Conservation technology: The next generation

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\textbf{Abstract}

Attitudes among conservation biologists toward technological innovations and solutions have changed over the years from mistrusting and dismissive to widely accepting. However, the time has come for the conservation community to move from being technology consumers to become innovation leaders and to actively seek to create novel technologies to provide conservation tools and solutions. This challenging but critical mind-set change requires thinking outside the box to establish and support the necessary bridges between the conservation community, technologists in both the public and the private sectors, and policy makers. The ingredients already exist, but success hinges on an open mind to new types of interactions, and bold but coordinated movements to nurture the organisational ecosystem in which such collaborations can thrive and be funded.

\textbf{KEYWORDS}

climate change, conservation technology, innovation, interdisciplinary, neoliberal conservation, open-source, remote sensing, telemetry

\section{INTRODUCTION}

The term ‘technology’ has a broad meaning which encompasses practically any expression of human ingenuity applied to solving practical problems and thriving as a species. A key distinction can be made between the design and production of physical tools, devices and machines, nowadays often requiring electronics, and more abstract methods such as mathematical algorithms, statistical techniques or computer software (Brian, 2009). Ecologists and conservation biologists play a prominent role in the advancement of the latter type of technological innovations (e.g., Anderson & May, 1992). However, for the purpose of this article we use the more restrictive definition of the term ‘technology’ found in the Oxford Dictionary—“Machinery and devices developed from scientific knowledge” (Oxford Living Dictionary Online, 2017). The role of such technological innovations in modern conservation biology has changed drastically over the last several decades. In fact, less than 30 years ago, the reliance on technology to solve conservation problems has been hailed as short-sighted and self-defeating, concentrating on treating the symptoms and not the disease (Meffe, 1992), and often considered only as a last possible resort (Conway, 1986). However, the field of conservation biology has grown through several paradigm shifts in the last few decades and the current prevailing approach to conservation is interdisciplinary at its core (Mace, 2014). These paradigm shifts, along with the continuous decline in biodiversity and the devastating effects of climate change on one hand, and the rapid development of better, cheaper and easily available technologies on the other, have made technological tools a common and indispensable part of conservation work today (Pimm et al., 2015; Snaddon, Petrokofsky, Jepson, & Willis, 2013).

Technology provides key tools to collect more and better data and to improve the monitoring of wildlife, habitats and threats, thereby assisting management decisions (technological enablers). Monitoring is also an integral part of biodiversity-related international policy agreements such as
the Aichi Biodiversity Targets of the Convention on Biological Diversity and some of the United Nation’s Sustainable Development Goals. Technology can also provide tools to aid conservation action on the ground, including fighting illegal activities that threaten biodiversity or reducing pollution (technological solutions). Such tools could empower conservation organisations as well as officials in charge of implementing related policy such as halting illegal harvesting and trafficking (e.g., CITES).

Examples of the uses of technology in conservation abound. GPS and other telemetry technologies (e.g., sensor tags, camera traps) are commonly used to monitor both extant and reintroduced populations in greater and greater detail (Berger-Tal & Saltz, 2014; Hussey et al., 2015; Kays, Crofoot, Jetz, & Wikelski, 2015). Remote sensing, whether through satellites or drones, is increasingly applied to wildlife monitoring, land-cover classification, and as a mitigation tool (e.g., early warning for poaching activities; Turner et al., 2003; Wich, 2015). The latest advancement in biotechnology and bioengineering are also increasingly changing our approach to species conservation. Pembient is offering to biofabricate wildlife products such as rhino horns or shark fins in order to combat poaching, the government of New Zealand is planning to use gene drive techniques such as CRISPR/Cas9 to assist with the eradication of all invasive predators by the year 2050 (Owens, 2017), and just as controversially, cloning technology is suggested as a driver of species de-extinction (O’Brien, 2015). All of these examples and many more demonstrate that technology is both central for efficient conservation science and practice nowadays, as well as instrumental in defining the conservation paradigms of the future.

