Trends in Ecology & Evolution

Review

Emerging Technologies to Conserve Biodiversity

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Technologies to identify individual animals, follow their movements, identify and locate animal and plant species, and assess the status of their habitats remotely have become better, faster, and cheaper as threats to the survival of species are increasing. New technologies alone do not save species, and new data create new problems. For example, improving technologies alone cannot prevent poaching: solutions require providing appropriate tools to the right people. Habitat loss is another driver: the challenge here is to connect existing sophisticated remote sensing with species occurrence data to predict where species remain. Other challenges include assembling a wider public to crowdsource data, managing the massive quantities of data generated, and developing solutions to rapidly emerging threats.

Trends

Conservation requires methods to identify species and to identify, locate, and track individual plants and animals. These methods have become better, faster, less intrusive, and cheaper. So, too, has remote sensing that now allows detailed and frequent assessments of species' habitats and how human actions are changing them.

Even the best technologies to mark individuals may pose unacceptable hazards for endangered species. Creative approaches find new, non-invasive alternatives.

Crowdsourced data are becoming the dominant source of information on species' distributions and new approaches are solving the problems of reliability.

The most important trends are progress in technologies that are appropriate to the often remote and low-technology environments in which frontline conservation actions unfold and the inclusion of previously unused communities who might contribute essential data.

The Challenge and Opportunity of New Technologies

Human actions are exterminating species at exceptional rates and threaten large fractions of species across many taxa [1]. Over most of the land [2] and oceans [3], humans have eliminated top predators and large-bodied species, massively changing the remaining ecological communities [4,5]. Finally, although there has been impressive progress to protect more land and ocean, the range of ecosystems protected is uneven [6]. International consensus affirms the severity of these problems [7] and demands solutions.

New technologies have the potential to help with these solutions. We will review the development of these technologies only briefly because there are excellent and recent reviews of advances elsewhere. Our aim is merely to capture the pace and scope of their development and to provide examples for further discussion. We concentrate on emerging issues that could expand or limit solutions for species conservation.

Individuals and Their Movements

The past decade witnessed unprecedented expansion in technologies providing data on where individuals are and on their movements [8]. Tracking individuals has moved from using bulky and expensive radio-collars to smaller satellite-based devices and even to innovative non-invasive approaches. Technology provides new opportunities through informative compounds from the tracked animal's tissue (such as isotopes and genetic material) and even directly from remote sensing.

Location Data

Obtaining locations of species has also shown impressive improvements. Digital camera traps have replaced film-loaded ones, greatly expanding our abilities to detect rare or secretive species. Satellite-borne cameras can detect and monitor some animals in open habitats. Examples include using Landsat 30 m resolution satellite data to detect the presence and size

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of emperor penguin colonies in Antarctica [9], and Geo-Eye 1.65 m resolution satellite data to estimate population sizes of elephants, wildebeest, and zebra [10,11].

Airplane surveillance has monitored wildlife for decades, but unmanned aerial vehicles (UAVs or 'drones') capable of taking photos and videos could provide better, cheaper, and timely information compared to manned aircraft surveillance or satellite images.

Databases on species occurrence have also expanded rapidly. For example, the Global Biodiversity Information Facility (GBIF) has 420 million records and 1.45 million species names (Global Biodiversity Information Facility; www.gbif.org), while Tropicos (www.tropicos.org) has 4.4 million plant records. Records enter these databases via four main routes: museum and herbarium specimen collection, DNA sampling, crowdsourced observations, and remotely sensed images or sounds.

Natural history collections detect species at a specific location, including the identification of these detections. These are archived in museums before being digitized and incorporated into GBIF. Museum specimens require considerable expertise and expensive curation but offer the best evidence for the presence of a species, and for subsequent morphological, genetic, or isotopic research.

DNA libraries have been built for 2000 endangered species and an additional 2 891 971 specimens, making up 192 480 species (The Barcode Library, Barcode of Life Data Sytems; http://ibol.org/resources/barcode-library/). Both these sources limit the pace and scale of what can be collected, however [1].

Image-recognition algorithms are being applied to pictures of species. For example, the Smithsonian LeafSnap iPhone application (http://leafsnap.com) uses image recognition to identify Eastern North American tree leaves. Automated identification of bird or bat calls has been an active area of research for over a decade.

The most rapid advance in collecting location data comes from smartphone-wielding citizen scientists. For example, eBird (www.ebird.org) became an international depository in 2010 and already has >100 000 observers and >100 million observations. It permits fine-scale mapping and month-by-month changes in the distribution of some species. When photos or other vouchers are lacking, additional care is needed in vetting observations.

Remote Sensing of Environmental Drivers

Finally, there is our ability to monitor the environmental changes that cause species declines or, in the case of invasive or introduced species, their expansion. Responding to a request from the conservation community, NASA provided free Landsat imagery for 1990 and 2000 only in 2001. Now, much higher resolution imagery is freely and widely available, if not globally, that was usually first developed for consumer markets. Unprecedented amounts of data are becoming available from constellations of cubesats. (These are low-cost, small satellites that harness consumer technology rather than bespoke technologies and that have exceptional power in constellations. They are an alternative to a single, powerful but – by the time it reaches space – sometimes out-dated satellite.) They look to revolutionize medium resolution imaging through global, daily coverage (e.g., Skybox/Google, Planet Labs) and are being launched by an increasing number of countries and private companies [12–15]. Between 2012 and 2027, member agencies of the Committee on Earth Observation Satellites (CEOS) will operate or plan to operate 268 individual satellite missions [15]. Recently, the European Commission agreed to make the new Sentinel satellite data freely available. Drones are increasingly sophisticated and affordable providing unprecedented coverage of environmental changes [16].

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