1 A Brief Introduction to Conservation and Conservation Remote Sensing

Graeme M. Buchanan and Allison K. Leidner

1.1 THE CONSERVATION CRISIS

Biological diversity, or biodiversity, is a broad term applied to describe nature. It is formally defined as 'the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems' by the Convention on Biological Diversity (CBD; CBD 2010). This definition captures the complexity of biodiversity, in that it can represent all levels of biological organisation, from genetic variation to organisms and species, up through communities, ecosystems, and biomes.

Earth's biodiversity is facing a well-documented extinction crisis (e.g. Ceballos *et al.* 2015). The rate of extinction is beyond any natural or 'background' levels, defined as the rate that species had gone extinct over history prior to humans (Pimm *et al.* 1995). As the human population increases, human activities affect ever more places on Earth in ever more diverse ways. Human migration has been documented as having a negative impact on biodiversity for millennia. The settlement of Australia some 50,000 years ago potentially resulted in a rapid depletion of the megafauna of that continent around 45,000 years ago (Van Der Kaars *et al.* 2017). This pattern was also reflected in the extinction of moas (endemic flightless birds) in New Zealand and elephant birds (another group of endemic flightless birds) in Madagascar following the initial settlement of these islands by humans (e.g. Diamond 2013).

Numerous studies have documented elevated modern extinction rates in a variety of taxa and geographies, and all point toward the same trend. The current rate of extinction of species is estimated to be two to three orders of magnitude above the background rate (De Vos *et al.* 2015). Out of approximately 21,000 species of birds, mammals, and amphibians extant in 1904, 215 were extinct 100 years later (Baillie *et al.* 2004). Coining the term 'Anthropocene defaunation', Dirzo *et al.* (2014) estimated that 322 species of terrestrial vertebrates have gone extinct since 1500. Extinction rates could be worse for invertebrates, as the same authors estimated a 45 per cent decline in 67 per cent of monitored populations. Notably, these figures are estimates; we cannot know the real figures because we still do not know how many species there are on the planet and do not have anything resembling a species inventory for Earth. New extant species of birds and mammals, perhaps the two best-studied taxa, are still being found. One thing we do know, though, is that plant and animal populations are dwindling. The Living Planet Index, a metric derived from studies of animal populations across the globe, continues to decline (WWF 2016), indicating that extinctions are continuing. The Red List Index, a metric of the number of species facing extinction, continues to deteriorate (IUCN 2017). Understanding why species are declining and going extinct is essential if we are to halt, and then reverse, these declines.

The extinction risk to species can be measured by the International Union for the Conservation of Nature (IUCN) Red List (IUCN 2001). This globally accepted assessment of extinction risk involves the assimilation of information on the various threats that a species is known to face, or is thought to face, based upon expert evaluation. Conclusions on the status of a species are drawn from changes in range size, population sizes, or models quantifying risks of extinction (e.g. population viability analysis). Based upon the worst-case scenario from these criteria, species are assigned a category relating to imminence of extinction, from Least Concern, where the species might still be declining but not a pressing concern, through Near

Cambridge University Press
978-1-316-51386-6 — Satellite Remote Sensing for Conservation Action
Edited by Allison K. Leidner , Graeme M. Buchanan
Excerpt
More Information

Threatened, Vulnerable (facing a high risk of extinction in the wild), Endangered (facing a very high risk of extinction in the wild), or Critically Endangered (facing an extremely high risk of extinction in the wild). Fewer than 5 per cent of species have been evaluated with the IUCN criteria but, in 2017, some 24,431 species were identified as Threatened (IUCN 2017). However, even species that are of Least Concern (the lowest-threat category) can experience population or range declines, which can lead to local extinctions and the loss of ecosystem functioning (Ceballos *et al.* 2017).

Habitat alteration and loss are the most prevalent pressures faced by plants and animals (Maxwell *et al.* 2016). The IUCN Red List data indicate that of 8,688 species that are Threatened or Near Threatened, more than 80 per cent are at risk from overexploitation of their populations or the habitat they rely upon. Almost half are at risk from logging of forests while more than half are at risk from agricultural expansion. These figures are of course not mutually exclusive and many species are at risk from both threats, as forests are cleared for agriculture. The massive threat to habitats indicated by these figures in turn highlights the need to have a global assessment of ecosystems status. The IUCN has recently produced a set of criteria for just this purpose (Rodríguez *et al.* 2011, Keith *et al.* 2013). The Red List of Ecosystems will identify the areas on the planet that are suffering from dangerous levels of degradation, which could ultimately lead to ecosystem collapse. The goal is to have a complete assessment for all ecosystems by 2025. Given the high number of species which are of conservation concern, it is perhaps not a surprise that the majority of ecosystems assessed to date have also been identified as being of conservation concern. Indeed, one ecosystem, the Aral Sea, has been so badly degraded that it is now classified as Collapsed, the most severe status that can be assigned to an ecosystem (IUCN-CEM 2016).