2 | A NEW ERA OF CONSERVATION TECHNOLOGY

A common feature shared by most of these devices is that they (or at least the technologies underpinning them) were originally developed for other purposes (e.g., military or medical) and were later ‘adopted’ by the conservation community (Figure 1 top). This might also explain the skew that current technology-related methods in conservation have toward (1) monitoring of wildlife and the environments they inhabit, since numerous advanced monitoring tools (such as GPS tracking devices or drones) are readily available to the general public and (2) conservation genetics (Frankham, Ballou, & Briscoe, 2010), building upon the well-established and constantly growing field of genetics.

The use of such technologies in conservation has also attracted its fair share of criticism. Technology can and is used in ways that expedite the environmental crisis our world is facing (e.g., any industry or man-made device that is fueled by fossil fuels), and it can be used to increase the success of environmental criminals (e.g., poachers). Furthermore, technology can be seen as an agent of neoliberal conservation where the reliance on technologies that are manufactured and distributed by “first world” countries help exclude local communities in “third world” countries from having any control over policy implementation and management decision-making in their own lands, and place this control in the hands of foreign elites, thereby deepening the so called “north/south divide” (Arrighi, Silver, & Brewer, 2003; Igoe & Brockington, 2007). Thus, while the first era of conservation biology in respect to technology can be best described as being governed by a general wariness toward technological solutions and innovations, the second era is characterized by a widely accepting, albeit opportunistic and mostly centralized approach. We argue that the circumstances are now ripe for the establishment of a new era in conservation biology and its relationship with technology—an era of leadership and innovation, increasingly governed by bottom-up processes (Figure 1 bottom).

3 | FACILITATING SMALL-SCALE INNOVATION

This change has started happening, at a small but increasing scale (Pimm et al., 2015, Marvin et al., 2016; Snaddon et al., 2013). More and more, conservation researchers and practitioners are not content with simply looking for existing technological tools, but rather actively seek to design and produce new and innovative solutions to tackle specific needs, from relatively simple yet useful devices (e.g., smart nest box monitoring system, Zárybnická, Kubizňák, Šindelář, & Hlaváč, 2016; low-cost open-source programmable acoustic logger, Hill et al., 2018) to complex systems (e.g., large-scale real-time monitoring of elephant movement behaviour, Wall, Witttemyer, Klinenberg, & Douglas-Hamilton, 2014; Unmanned Aerial System to automatically locate radio-tagged wildlife, Cliff, Fitch, Sukkariieh, Saunders, & Heinsohn, 2015). Such solutions usually involve interdisciplinary teams of conservationists/ecologists and engineers/computer scientists. This is our first key message: becoming conservation innovators requires close collaboration or partnerships between the conservationists on the ground (i.e., those with first-hand knowledge of local conservation needs and obstacles) with the technologists that can develop and implement new solutions.

The second key message is that technology and innovation are no longer elite and resource intensive. In order to regain control and responsibility over their lands, and break free from the clutches of neoliberal conservation, local communities must be able to easily acquire skills and technology that are necessary to care for nature (Goldman, 2001). This is now possible thanks to extremely cheap prototyping and
FIGURE 1 Moving from the current role as technology consumers (classic model) to technology drivers and innovators (alternative model).

