest research using case studies covering the application of satellite-based information and remote sensing techniques to the science and conservation of plant diversity at multiple scales: from mapping individual tree species to assess the impact of local land-use to analysing global extinction risk from deforestation. Locally in Peru, we are using the latest techniques through the application of object-oriented image analysis applied to very high resolution satellite and UAV images to map five common tree species of the coastal dry forest of northern Peru. Regionally, we are unravelling the full potential of the Landsat continuity mission in combination with spatial distribution models and future climate projections to map and predict the distribution of wild coffee forests in Ethiopia. Globally, through the Sampled Red List Index for Plants project we will show how outputs from remote sensing such as deforestation maps can be applied directly to Red List assessments linked to global policy targets. We continue to drive Kew's science and conservation outputs through the application and development of these Remote Sensing techniques which contribute widely to support global conservation management and decision making. www.kew.org/gis

Very High Resolution remote sensing products for the monitoring of Natura 2000 areas and surroundings: the outputs of the BIO_SOS project (FP7-SPACE-2010 Ga. 263435) (start: Nov. 2010; end: Nov 2013)

Palma Blonda (attending) and Richard Lucas on behalf of the BIO_SOS consortium; CNR-ISSIA, Via Amendola 122/D. 70126 Bari-Italy

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The Biodiversity Multi-Source Monitoring System: From Space To Species (BIO_SOS) project (www.biosos.eu) developed a pre-operational knowledge driven classification system suitable for multi-annual monitoring of NATURA 2000 sites and their surroundings. Its input data sources are satellite Earth Observation (EO) and on-site data. Ontologies are used to represent the expert knowledge from botanists, ecologists and remote sensing experts.
The system can provide:
• Very high spatial resolution (VHR) land cover/use (LCLU) maps;
• VHR habitat maps, with these based on Annex 1, Eunis taxonomy and General Habitat Categories (GHCs), based on the combination of LCLU classes with on-site data (e.g., lithology, water salinity) and LIDAR products;
• Change maps of both LCLU and habitat classes;
• Landscape indicators as basis of biodiversity indicators.
The system is based on an object-oriented classification approach and is implemented as open source software. The Food and Agriculture (FAO) Land Cover Classification System (LCCS) taxonomy is used for LCLU class identification since it was demonstrated more suitable than CORINE for subsequent translation of LCLU classes to habitat categories. The system outputs are used as inputs to a modelling framework including:
- Quantitative landscape pattern analysis to produce site/scale specific indicators for monitoring;
- Model for scenario analyses relative to water and sediment flux connectivity, enabling examination of the internal robustness of ecosystems and its susceptibility to external pressures
- New mathematical model for predator-prey populations - metapopulation dynamics in fragmented habitats
- Ecological niche modelling to evaluate the importance of GHCs as environmental variables to explain the distribution of the target species better than LC/LU.

A Remote Sensing Approach to Mapping and Modeling of Flora and Fauna Distributions on Cors Fochno Raised Peat Bog

Rebecca Charnock (attending), Aberystwyth University, Peter Bunting, Peter Dennis and Richard Lucas

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This research aims to establish the potential of very high resolution Worldview-2 (WV-2) spaceborne optical and airborne LiDAR data for providing input to species distribution models for both flora and fauna, with focus on the active raised bog and surrounding landscapes in Cors Fochno, mid Wales. During 2013 (March to November), field spectro-radiometer measurements were collected on a monthly basis for the dominant active bog plant species present on site, including *Eriophorum, Calluna, Myrica* and *Sphagnum*. Measurements were also collected for a number of species (e.g., *Molinia, Phragmites*) associated with degraded raised bog. Over the same period, 40 sets of insect traps (paired pitfall and sticky) were set up over four distinct vegetation areas representing a transition from active primary raised bog through to degraded secondary raised bog. Coleoptera, Arachnida, Formicidae and Diptera were the main recorded groups. Comparison of WV-2 and field spectral curves demonstrated comparable patterns were observed and variability in the spectra of dominant plant species over the growing season. Spectral indices relating to plant attributes such as greenness, senescence and moisture derived from WV-2 data and acquired during pre-, peak- and post-flush periods were used in conjunction with LiDAR height metrics to classify the UN-FAO Land Cover Classification System (LCCS) categories and dominant plant species. Current focus is on using these maps and derived vegetation attributes with species distribution models to establish how fauna (particularly insects) of varying degrees of scarcity can be predicted, thereby assisting future management of the active raised bog and surrounds.