Human-induced climate change is a relatively new anthropogenic threat to species and ecosystems. Although the climate of the Earth has changed in the past, it is the rapidity of the current changes that poses a novel threat to biodiversity. There is not enough time for species to adapt by evolving in a given location to cope with changes in temperature and precipitation regimes or to migrate to locations with more suitable climate. One estimate has indicated that between 24 and 50 per cent of bird species, 22 and 44 per cent of amphibians, and 15 and 32 per cent of corals are at risk of extinction due to climate change (Foden *et al.* 2013). Although there is regional variation in the magnitude of climate change, and some species and ecosystems are more vulnerable to such changes than others, few places on land or in the water have been untouched by this force.

To further compound the problem, climate change interacts, often synergistically, with other threats to species and ecosystems (Staudt *et al.* 2013). The deleterious effects of climate change on biodiversity are anticipated to increase in the coming decades, as humans continue to alter the climate (IPCC 2017). Addressing this major threat to ecosystems will remain at the forefront of environmental policy, but 'traditional' threats to biodiversity, such as habitat loss, habitat fragmentation, invasive species, and overhunting and overfishing, are still the main drivers of species endangerment. These threats will likely continue to drive the decline and extinction of species and the degradation of ecosystems.

Extinction of individual plants and animals should be a concern to us all, as extinctions do not occur in isolation from other events. Some species are indicators of the state of an ecosystem, and problems and threats to an entire ecosystem can be manifest first in the decline and loss of such indicator species (e.g. Lindenmayer *et al.* 2000). Some species are keystone species (Paine 1969), upon which many other species within the ecosystem depend, or which play a major role in shaping the ecology of the system. Loss of these species can have cascading implications for other species. Earth's biodiversity, including the ecosystems in which plants and animals live and interact, is the life support system for Earth, and thus for people. Degradation of ecosystems and resultant species loss has consequences beyond the aesthetic and cultural value that some attach to species and wild places. Natural habitats provide ecosystem services that humans

Cambridge University Press
978-1-316-51386-6 — Satellite Remote Sensing for Conservation Action
Edited by Allison K. Leidner , Graeme M. Buchanan
Excerpt
More Information

rely upon, many of which are expensive to replicate (Costanza *et al.* 1997). These services range from global to local and include climate regulation (forests, soils, and the ocean are sinks for vast quantities of carbon, which, if released, might increase the rate of climate change), water regulation (including clean drinking water and flood management), pollination of crops, and food production (fishing and bushmeat are critical sources of protein for many communities) (Costanza *et al.* 1997).

1.2 CONSERVATION SOLUTIONS

The pressures upon biodiversity are well known and the need for action is recognised. The terms 'conservation', 'conservation biology', and 'conservation science' are used as a 'catch all' to capture the multitudinous actions that are undertaken to understand, maintain, and restore Earth's biodiversity. People have been managing resources in sustainable ways for millennia. Consequently, pinning down the start and foundations of what qualifies as the 'modern' conservation movement is a challenge (Meine 2010). This endeavour is even more daunting if we attempt to summarise this history in a way that is not biased towards a European and North American perspective. Such an undertaking, though incredibly important, would be a book unto itself.

We can look back and see the dates at which various conservation organisations were founded as an indicator of conservation activity. Civil society organisations that promote conservation-related topics have been in existence in one form or another from just before the turn of the twentieth century. In the UK, the organisation that was to become the Royal Society for the Protection of Birds was a fledgling in 1889, and, by the 1920s, the International Council for Bird Preservation, the predecessor of BirdLife International, had been founded. BirdLife International is now a partnership formed of over 100 national biodiversity conservation non-governmental organisations. In the United States, the Wildlife Conservation Society was founded in 1895 and The Nature Conservancy in 1951. Both were preceded, in 1892, by the Sierra Club. Scottish-born John Muir was behind this club, and was also the man who promoted the establishment of Yosemite National Park (California, USA) in 1890, which in turn led to the foundation of the US National Park Service in 1916. However, such a catalogue of dates in which conservation organisations were founded is by no means a satisfactory way to describe the development of the conservation process. It fails to capture actions by governments or by individuals. Neither does it capture rapid expansions or leaps in awareness of the need for conservation. For example, the publication of *Silent Spring* by Rachel Carson in 1962 (by Houghton Mifflin) is often seen as a catalyst for the environmental movement in the USA. We refer the reader to Sodhi and Ehrlich (2010), a free online textbook, for a more thorough history of conservation.