(1) In the classic model the development of new technology is determined mostly by the demand and needs of large bodies such as the military, the biomed industry, governments and the consumer electronics market. Technologists developing the new technologies usually work within the industry, inside the companies commissioning these solutions. These companies also provide the capital and physical and human infrastructure required for technological development to happen. (2) The companies follow the classic production model based on economies of scale, mass producing to obtain profit while offering reduced prices. (3) The conservation community heavily relies on technologies developed for other purposes and agendas (e.g., a handheld GPS device). These technologies may be modified or adjusted to meet the needs of the conservation community by a reduced number of small specialized companies (e.g., a GPS processing unit repackaged into a wildlife tracking collar). The production model stays the same, although at a smaller scale—production is driven by the existence of a market niche (e.g., wildlife biologists) and product prices reflect rarity. (4) In the alternative model, the conservation community (the traditional “clients”), coordinated through online platforms, drive the creation of new technology thanks to new ways to collaborate with technologists at a global scale, often working outside the classic industry (e.g., the Maker community, or professional technologists volunteering their skills for a cause, individually or through organized events like hackathons). Funding may also come from alternative schemes including distributed contributions, donations or crowdsourcing. (5) The alternative model is possible thanks to the emergence of a new production model, which allows affordable design and production of customized technology in small numbers. Cheap prototyping and design tools (including microcontrollers like Arduino and single-board computers like Raspberry Pi), affordable online ordering of Printed Circuit Boards (PCB) and 3D-printing facilitate this process. (6) This new pathway gives access to newer, cheaper and/or more specialized and customizable technology to a larger part of the conservation community. It provides specific solutions to specific problems and reduces reliance on other technology development agendas. (7) There is a direct feedback from the field, which further affects the needs and requirements of the conservation community and consequently drives further technological developments. (Drawing by Elia Pirtle)

designing tools (including microcontrollers like Arduino and single-board computers like Raspberry Pi), as well as affordable online ordering of Printed Circuit Boards (PCB) and cheap consumer-oriented 3D-printers. This revolution has already led to the establishment of several initiatives aimed at empowering local communities and individuals to build and design their own technological solutions, such as TReND4 (Teaching and Research in Natural Sciences for Development) and their Open Labware project (Baden et al., 2015); ExCiteS5 (Extreme Citizen Science); and Sapelli6—an open-source project creating a mobile data collection and sharing platform designed for illiterate users with no technological experience. In this respect, mobile phones technology is one of the biggest emerging platforms in conservation technologies providing individuals from the poorest regions of the world with access to technologies such as GPS or the Internet, as well as to specialized conservation applications such as CyberTracker7 or iNaturalist.8
Our third key message is that even individuals or small teams with the right skills and know-how can have a profound impact. For example, the physicist and software engineer T. White invented an antilogging device while working as a volunteer in a nature reserve in Borneo. The device, entirely made of discarded Android phones, records all sounds and transmits them to a cloud server that analyses the data for signs of man-made machinery and alerts park rangers of any possible illegal logging activity in real-time. It required developing the technology to make solar panels work well in low-light conditions under jungle canopy (Gross, 2014). Sheppard, McGann, Lanzone, and Swaisgood (2015) sought to protect the critically endangered California condor from colliding with wind turbines by developing an autonomous alert system that successfully miniaturizes and integrates virtual “geo-fence” capability into a solar-powered biotelemetry device. Fitted on the condors, the device transmits SMS alerts whenever they approach a wind turbine, which can be used, for example, to automatically shut the wind turbines down until the condor leaves the area. For the first time in history, low prototyping and production costs make the development and production of low volumes of targeted devices economically viable, freeing the conservation community from the traditional production model that relies on large companies and economies of scale, and opening the scene to small-scale targeted development by small players, even individuals (Figure 1).

4 | COLLABORATION AND COORDINATION AS KEY TO SCALING UP INNOVATION

Our last and most important point is that, for this largely untapped model to become a powerful source of innovation instead of the current scattered efforts, the scaling of these activities requires coordination and a conscious effort to mainstream this mind-set. Recent experience has proven that individual initiatives are rarely enough; except for a couple of areas with a longer history of development (e.g., animal tracking), scattered efforts to develop bespoke technology solutions have typically failed to scale up to the level at which they could have a substantial global impact. The structures to ensure the long-term sustainability of these technologies and a business-oriented mind-set are most often lacking.

