Royal Society Publishing
Informing the science of the future

Conservation biology

Biodiversity technologies: tools as change agents

Jake Snaddon[1], Gillian Petrokofsky[1], Paul Jepson[2] and Katherine J. Willis[1,3]

[1]Biodiversity Institute, Oxford Martin School, Department of Zoology, University of Oxford, Oxford OX1 3PS, UK
[2]School of Geography and the Environment, University of Oxford, Oxford OX1 3QY, UK
[3]Department of Biology, University of Bergen, Allégaten 41, 5007 Bergen, Norway

A meeting on Biodiversity Technologies was held by the Biodiversity Institute, Oxford on the 27–28 of September 2012 at the Department of Zoology, University of Oxford. The symposium brought together 36 speakers from North America, Australia and across Europe, presenting the latest research on emerging technologies in biodiversity science and conservation. Here we present a perspective on the general trends emerging from the symposium.

1. Introduction

The information revolution is bringing about rapid advances in computer and communication technologies, which are transforming our ability to collect, analyse and store data at faster speeds and volumes than ever before. The exponential growth of communication technologies can be illustrated by the increase in subscriptions to mobile devices from 215 million in 1997 to 6.3 billion in 2012 [1,2]. Access to the Internet is a key driver of the expansion in cellular networks, mobile data traffic has doubled between 2011 and 2012 [1] and the launch of the Apple App Store and Android market in 2008 is transforming the computational abilities of smartphones. These global virtual software application (App) stores enable the development, distribution and acquisition of bespoke biodiversity applications. There have been parallel increases in the development of rapid, accurate gene technologies which have transformed genetic research generally and the study of biodiversity specifically. Since 2005 the sequencing capacity has been doubling every five months [3,4], this development is enabling projects to conduct comprehensive inventories of highly contextualized 'biodiversity genomics' data [5].

The development of biodiversity technologies presents a multitude of opportunities to build on the interplay between biodiversity science, conservation and society. The aims of the symposium were to (i) highlight new biodiversity technologies; (ii) demonstrate how they are changing the quality and type of data being collected; (iii) examine how they are influencing the way biodiversity data can be analysed; and (iv) identify knowledge gaps and future research avenues. Sessions included talks on bioacoustics, genetic techniques, genomic observatories, citizen science, virtual tools and the technology-inspired future visions.

2. Novel technologies for collecting field data

Over half the presentations in the symposium discussed developments in the collection of field data, either as new tools or new data types. Many of the innovations in this area have come from the exponential growth in capabilities of digital electronic devices—increasing processing speeds, storage and network capacity, battery life, at the same time as decreasing the cost and size of devices. Daniel Kissling (Aarhus University) highlighted the possibilities of miniaturizing radio transmitters to track insect behaviour and habitat use and in particular, the

relevance of this technology for documenting bee movements and their ecosystem service potential. Miniaturization was also one of the goals being realized in research presented by Tim Coulson (Imperial College London), where 1 kg sensors have been reduced to less than or equal to 1 g so that they can be used to track small rodents to an accuracy of 0.25 m^2. Stephen Ellwood (University of Oxford) reported on an interdisciplinary project (the WildSensing project) between computer science and zoology, which uses automated data collection tracking the flow of information from transmitters on badgers to a network of receiver base stations. This project shows how new technologies can bring value to long-term projects, building on over 20 years of badger population dynamics data. Tim Guilford (University of Oxford) demonstrated how state of the art tagging technologies using geo-location is revolutionizing the study of animal migration. A combination of geo-location data with other environmental information can provide additional information about the behaviour of animals, such as the Balearic shearwater (*Puffinus mauretanicus*). The deep-sea floor is one of the least biologically explored environments. With the use of bathymetry data to locate Indian Ocean seamounts, Michelle Taylor (University of Oxford) demonstrated the use of video annotation and reference systems to model suitable habitat for octocorals on seamounts.

(a) Bioacoustics

One of the growing dimensions in biodiversity science is the use of bioacoustics. Bioacoustics technologies are being developed for a wide array of applications, from identification of terrestrial and aquatic animals, monitoring habitat quality and the health of the environment, to public engagement [6]. David Chesmore (University of York) discussed the benefits of using bioacoustics for automated identification of species, with particular reference to Orthoptera, highlighting the increased speed at sorting samples and the potential for long-term unattended operation. Karl-Heinz Frommolt's (Museum für Naturkunde, Berlin) presented results from his recent work on monitoring nocturnal wetland birds using bioacoustics. He highlighted the importance of this approach to gain population assessments under difficult conditions (in the dark) and in inaccessible locations (wetland reed beds). Gianni Pavan (University of Pavia) emphasized the contribution that bioacoustics can make to citizen science and public engagement, demonstrating a project to record soundscapes, and discussing how soundscape libraries can inform and connect people to natural areas. Neil Boucher (SoundID) demonstrated that accurate automated sound recognition is possible even for complexity soundscapes such as the dawn chorus.