Civil society organisations are not the only groups engaged in conservation. Governmental and non-governmental conservation organisations frequently work together, in collaboration with other sectors of society, to deliver effective conservation. For example, the IUCN (originally called the International Union for the Protection of Nature) was founded in 1948, and its membership is comprised of both governmental and non-governmental organisations, with a focus on providing information and tools to members that enable conservation. The IUCN's efforts led to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), a species-focused agreement that was adopted by 80 countries and went into force in 1975. That same year, an ecosystem-focused international agreement, the (Ramsar) Convention on Wetlands, also went into effect. The 1992 Rio Earth Summit was a landmark event, from which the CBD was opened for signature. This agreement, signed by 168 nations, calls for conservation of biological diversity, sustainable use of biodiversity, and a fair and equitable sharing of genetic resources derived from biodiversity. In 2010, the CBD strategic plan (CBD 2010) set 20 conservation objectives (named the Aichi targets) to be achieved by signatories by 2020. These address topics including the underlying causes and pressures that result in biodiversity loss, as well as calls to improve the status of biodiversity and enhance its benefits to society.

Conservation involves all levels of society. Together, irrespective of whether they are running a local project or working on pan-governmental environmental conventions, conservationists are working to halt and reverse biodiversity loss and ecosystem degradation. Regardless of the spatial or societal scale at which they are working, the financial and technical resources available to them are often limited. A recent estimate indicated that the funds available to conservationists to meet just two of the 20 Aichi targets (targets 11 and 12) were an order of magnitude lower than what was required (McCarthy *et al.* 2012). Time is also often in short supply. Waiting years to respond to changes in plant or animal populations will only make the problem harder or even impossible to solve. Consequently, the limited resources available to the conservation community need to be targeted to where they are needed most urgently; actions should be based on sound scientific evidence. The field of science that delivers the required evidence can be variously referred to as conservation biology, conservation science, or conservation evidence. There is no one definition of conservation science but Soulé (1985) suggested that 'Conservation biology, a new stage in the application of science to conservation problems, addresses the biology of species, communities, and ecosystems that are perturbed, either directly or indirectly, by human activities or other agents.'

As with biodiversity conservation itself, it is not possible to identify when conservation science emerged as a rigorous, professional discipline. One key professional society, the Society for Conservation Biology, was formed in 1985, and it publishes the journal *Conservation Biology*. The journal *Biological Conservation* began publishing in 1968. However, many of the preceding ecology professional societies and journals made strong contributions to conservation. The British Ecological Society, which was formed in 1913 and is the world's oldest ecological science society, first published the *Journal of Applied Ecology* in 1964.

Conservation does not occur in a vacuum. It requires an understanding of the causes of human activities that lead to conservation problems, and the motivation that people have to see ecosystem services preserved or restored. Conservation science is thus not a strictly biological science. To name just a subset of disciplines, it incorporates anthropology, ecology, natural resource management, psychology, economics, and public policy. The processing and analysis of conservation data has seen computer scientists, mathematicians, and physicists contribute to the field. As you will see in the case studies presented in this book, successful conservation draws upon many disciplines.

Many in the conservation community utilise an adaptive management framework to implement conservation activities (Figure 1.1). This framework integrates research into the design, management, and monitoring of conservation projects in a way that facilitates iterative improvements and adaptation to better achieve the desired outcomes (Salafsky *et al.* 2008). Key steps in this process include identifying a management objective, designing a model of the system, developing a management and monitoring plan to test assumptions, implementing the plans, analysing the results, and then incorporating the findings to optimise future implementation and monitoring (Salafsky *et al.* 2008). Ideally, through routine evaluation and improvement, conservation objectives can be achieved. In reality, the full adaptive management cycle is often not comprehensively implemented, and different aspects of it, such as research and management implementation, are not as integrated as they could be. Satellite remote sensing can potentially play a role in all stages of adaptive management, as evidenced by the case studies presented in subsequent chapters.