Spectral observations to inform tree health

William A. Cornforth (attending), University of Edinburgh; Caroline J. Nichol and Anna V. Brown

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Scots pine is a key species for biodiversity in Scotland; the ancient Caledonian pinewoods being home to wild cats, capercaillie, pine martens and the Scottish crossbill, Britain's only endemic bird. Significant threats to Scotland's forests from introduced pests and pathogens now exist, and climate change poses questions for Scots pine's long-term viability in Scotland. Using narrow-band reflectance measurements we show the relevance of high temporal observations as an early warning system to habitat degradation and tree stress diagnosis, for which no methodologies had existed. Experiments with the prevailing rampant Scots pine disease, Dothistroma needle blight, as well as a variety of abiotic stressors will determine to what extent hyperspectral remote sensing may play in early detection and identification of tree health issues.

Using remote sensing to understand patterns of marine biodiversity in the Chagos marine reserve

David Curnick[1,2] (attending), Kate Jones[1,2], Kirsty Kemp[2], Heather Koldewey[2] and Ben Collen[1]
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In recent years, large scale marine protected areas (MPAs) have been suggested as a means of protecting marine biodiversity. The Chagos MPA was established in the Indian Ocean in April 2010 by the UK Foreign and Commonwealth Office despite significant objections from the fishing industry. Questions were raised over the MPAs efficacy as a means of protecting pelagic fish populations, including whether this form of spatial management is sufficient to protect commercially important and wide-ranging pelagic species such as tuna and sharks. Here, we present a detailed analysis of fisheries records from across the West Indian Ocean, and specifically those within the MPA, to address this question. These records will be coupled with data collected through satellite tagging of pelagic sharks and tunas to understand in greater detail how these predators utilise the habitats that exist within the Chagos MPA. The distribution of the pelagic community, both temporally and spatially, is presented whilst also exploring the future application of remote sensing data to understand these distributions. Without answers to these critical questions the management efficacy of these fish populations will remain limited and the provision of food for the global community jeopardised.

Do community-conserved areas in Tanzania achieve conservation goals? An initiative-wide study using remote imagery and matching methods

Anthony Dancer, Imperial College London

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Tanzania's Wildlife Management Areas (WMAs), community-managed wildlife zones outside of core protected areas, represent a major conservation initiative, for which little impact evaluation has taken place but for which reasonable doubts over their efficacy exist. Since their inception WMAs have attracted a large proportion of conservation funding, due to their potential to help protect economically and biologically important large mammal populations, and improve the wellbeing of poor rural communities. However, until recently, almost nothing was known about the conservation impact of WMAs, due to a paucity of environmental data, and our understanding of socioeconomic impacts is based on case studies. These limited analyses indicated that communities within WMAs may be experiencing lower income than they earned prior to gazettement, despite benefits to both communities and wildlife being necessary for the model to be a success. In 2013 I undertook the first initiative-wide assessment of the environmental impact of WMAs, drawing on satellite imagery to compare change in habitat attributes within WMAs in comparison to change in unprotected areas, and using innovative matching methods based on observable characteristics to account for biases in WMA placement.

This study indicated that WMAs are not having a discernible effect on habitat outcomes, or any effect is so slight as to be indistinguishable amongst high background variation, providing validation for concerns over WMAs and insights into remote assessment of PA impacts. In addition, traditional methods which do not account for non-random placement, or which draw conclusions from simple before/after assessments, would have overstated WMA impacts.

Planning for Change: Managing Mangroves in the Face of Climate Change

Clare Duncan, Institute of Zoology, Zoological Society of London

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Mangrove forests are highly important ecosystems, providing habitat and resources for biodiversity and a plethora of ecosystem services benefits to humanity. At a global scale they play a vital role in climate regulation as some of the most carbon-rich forests in the tropics, and locally afford coastal protection from extreme weather events such as hurricanes and tidal surges, and food and timber resources. However, due to the effects of multiple interacting global threats of land-use (particularly for aquaculture) and climate change, mangroves are now one of the world's most threatened biomes. Mangrove forests are highly sensitive to environmental and ecological changes. The future outlook for mangroves is thus severely compromised by climate change, and particularly by sea level rise (SLR). Mangroves can exhibit resilience to SLR through expansion at their inland fringes. However, the strong influence of hydrology and inundation on mangrove ecology and zonation means that inland expansion is only possible if appropriate sloping conditions exist. Applications of remote sensing analyses to these largely remote areas have enabled the mapping of both mangrove coastline retreat and inland expansion under SLR. However, tropics-wide coverage of studies is limited, restricting our understanding of potential generalities in the contextual and ecological requirements promoting resilience to SLR, and hindering the direction of management priorities for land-use planning. This work aims to fill this knowledge gap, utilising moderate resolution radar and multispectral satellite data (ALOS PALSAR, Landsat 5 TM and ASTER) across 12 mangrove sites currently affected by SLR to explore conditions (elevational and climatic) under which mangrove inland expansion is promoted. This poster discusses the methodologies that will be employed in this study, and presents some preliminary findings from one study site in the Ruvuma Estuary Marine Park on the border of Tanzania and Mozambique.