(b) Smartphones and citizen science

With the increasing speed and connectivity of handheld devices, research is also moving towards creating portable components for widespread use, such as smartphone apps for species detection—creating a 'Shazam for biodiversity'. Alex Rogers (University of Southampton) presented the stages in developing their smartphone app that will augment human hearing to track down the New Forest cicada (http://newforestcicada.info). In addition, Rogers emphasized the prerequisite of social mobilization to attract people to collect data, a topic also discussed by Chris Sandbrook (University of Cambridge) in his talk on the possible links between conservation and computer gaming. The growth of personal portable devices, such as smartphones and tablets, with advanced computing and connectivity capabilities, such as GPS and geo-referencing, is expanding the interface between citizen science, public engagement and education—reforming the collection, management and quality control of data [7]. This is enabling non-technical people to record and monitor their environment, as was shown by Jon Parson's (Global Canopy Programme) work in Guyana where the community is managing data collection on farming and their environment; or the myForest service, a project presented by Alistair Yeomans (Sylva Foundation), an online service where landowners can map their own woodlands—improving forest management and addressing the state of British woodlands. Tom Hart (University of Oxford) showed that citizen science is engaging people in an array of projects from sourcing and identifying locations in historical photographs to validating algorithms for the identification of penguins. Underpinning these citizen science projects is the idea that people like to share knowledge and as Andy Clements (British Trust for Ornithology) stated, the only qualification required to be involved is curiosity. One innovation using the success of social networking is iSpot (http://ispot.org.uk). Jonathan Silvertown (Open University) explained how iSpot encourages experts to assist beginners with specimen identifications—the iSpot community now has over 20 000 registered users, 150 000 observations—with over 80 per cent of observations being indentified within 24 h.

(c) Genetic technologies and genomic observatories

One of the themes of the genetic technologies and genomic observatories sessions was that DNA is a foundation layer to biodiversity, from which both evolutionary and functional information can be gained. Neil Davis (University of California Berkeley) and Dawn Field (CEH, University of Oxford) discussed two projects: The Moorea Biocode project (http://mooreabiocode.org), the first comprehensive inventory of all non-microbial life in a complex tropical ecosystem; and Ocean Sampling Day (http://www.oceansamplingday.org), the first global mega-sequencing campaign from which microbial diversity and function can be described. These projects are examples of a network of sites established as genomic observations [5] and representing the move from 'find and grind' (isolation sequencing) to 'grind and find' (community sequencing), which was also talked about by Guy Cochrane (European Bioinformatics Institute). Marta Riutort's (Universitat of Barcelona) work on the development of phylogeny of taxa that lack morphological characteristics, such as planarians, showed the value of high-throughput molecular methodologies, whereas Bastien Boussau's (University of California Berkeley) Strepsiptera phylogenetic enigma and Ludovic Orlando's (University of Copenhagen) research on the Przewalski horse both show the value of whole-genome sequencing to identify evolutionary relationships.

3. Network and application: access to large global datasets and tools

Access to data and data publishing were a theme that cut across all the sessions at the symposium. Biodiversity science and conservation are benefiting from the development of global biodiversity informatics databases, which are facilitating the

mobilization and access to taxonomic data [8–10]). Stephen Harris (University of Oxford) highlighted the valuable data held in collections such as herbaria around the world; whereas Ben Clark (University of Oxford) and Dave Roberts (Natural History Museum, London) emphasized the importance of digitizing information in providing access and collaborative data management using virtual research environments (Scratchpads) in projects such e-Monocot (http://e-monocot.org/) and ViBRANT (http://vbrant.eu/). The formation of links between global datasets necessitates standardization of biodiversity data. This was emphasized in presentations by Yuri Roskov (University of Reading) on the Catalogue of Life—a digitized and unified index of biodiversity; David Schindel (Smithsonian Institute) on the Barcode for Life—promotion of barcoding as a global standard for species identification; and Éamonn Ó Tuama (Global Biodiversity Information Facility; GBIF) who discussed accommodating genomic data into the GBIF. The increasing global biodiversity informatics infrastructure, such as GBIF (http://www.gbif.org/) which now contains nearly 400 million indexed geospatial records, is permitting the development of conservation planning tools and policy support systems. Atte Moilanen (University of Helsinki) presented the ZONATION conservation planning software, which produces a hierarchical prioritization across landscapes, whereas Peter Long (University of Oxford) discussed the remote ecological assessment of landscapes using the Local Ecological Footprinting Tool. Two policy support systems, Waterworld and Co$ting Nature, which map ecosystem services were discussed by Mark Mulligan (Kings College London). Hannes Gaisberger (Bioversity International) showed us that, as well as informing spatial conservation priorities, making links between genetic and climatic data can realize the threats and conservation precedence for endangered and vulnerable species.