We find encouraging that the last couple of years have witnessed the formation of several promising partnerships and organisations, which have started working toward making global conservation technology a reality. Some, like Wildtech and WILDLABS.NET, provide online platforms and communities for conservationists and technologists to share ideas, needs and resources, and catalyse new technology developments. Conservation X Labs promotes open innovation through Grand Challenges, combining prizes and crowdsourcing, and encourages technology sharing and mass collaboration through their Digital Makerspace. Smart Earth Network assists protected areas in executing strategic technology investments to improve conservation management. The Conservation Technology Working Group of the Society for Conservation Biology aims to foster collaboration between the different organizations as well as to coordinate international discussion forums (e.g., conferences), and roadmap technology needs and conservation technology research. Together, these organisations and others form the seed of a new movement with phenomenal potential to change the way we approach conservation challenges, mainstreaming communication channels between the conservation needs and the technology developers (more effective than open calls, e.g., O'Donoghue & Rutz, 2016), experimenting with new ways of harnessing collective skills and knowledge (e.g., open-source collaborative development; Greenville & Emery, 2016; Pearce, 2012), and interacting with industry and the public sector to bring technology and engineering talent into conservation (Joppa, 2015). Their efforts is supported by the existence of online data portals (often associated with citizen science data collection, e.g., iNaturalist or eBird) and by corporations whose social responsibility and philanthropic programs can provide scalable technology platforms that bring computing and IT services (e.g., Google Earth Outreach, Microsoft’s AI for Earth, Cisco/Dimension Data’s Connected Conservation and resources (e.g., Vulcan Inc.) to conservation programs.

New and creative uses of the opportunities offered by online connectivity and social networks (including platforms used by professionals and the industry like LinkedIn) will play an important role in bringing conservationists and technologist together. Most importantly, these aforementioned organisations have the collective responsibility to develop and nurture the organisational ecosystem that can ensure the long-term viability and scalability of conservation technology.

5 | CONCLUSIONS

Once conservation researchers and practitioners break free from the constraints of relying on available technological tools and start joining forces with technologists (engineers, computer scientists, programmers, data analysts, electronic hobbyists, Makers, etc.; both in research and industry) to create innovative tools to tackle the challenges they are facing, we will finally move beyond merely using technology to monitor wildlife and be able to greatly advance other aspects of conservation such as restoring habitats, battling invasive species, and perhaps even countering some of the effects of global warming.
With this article, we aim to strengthen the emerging voice of conservation technology, and contribute to the growing awareness of its crucial role in conservation, while at the same time remembering that technology by itself is a means to an end and should not be used as an excuse to avoid dealing with the underlining causes of the environmental crisis. We hope our call resonates through different disciplines. Members of the technology community must be aware that saving species and habitats is in their hands; their contribution will be key in coming years to boost scientists' capacity to understand and take care of our natural world. The entities mentioned in our article are collectively working toward delivering an organisational ecosystem that can sustain fruitful interactions between the technology and conservation communities. For this ecosystem to function, it is paramount that technologists become active members in it. This is just as true for members of the conservation community. They must take the time to familiarise themselves with the services and opportunities offered by the different emerging platforms we describe above, and make the effort to connect with technologists in different fields, both in academia and industry, to create partnerships that could successfully tackle conservation challenges. Conservation technology can also provide essential tools for policy makers, enabling them to track progress toward internationally agreed biodiversity goals (e.g., Aichi Biodiversity Targets), and to enforce international policies (e.g., on illegal trade of endangered species). Yet, currently there are no specific plans within the framework of international biodiversity policy agreements to promote conservation technology and harness this potential. It is therefore time to start a dialogue about the policies and organizational structures that will support the development and effective deployment of conservation technology tools at unprecedented scales.

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ENDNOTES
1 Convention on International Trade in Endangered Species of Wild Fauna and Flora; http://www.cites.org
2 http://www.pembient.com/
3 http://www.inaturalist.org
4 http://wildtech.mongabay.com
5 http://www.wildlabs.net
6 http://www.information-age.com/poachers-using-conservationists-tech-123464843/
7 http://www.cybertracker.org
8 http://ebird.org
9 http://www.google.com.au/earth/outreach
10 http://www.microsoft.com/en-us/aiforearth
11 http://www.vulcan.com/areas-of-practice/philanthropy/key-initiatives/conservation
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