Bottom-up resource limitation: the ecosystem energy balance predicts the quality of nutrition in a herbivore prey population

Néstor Fernández (attending), Mónica García, Esperanza Gil, Emmanuel Serrano & Miguel Delibes

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Vegetation greenness indices from remote sensing are increasingly used in population ecology studies assuming that land surface reflectance can reflect the availability of nutritional resources for primary consumers. However, the relationship between these indices and the characteristics of the herbivore diet has been insufficiently tested. We hypothesized that in drylands, where water availability is a prime control of ecosystem functioning, remote sensing indicators of vegetation drought stress are critical to predict the nutritional quality of herbivore habitats. This hypothesis was analyzed by measuring the dynamics in diet quality for the European rabbit, a key prey in Mediterranean communities. Rabbit nutrition was measured in six habitats throughout a year using faecal nitrogen (FN) content, an indicator of the levels of ingested protein. Then we tested the accuracy for predicting diet quality of the Enhanced Vegetation Index (EVI) and two remote sensing vegetation stress indicators: the Temperature Difference Vegetation Index (TVDI) and a latent heat flux index (Hr) calculated from the dynamics of surface temperature at each site. Generalized mixed models showed that temperature indices significantly contributed to explain the dynamics of diet quality: models including either TVDI or Hr shower a better fit than those exclusively based in EVI ($R2 = 0.43—0.60$). Whereas FN showed a positive relationship with EVI, the effect of TVDI and Hr was negative. Extracting the temporal component further allowed us to characterize the overall quality of each habitat and to relate it with rabbit abundance. Results have far-reaching implications for assessing habitat quality and the effects of functional ecosystem changes on a keystone prey herbivore and associated communities.

Mapping change in human pressure globally on land and within protected areas

Jonas Geldmann (attending; Natural History Museum of Denmark, University of Copenhagen), Lucas N. Joppa and Neil D. Burgess

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It is widely accepted that the main driver of the observed decline in biological diversity is the increasing human pressure on earth systems. However, the spatial patterns of change in human pressure and their relation to human conservation responses are less well-known. Here we develop a spatially explicit and temporal map of change in human pressure over two decades, which is applicable globally on land at a resolution of 10 km^2. Following a detailed evaluation of 22 remote sensed products our compiled temporal pressure index is based on i) population density, ii) land transformation, and iii) electrical power infrastructure. Over two decades 64% of the terrestrial world experienced increases in human pressure with the largest increases found in South East Asia. Protected areas also experienced overall increases in human pressure, the degree varying with geographical location and IUCN category. Only 'wilderness areas' and 'natural monuments' (IUCN management category Ib and III) experienced decreases, while protected areas not assigned any category experienced the greatest increases. Higher Human Development Index values and greater mean elevation correlated with greater reductions in pressure across protected areas, while increasing age of the protected area correlated with increases in pressure. We regard our analysis as an initial step towards mapping changes in pressure on the natural world over time, and modeling pressures into the future. Only three datasets were included in our spatio-temporal global pressure map, highlighting challenges to measure pressure changes and potentially evaluate the success of conservation strategies over time.

A Biodiversity Indicators Dashboard: Addressing Challenges to Monitoring Progress towards the Aichi Biodiversity Targets and its Application of Remote Sensing

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Recognizing the imperilled status of biodiversity and its benefit to human well-being, the world's governments committed in 2010 to take effective and urgent action to halt biodiversity loss through the Strategic Plan for Biodiversity 2011-2020 and its "Aichi Targets". These targets, and many other conservation programs, require monitoring to assess progress toward specific goals. However, comprehensive and easily understood information on biodiversity trends at appropriate spatial scales is often not available to the policy makers, managers, and scientists who require it. To begin to address this need, we designed and are implementing a biodiversity "dashboard"—a visualization of biodiversity indicators designed to enable tracking of biodiversity and conservation performance data in a clear, user-friendly format, structured around the Pressure-State-Response-Benefit framework, selecting four indicators to measure pressure on biodiversity (deforestation rate), state of species (Red List Index), conservation response (protection of key biodiversity areas), and benefits to human populations (freshwater provision). The biodiversity indicators dashboard will help track progress toward the Aichi Targets, support national monitoring and reporting, and inform outcome-based policy-making for the protection of natural resources. Remotely sensed data was applied to generate various indicators and has a great potential contributing to the biodiversity indicators' study and related conservation impact assessment.