4. Conclusion: technology-inspired future visions

As well as hearing about innovations in the use of technologies as tools for progressing research, the meeting paused to ask how should we as a scientific community approach the exciting but uncertain times ahead? Should we 'go with the flow'—adopt and innovate with new technologies and allow a new biodiversity science to emerge? Or should we start outlining visions of a future biodiversity science and conservation that technologies could enable, as a means to develop new agendas, identify opportunities and think through issues before they arise? Thomas von Rintelen's (Museum für Naturkunde, Berlin) NHM 3.0 vision of industrial scale description of new species (200 000 per year), and Paul Jepson's (University of Oxford) opti-hunting vision whereby a spotting-scope/gun/app-phone hybrid converts a shot bird into software rather than corpse, where two 'experimental' presentations that captured the transformative opportunities of new technologies, whereas Muki Haklay's (University College London) extreme citizen science and Liam Pin Koh's (ETH Zurich) conservation drones visions flagged two crucial points: that we will need to adapt our research ethics and engage with regulators concerning the deployment of new technologies in fieldwork.

It is increasingly acknowledged that humanity is entering an 'information revolution' [11,12]. New technological forces are introducing new dynamics and forms of agency into the socio-ecological system of biodiversity science and conservation sensu [13]. There is talk of a fourth scientific paradigm in which transformations in data availability lead to patterns being sought directly rather than through more traditional hypothetico-deductive methods [14]. At a time when research funding continues to come under extreme pressure in almost all countries, policy-makers will seek implementation solutions and tools that deliver value for money, and technologies that combine high speed, high accuracy and cloud-sourcing are likely to be those that gain traction. The presenters in this meeting, coming from across the range of subdisciplines, in biodiversity science conveyed a similar message, namely that new technological forces are causing biodiversity scientists to innovate, to forge new cross-disciplinary collaborations and to think bigger and more ambitiously.

References

1. Ericsson. 2012 Traffic and market report (interim update August 2012). See www.ericsson.com/traffic-market-report.

2. Bauer HH, Barnes SJ, Reichardt T, Neumann MM. 2011 Driving consumer acceptance of mobile marketing: a theoretical framework and empirical study. J. Electron. Commer. Res. 6, 181–192.

3. Poole AM, Stouffer DB, Tylianakis JM. 2012 'Ecosystomics': ecology by sequencer. Trends Ecol. Evol. 27, 309–310. (doi:10.1016/j.tree.2012.03.008)

4. Stein LD. 2010 The case for cloud computing in genome informatics. Genome Biol. 11, 205. (doi:10.1186/gb-2010-11-5-207)

5. Davies N et al. 2012 A call for an international network of genomic observatories (GOs). GigaScience 1, 1–5. (doi:10.1186/2047-217X-1-5).

6. McGregor PK. 2012 Applying bioacoustics: what can be learned from pure and applied aspects? Bioacoustics 21, 13–15. (doi:10.1080/09524622.2011.647526).

7. Newman G, Wiggins A, Crall A, Graham E, Newman S, Crowston K. 2012 The future of citizen science: emerging technologies and shifting paradigms. Front. Ecol. Environ. 10, 298–304. (doi:10.1890/110294)

8. Dengler J, Ewald J, Kuehn I, Peet RK. 2011 Ecoinformatics and global change—an overdue liaison. J. Vegetation Sci. 22, 577–581. (doi:10.1111/j.1654-1103.2011.01313.x)

9. Hale SS, Hollister JW. 2009 Beyond data management: how ecoinformatics can benefit environmental monitoring programs. Environ. Monit. Assess. 150, 227–235. (doi:10.1007/s10661-008-0675-x)

10. NaturalEurope. 2012 Biodiversity Informatics white paper. See http://www.natural-europe.eu/en/news-and-events/news/relevant-news/298-biodiversity-informatics-white-paper.

11. Sliwa J, Benoist E. 2011 Pervasive computing—the next technical revolution. In Proc. the 2011 4th Int. Conf. on Developments in e-systems engineering (DeSE 2011), pp. 621–626. Dubai: IEEE. (doi:10.1109/DeSE.2011.61)

12. Saylor M. 2012 The mobile wave: how mobile intelligence will change everything, p. 304. Northbridge, WA: Vanguard Press.

13. Jepson P, Barua M, Buckingham K. 2011 What is a conservation actor? Conserv. Soc. 9, 229–235. (doi:10.4103/0972-4923.86993)

14. Hey T, Tansley S, Tolle K. 2009 The fourth paradigm: data-intensive scientific discovery, p. 284. Redmond, WA: Microsoft Research.