1.3 OBSERVING THE EARTH

The first iconic images of the Earth from space were captured during the active days of the 1960s and 1970s. The 1968 Earthrise photograph taken by Apollo 8 astronauts and the 1972 blue marble image (Figure 1.2) were used by the growing environmental movement to

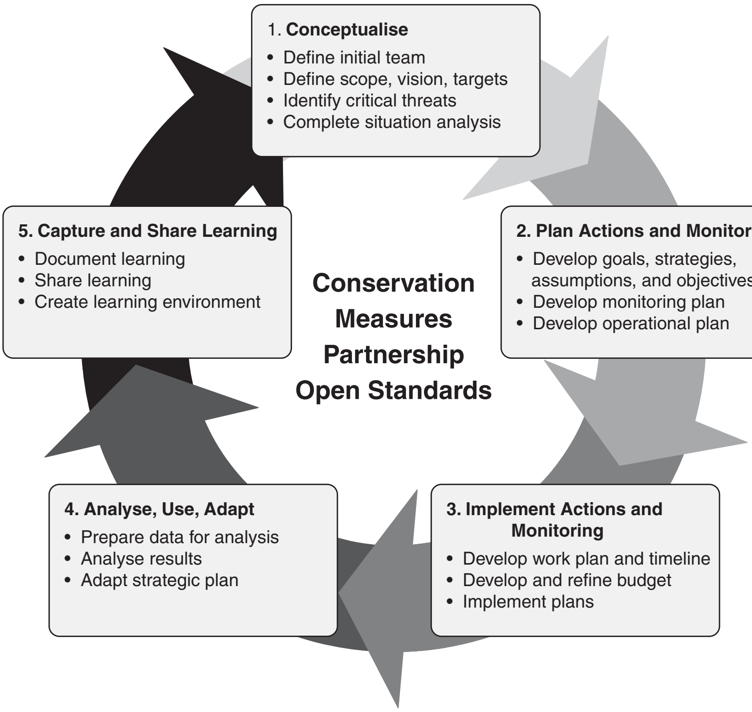

FIGURE 1.1 An example of the adaptive management cycle for conservation.
(Credit Creative Commons.)

rally support. By this point, regular monitoring of the Earth using satellites was already underway. The first non-military satellites were weather satellites, which captured very large-scale images of the Earth on a daily basis. In 1972, the first satellite designed to look at the surface of the Earth, rather than its atmosphere, was launched. The Earth Resources Technology Satellite 1 was the first mission of the pioneering Landsat programme and the ecological community quickly picked up on these Earth observations and other opportunities to explore the processes and functioning of land and sea. However, the cost of images and the need for special computer programmes and computer hardware limited the utilisation of remote sensing images by ecologists and conservationists during this time. High-end

Cambridge University Press
978-1-316-51386-6 — Satellite Remote Sensing for Conservation Action
Edited by Allison K. Leidner , Graeme M. Buchanan
Excerpt
More Information

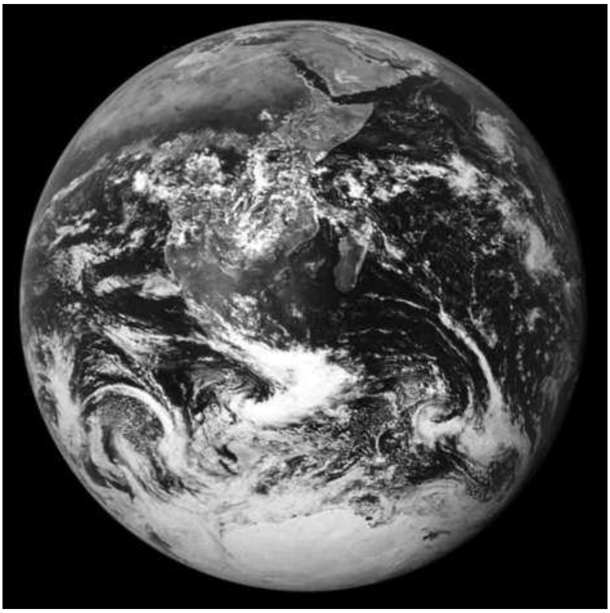

FIGURE 1.2 An image of the Earth, as seen by the Apollo 17 crew. (Image credit: NASA.) (A black and white version of this figure will appear in some formats. For the colour version, please refer to the plate section.)

expensive computers were needed to store and process the satellite images. Often, highly trained specialists were also required to manipulate and process the observational data, making them not particularly conducive to use by conservationists. Despite these significant challenges, some in the ecology and conservation communities realised early on that satellite remote sensing captured global, repeated data, which provided a unique perspective on land cover and ocean conditions (Roughgarden *et al.* 1991) and were able to garner the resources to overcome these challenges. Those who are new to the field of satellite remote sensing, or people with some knowledge but who want a more detailed synopsis of the topic, will benefit from reading Chapter 2, where Brink *et al.* provide an excellent introduction to remote sensing and the history of its use in conservation. In Chapter 9, Tabor and Hewson describe how Conservation International, a conservation non-governmental organisation, has utilised these data over the years.