*attending

Conservation at NASA: The Biodiversity and Ecological Forecasting Programs

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For over 40 years, NASA has used the vantage point of space to study Earth as a system. These observations have played a critical role in advancing biodiversity research and conservation applications. The Earth Science Division (ESD) at NASA supports two conservation-related programs: Biodiversity and Ecological Forecasting. The Biodiversity Program, focused on basic research, sponsors the use of satellite and airborne remote sensing technology to understand biodiversity patterns and processes and characterize how and why they are changing through time. The Ecological Forecasting Program, an applications program, promotes the use of NASA science for societal benefit by transitioning tools and applications to use by conservation partners. Here, I provide an overview of the aims of the two programs, describe how they fit within the NASA organizational structure, and review how the programs interface with other U.S. government agencies, the non-governmental organization community, and international organizations. Recently funded research and applications projects that demonstrate the contributions of NASA programs to conservation will also be featured. Finally, I will highlight recently launched and soon-to-be launched NASA satellite missions that will contribute to the next generation of observations that advance conservation science and practice.

The assessment of plant species ranges against the degree of human impact using Co$ting Nature

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The continuing increase in human population, in conjunction with rising per-capita consumption rates, is placing unprecedented pressure on natural ecosystems, threatening to push many species into extinction. The aim of this project is to develop an automated procedure to assess and re-assess plant species' conservation status pan-tropically. The project focuses on improving the methodology for calculating species ranges using the available IUCN Sampled Red List Index plant data and producing the Extent of Suitable Habitat for each species and a global species richness map. The species Extent of Suitable Habitat maps are being produced based on information of the appropriate ecology for the species as well as land cover and environmental information, both within the convex hull defining the species' Extent of Occurrence. These ranges are then assessed against the degree of human impact using the human pressure layer from the Co$ting Nature conservation prioritisation tool (www.policysupport.org) as well as information on progressive land cover change using a real-time pan-tropical monitoring system for deforestation, called Terra-i (www.terra-i.org). By using land cover change as a proxy for local extinction risk and by understanding the impacts of fragmentation on ranges we should be able to provide more dynamic and spatially detailed Red List Index updates.

A Satellite Driven Dynamic Biome Product to Predict and Protect Coastal Fish Species

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Fisheries managers balance resource extraction and the protection of dynamic marine systems. In terrestrial systems, biomes are relatively fixed in space, as they are predominantly tied to slowly changing landscapes. The fluid nature of seascapes does not lend themselves to time-static partitions often used in management practices. Static partitioning of marine systems lead to poorly resolved marine biome locations and lead either to excessively large and unmanageable static partitions, or local partitions and boundaries that do not match regional dynamics. Here we propose a satellite derived, dynamic biome approach which accounts for the fluid nature of seascapes, mirrors climate signals, and automatically temporally and scales to the dominant physics of a marine system. The goal of this approach is to provide simple, dynamic, yet seasonally predictable framework that reflects the complexity of seascapes, and provide managers the theoretical ability to manage marine seascapes that reflect their spatial and temporal dynamics. We will present two examples of how satellite derived dynamic biomes have been, and are going to be used to predict and protect two coastal fish species (Atlantic Sturgeon, Butterfish) and how these models are being tested through robotic observations and expert commercial fishers.

Habitat Selection and Conservation of Sahelo-Saharan bustards

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Sahelo-Saharan bustards are among the most endangered and least studied birds globally. Knowledge on their ecology and conservation status are scarce and mostly local. In particular, we urgently need information on spatial and geographic distribution of the species, habitat requirements and potential threats to remaining populations. We present data on both Nubian and Arabian bustards from field survey in Niger and Chad carried out between 2001 and 2013. We used generalized linear models to (a) identify important habitat variables, (b) develop spatially-explicit predictive habitat models, and (c) assess how human activities might negatively impact bustards and their distribution. We also assess the current protection status of remaining suitable habitat. We found that both species select for habitat with lower roughness and intermediate level of normalized difference vegetation indices, with the Arabian bustard selecting higher level of vegetation indices. The model was validated using data from Chad which allowed the prediction of habitat suitability over Niger and Chad. Around a quarter of both species suitable habitat was found inside the protected areas of the regions. Human population density was found to negatively affect the presence of bustards and led to loss of 15-20% of the suitable habitat. This loss was found mostly outside protected areas. While this study improves current knowledge on Sahelo-Saharan bustards, more research needs to be done in order to understand seasonal distribution, conservation status and to implement appropriate conservation activities.

EU BON and its challenges on the use of remote sensing for biodiversity estimates

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Mapping and monitoring of biodiversity is a central point of the European contribution to the Biodiversity Observation Network (EU BON). The presented poster gives a short overview of the EU BON activities which are linked to remote sensing. These can be grouped in three categories: (i) mapping and monitoring biodiversity and its trends with the help of remote sensing, (ii) development of a new tool to classify land cover and (iii) the link between essential biodiversity variables (EBVs), the Aichi targets and remote sensing.

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Elephant poaching hotspots: a comparison of spatial clustering methods

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Spatial cluster analyses have been used for a wide range of applications including the study of criminal activities however, they have never compared for studying poaching activity. This study compares differences between two spatial clustering methods for predicting elephant poaching hotspots in the Tsavo ecosystem. Elephant poaching cases for the Tsavo ecosystem in Kenya during 2002–2012 were obtained from the Kenya Wildlife Service. The study area was divided into thirty-four blocks. Kulldorff's spatial scan statistic and flexible scan statistic were applied to the poaching data. Predictive accuracy of the methods was assessed using the prediction accuracy index (PAI).The results from this research indicated eight consistent 'poaching' blocks based on the two methods used. Kulldorff's spatial scan statistic had a slightly higher PAI value than the flexible scan statistic (2.39 vs 2.12). The results demonstrated that elephant poaching clusters obtained of two spatial clustering methods almost coincide, indicating that both of these methods are reliable to detect spatial elephant poaching clusters.

On the front line: composite front mapping for investigating oceanographic drivers of habitat use by marine predators

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Identifying critical at-sea habitats of wide-ranging marine predators is complex, yet necessary for effective conservation. Remotely-sensed oceanographic data can be used to provide context for movements of tracked animals, improving understanding of habitat use. Sea surface temperature (SST) and chlorophyll-a (chl-a) are frequently included as environmental covariates in predictive models, yet have limitations for identifying the processes that underlie foraging habitat use and preference. A diverse range of marine vertebrates are thought to associate with mesoscale (10s -100s kms) oceanographic fronts at the transitions between water masses. Front mapping via remote sensing is, therefore, a useful tool for identifying potentially important pelagic habitats. We present results of investigations using *composite front mapping* (Miller, 2009) together with tracking data (GLS, Argos-PTT, GPS) to elucidate the cross-taxa ecological significance of thermal and chl-a fronts. Using both 7-day and seasonal indices of frontal activity, we examine responses to mesoscale fronts as foraging cues, and the influence of persistent frontal zones on broader-scale habitat selection, in several different species inhabiting contrasting oceanographic regions; northern gannets (*Morus bassanus;* Celtic Sea), basking sharks (*Cetorhinus maximus;* UK waters), loggerhead turtles (*Caretta caretta*; Mauritanian Upwelling), and grey-headed albatrosses (*Thalassarche chrysostoma*; Southern Ocean).

Combining Remote Sensing and GIS: Deforestation and Degradation across Land Use Designations in the Peruvian Amazon

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The rapid loss of tropical forests and of their associated biodiversity, ecosystem services and livelihoods is arguably one of the most significant concerns of global change. To address this, the establishment of protected areas (PAs) has been the main conservation strategy; however, there is limited understanding of their impacts and how these compare to other land uses. In the Peruvian Amazon, land use titles have been granted for most of the land; yet, there has been no national-level assessment of the implications on land use change. This poster shows the usefulness of integrating remote sensing with environmental and socio-economic information to contribute towards addressing these knowledge gaps. In particular, this study (1) mapped 2006-2011 deforestation and forest degradation across the Peruvian Amazon (~785,000km^2) by analyzing Landsat images, validated through vegetation surveys and high-resolution satellite images; (2) integrated the satellite-based analysis with national-level datasets into a GIS-analysis to compare deforestation and degradation between state and private PAs, indigenous lands, logging concessions and mining concessions; and (3) modelled forest conversion to determine the main environmental and socio-economic drivers and controlling for these, assess whether PAs have helped to reduce deforestation and degradation. The results show that degradation affected a larger area than deforestation, emphasising the importance of integrating degradation into future assessments. Among the main land uses, mining concessions had the largest percent area degraded and deforested, and should therefore receive more conservation attention. Finally, controlling for main drivers, state-controlled PAs have helped to reduce deforestation and degradation in the Peruvian Amazon.

High-resolution remote sensing as a tool to assess resource selection by three sympatric ungulate species

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How ecologically similar species coexist in a shared habitat is a central question in ecology and directly relates to niche theory. Previous studies using classic home range methods (e.g. Minimum Convex Polygon) have found overlapping habitats for three ungulate species (Alpine ibex, chamois and red deer) inhabiting our study area in the Swiss National Park. However, habitat overlap does not provide evidence for competition, since mobile species are able to partition resources in space and time and to specialise on certain resource traits. Thus, our study focuses on the depletable resource forage with the aim of identifying and comparing key foraging areas of the three species. Therefore, we used data from the imaging spectrometer APEX to map forage quantity and quality (biomass, nitrogen and fibre content) on a 2 x 2 m grid. We split GPS data into movement phases based on the recently developed Time Local Convex Hull (T-LoCoH) method and identified foraging areas by selecting hulls with high visitation rate and intermediate duration of stay. We then compared the forage quantity and quality between the foraging areas of ibex and chamois using GLM models. Although there was no clear evidence for specialisation on a particular diet, we found that ibex and chamois foraged at different times and in different parts of their home ranges. In a next step, we will check for superabundance of resources and include the third species, red deer, in our models to complete the picture for this animal guild.

Remote Sensing of Invasive Vegetation using Spectral Angle Mapping and Mixture Tuned Matched Filtering on Hyperspectral Data

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Remote sensing is becoming increasingly beneficial across disciplines in identifying and analyzing land cover, both in the purest form and as a proxy for other phenomena or as input for further analysis. One such application is addressing the spread of invasive vegetation, a historical and contemporary challenge in land management. Leafy spurge *(Euphorbia esula)* is a noxious, quick spreading, and persistent weed that displaces vegetation typically grazed by cattle. Monitoring the distribution, abundance, and spread of leafy spurge is essential to the maintenance of healthy rangelands but is traditionally extremely time and resource intensive. Spectral angle mapping (SAM) and mixture tuned matched filtering (MTMF) remote sensing techniques provide a way of identifying coverage and estimating abundance of this species with minimal cost. Previous studies have successfully used these tools to identify presence and abundance of leafy spurge; however, these studies have been limited to both restrictively expensive satellite data and datasets with fine spatial resolutions. In this study, SAM and MTMF were used to identify leafy spurge on the Ucross Ranch in northeastern Wyoming. This work drew on free, publically available, 30m resolution data from NASA's Hyperion sensor stationed on board the EO-1 Satellite. Using field collected training sites, these methods proved successful in correctly identifying areas of dense leafy spurge, but overestimated its coverage and abundance in moist, low-lying areas. The success of these relatively untapped remote sensing methods and the use of freely available data have the potential to support many other areas of land management.

Satellite-derived NDVI outperformed temperature acceleration for predicting the timing of geese spring migration

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The green wave hypothesis predicts that herbivorous waterfowl will follow the flush of spring growth of forage plants along stopover sites during their spring migration. Satellite-derived NDVI time series (here referred to as satellite-derived green wave index or GWI) yield reasonable estimates of biomass, and has been widely adopted as a proxy for plant phenology in ecological studies. An alternative parameter that may be used to evaluate the green wave hypothesis is the rate of change in temperature acceleration (GDDjerk) that could be a proxy for the onset of spring. The GWI may be more directly related to the vegetation phenology than GDDjerk; however these two indices have never been compared for timing prediction of the herbivore waterfowl with respect to the green wave phenology. Here, we calculated the GWI from MODIS NDVI time series imagery and GDDjerk from gridded temperature data using GLDAS re-analysis products. To predict the timing of arrival at each stopover site, four years (2008-2011) of tracking data from 12 GPS-tagged barnacle geese were used. The geese arrival at the stopover sites was predicted more accurately using GWI (R2=0.67, RMSD=4.75) than GDDjerk (R2=0.53, RMSD=5.74). The result demonstrated that the GWI is a more accurate index for predicting geese migration timing.

Winter-flooded rice fields – the last refuge for Crested Ibis – are facing an unexpected decline

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Traditional agriculture benefits a rich diversity of plants and animals. The winter-flooded rice fields in the Qinling Mountains, China are the last refuge for the endangered Crested Ibis, and intensive efforts have been made to conserve and restore this unique anthropogenic habitat. Analyses of multi-temporal satellite data indicate that winter-flooded rice fields have been continuously reduced and fragmented in both the core-protected areas and non-protected areas during the past two decades. The rate of loss of these fields in the core areas has unexpectedly increased to a higher level than that in non-protected areas in the past decades, and the habitats in the non-protected areas have become even more fragmented. Our findings suggest that traditional agriculture in China is threatened by socio-economic and demographic changes, which may carry great risks for the long-term survival and recovery of threatened species, like the Crested Ibis, that rely on these anthropogenic habitats.

Mapping connectivity for a critical endangered endemic primate: San Martín titi monkey *(Callicebus oenanthe)*

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Locally known as the “Tocón”, the critically endangered San Martín titi monkey *(Callicebus oenanthe)* has one of the smallest geographic ranges of Peruvian primates. Its range has been severely impacted by land conversion for intensive agriculture, human settlements and mining. We have mapped remaining habitat using Aster (15m) multi-spectral data with the RandomForest algorithm to identify patches of primary and secondary forest. We also used historic Landsat data to identify forests previously disturbed since the 1980s. We then identify and prioritize the most important remaining habitat to preserve and/or restore based on habitat condition, landscape metrics, ownership and contribution to connectivity. A local non-profit, Proyecto Mono Tocón, has worked to better understand the Tocón’s habitat occupancy and requirements and to acquire land to protect against active deforestation. We have designed our work to link directly with the goals of Proyecto Mono Tocón for the preservation of this species.

Remote Sensing for Lesser Flamingo conservation

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In East Africa, the near-threatened Lesser Flamingo depends exclusively on a network of around 15 alkaline-saline lakes which are highly spatially and temporally variable and increasingly influenced by human activities. In this study, remote sensing was used to investigate these lakes and to address key questions on Lesser Flamingo ecology, such as the hydrological requirements for successful breeding and the spatial and temporal variability of their food supply, proving vital information for their future conservation. At Lake Natron, the sole breeding site for Lesser Flamingos in East Africa, breeding is hydrologically dependent. Landsat-derived lake surface area estimates and ground-based observations of flamingo breeding showed that breeding takes place on a receding lake level. Upper and lower limits for which breeding is feasible were defined based on the presence of islands in Landsat imagery. Lesser Flamingos are also dependent on the food reserves available within these lakes. In Lake Bogoria, an algorithm was developed for retrieving chlorophyll-a as an indicator of cyanobacterial biomass - the Lesser Flamingos' primary food source. Extending to a regional scale, a Landsat-based optical classification scheme was developed for alkaline-saline lakes, for determining their ecological status and consequent food value to Lesser Flamingos. The scheme was able to distinguish six classes with a classification accuracy of 73% when verified against *in situ* measurements. Classified imagery showed the potential importance to flamingos of the food resources offered by the highly remote Lake Logipi.

SMART Fire Monitoring

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Fire is a widespread natural phenomenon in tropical ecosystems, but is also the result of human activities, such as land clearance for agriculture. Poachers notoriously use fire to clear vegetation to control movement of wild animals and increase their visibility. Information on fire occurrence is therefore essential to track and identify human induced threats and pressures and quickly react to them. A standardized law enforcement and ecological monitoring and reporting tool, called SMART, has been developed by a global partnership of conservation institutions for strategic management of conservation areas. In this context we are developing a Fire Monitoring plugin for SMART which will provide access to satellite data of fire occurrence. Fire occurrence can be tracked in near-real time using publicly available NASA-FIRMS fire products derived from the MODIS sensor. Although these data are freely available, significant technical barriers prevent their usage where they are needed most, such as in protected areas. Our aim is to ensure conservation practitioners can access this information in the simplest and most timely manner possible. We have already developed a prototype plugin which retrieves near real-time MODIS fire information and integrates this into the SMART data model. Before this, SMART was dealing only with field data from patrolling activities. This integration of field and satellite derived information is important for active management. We plan to extend this plugin into an operational product and include historical fire information which can be used to define the status of the habitat and identify trends and anomalies.

MODISTools – downloading and processing MODIS remotely sensed data in R

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We present MODISTools, an R package for improving the accessibility and processing of MODIS Land Processes remotely sensed data. Data products derived from NASA's MODerate Resolution Imaging Spectroradiometer (MODIS) instruments have been used in many areas of ecology, conservation biology and global change research. An online form is available for accessing a spatially and temporally delimited subset, which allows the user to download one subset at a time. However, manual input of information can be both error-prone and time-consuming. A web service is available that can facilitate automation but this requires familiarity with protocols and languages such as SOAP and XML. Many ecological studies, such as meta-analyses or globally distributed experiments, combine large numbers of locations. The global coverage of remotely sensed data presents a valuable resource for global ecological studies but the existing MODIS access mechanisms make it hard to obtain the relevant data. MODISTools, an 'R' package, allows MODIS data for multiple locations, time periods and products to be downloaded and stored using a single line of code. MODISTools provides functions for processing downloaded data and merging these data back with the user's ecological response data, making it possible to apply MODIS data to research questions with minimal effort. By avoiding the time-consuming and often error-prone manual steps, the package greatly simplifies access to MODIS data, thereby increasing research efficiency. The current stable release of MODISTools is available on CRAN and can be installed by running: install.packages('MODISTools'). The latest 'in-development' version of MODISTools can be accessed at https://github.com/seantuck12/MODISTools.

A tool for monitoring woody biomass (change) in woodland ecosystems

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Changes in forest area, forest biomass and related carbon emissions are altering the global carbon cycle. Knowledge of the magnitude, location and causes of forest carbon stock changes is crucial to achieving sustainable forest management. In this paper we present the Biomass Assessment and Mapping Tool (BATMAP), which was first developed over a woodland forest area of 1,160 km-2 located in central Mozambique, where an inventory of ninety-six plots was used to calibrate L-band high resolution radar data (ALOS PALSAR). Biomass maps were generated and carbon stock quantified with per-pixel random errors of 10 MgC ha-1 and scene-wide bias of 1.6 MgC ha-1 (95% confidence intervals) over a three-year period between 2007 and 2010. To investigate the tool's versatility in assessing woody carbon stocks and their change in similar African woodland ecosystems, two case studies were investigated, in collaboration with LTS International Ltd. The first project involved assessing the effects of degradation in the middle Shire river basin in Southern Malawi. Degradation accounted for more than 36% of the total biomass loss, illustrating the important role of degradation alongside deforestation in woodland landscapes. The objective of the second project was to test Batmap on different forest ecosystems, which confirmed the importance of site-specific parameterisation of the tool."

Impact of logging on the canopy structure of a Bornean peat swamp forest

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Tropical forests are increasingly affected by, or recovering from, human disturbance such as logging. As the conservation value of logged forests is broadly recognised, it is important to assess the long-lasting alterations to their natural processes. In particular, logging creates artificial canopy gaps, a feature crucial for functional diversity and for carbon turnover. Laser remote sensing (lidar) has proved to be a key tool in measuring small-scale canopy structure across large spatial scales. Here, we aimed to characterise the impact of past and current logging on the canopy structure of Bornean peat swamp forest using lidar data. The studied peat swamp forest grows on nutrient-poor peat, reaching depths of up to 12 m. We measured forest height and gap sizes at different heights above-ground in areas logged to different degrees, while taking the underlying peat depth gradient into account. In both shallow- and deep-peat areas, forests appeared to have recovered from past concessionary logging. Recent informal logging, however, led to a dramatic increase in large canopy gaps in deep-peat forests. The impact of logging was different across the peat depth gradient, highlighting the need to account for natural variability in canopy structure in order to detect human disturbance. Owing to its destructive nature, current informal logging likely will lead to long-lasting structural scars, shift in recruited species and increased fire frequency.

Environmental predictors of forest biodiversity - the role of forest structure

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Vegetation structure is a key variable in forest biodiversity conservation and management. However, quantifying forest habitat structure and quality across large areas has only recently become feasible with the emergence of remote sensing technologies. The goal of our study is to develop predictive models for species richness and diversity patterns of plants, butterflies and birds in Swiss forest landscapes. We use nationwide datasets of airborne laser scanning (ALS), SPOT satellite images, climate, topography, and species occurrence. We grouped all species according to their degree of forest association, their level of international responsibility, and priority for national species action plans. Preliminary results suggest that remotely sensed variables provide most valuable complimentary information for describing species habitats, when compared to conventional environmental data such as climate or topography. Richness of species with international responsibility is predicted best, with up to 75% explained deviance. Richness of priority butterfly species, for example, is predicted with an accuracy of more than 40% explained deviance, where remotely sensed variables explain more of the deviance than climatic and topographic variables together. ALS-derived variables of forest structure represent the availability of light along the vertical forest profile, which constitutes an important, manageable environmental predictor that has not been well described at the landscape-scale so far. Our approach allows for large-scale predictions of forest habitat quality at an unprecedented accuracy and level of detail and will facilitate the integration of conservation relevant information into national and regional forest management plans.