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Protecting species diversity and ecological structure in relation to sustainable development goals (SDGs) 14 and 15. A scoping review

Cornelius KA Pienaah[*1], Samuel Jerry Cobbina[1], Matthew Nkoom[1], Mahama Dangana[1], Ernest Doodaa[2], Angkyelaa Joseph[3], Grace Antwi[2]

[1]*Department of Environment and Sustainability Sciences, Faculty of Natural Resources and Environment, University for Development Studies, Ghana*

[2]*College of Agricultural and Natural Sciences, School of Agriculture, University of Cape Coast, Ghana*

[3]*Department of Agricultural Engineering, School of Engineering, Ho Technical University, Ghana*

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Abstract

The paper explored and highlighted evolving science, technologies, current improvements, and emerging techniques that are being employed to protect species diversity and their ecological structures in relation to Sustainable Development Goals (SDGs) 14 and 15. A desktop review of literature on protection of species diversity and ecological structure was conducted. For the desktop review, Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) framework was used in searching for and analyzing the literature between 2015 and 2021 year. The study identified "Robotic jelly fish", "Biobag", environmental Deoxyribonucleic Acid (eDNA), use of drones to plant trees, remote sensing, and Geographic Information System (GIS), automated bioacoustics, International Union for Conservation of Nature (IUCN) Green list technologies, artificial intelligence and anti-poaching transmitters as some recent technologies employed towards the achievement of SDG 14 and 15. Species diversity and ecological structures are important for nature conservation and human well-being; hitherto human knowledge is inadequate on the overall condition of species diversity and ecological structure and its threats. Finally, to enhance conservation of this threating loss, technology should be advanced to attain SDG 14 and 15.

***Corresponding Author:** Cornelius KA Pienaah ✉ corneliuspi1594@uds.edu.gh

Introduction

According to the United Nations Sustainable Development Goal (SDG 14 & 15), biodiversity includes vertebrates (fishes, mammals, birds, reptiles, and amphibians), invertebrates (insects, molluscs, crustaceans, and other living organisms without backbone) and plants species (algae, fungi, mosses, lichens, angiosperms, ferns, and allies) living and interacting in land, water, forest, and other ecosystems that describes the biological variety and variability of species life on earth. SDG 14 aimed to conserve and sustainably use the oceans, seas, and marine resources for sustainable development whereas SDG 15 aimed to protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss.

Globally, it is an undoubtable fact that, species diversity and ecological structures is fast losing due to loss of biodiversity mostly because of anthropogenic activities (FAO, 2018, WWF's Living Planet Report 2018, Lambertini and Marco, 2018, Habel *et al.*, 2019, United Nations 2019, IUCN, 2021). Species over exploitation is fast leading to extinction in the world especially in Africa due to inadequate conservation technologies, poverty, and developmental needs (IUCN, 2021). The United Nations' Sustainability Development Goals (SDG's), specifically SDG-14 Life below water, and SDG-15 Life on land (hereafter SDG-14 & 15) are the most recent international call for action to address the crisis which interconnects to the broader environmental, societal, and economic sustainability (UN, 2020).

Recently, the IUCN Red List now includes 134,425 species of which 37,480 are threatened with extinction (IUCN, 2021). According to the IUCN, 2021, population declines over several decades due to poaching for ivory and loss of habitat. The African forest elephant (Loxodonta cyclotis) is now listed as critically endangered and the African savanna elephant (Loxodonta africana) as endangered on the IUCN Red List of threatened species.

Until this declaration, the African elephants were treated as a single species, listed as vulnerable; this is the first time the two species have been assessed separately for the IUCN Red List, following the emergence of new genetic evidence. The latest assessments highlight a broad scale decline in African elephant numbers across the continent. The number of African forest elephants fell by more than 86% over a period of 31 years, while the population of African savanna elephants decreased by at least 60% over the last 50 years, according to the assessments (IUCN, 2021). Both species suffered sharp declines since 2008 due to a significant increase in poaching, which peaked in 2011 but continues to threaten populations.

Conservation of species diversity and ecological structures are directly linked to SDGs 14 & 15 because once species extinct, humankind cannot get it back. Therefore, conservation of species diversity and ecological structures effort are geared towards ensuring sustainable development (Williams *et al.*, 2020). The study therefore aims at identifying conservation efforts made towards attaining healthy biodiversity in both terrestrial and the aquatic ecosystem. Several studies have been conducted that looks at efforts made towards achieving sustainable development through protecting species diversity and ecological structures. Some of which include (Aiba and Kitayama 1999, Behangana *et al.*, 2020). Diversity plays an essential role in providing ecosystem services (Tahmasebi *et al.*, 2017). It is believed that there is a positive relationship between biodiversity and ecosystem functioning and sustainability (Penuelas *et al.*, 2020). To make a more efficient, productive, and sustainable ecosystem, it is important to maintain high species diversity and ecological structure to attain Sustainable Development Goal SDGs 14 (Life below Water) and 15 (Life on Land).

Materials and methods

Method

A desktop review of literature on the subject of protection of species diversity and ecological structure was conducted. For the desktop review, Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) framework was used in searching for and analyzing the literature that was sourced (Liberati, *et al*., 2009; Creswell, 2005). Literature searches were performed in only English on PubMed, SciVerse Scopus, and ISI Web of Knowledge databases. Other searches included articles from google scholar, Sage journals, research gate, frontiers and Francis and Taylor journal pages using key words and phrases such as "Species diversity", "Technologies for protecting species diversity", "Ecological structures" "Cutting-edge technologies for species conservation" "Biodiversity protection strategies", and "Ecosystem's protection technologies".

Sampling

In order to highlight the evolving science, technologies, current improvements and emerging techniques that are being used to protect species diversity and their ecological structures between 2015 and 2021 year.

Documents reviewed were selected after reading their abstract or a preliminary reading of full document in order to assess the suitability to be used for this study. Research articles from 2015 to 2021 were reviewed in this study. The primary search identified 107 publications whose titles discussed biodiversity, species diversity, conservation and ecological structure and were screened by tittle. An additional 17 publications identified from other sources. Sixteen 16 were excluded because they were not relevant by title. Furthermore, 91 were screened by abstract and excluded 12 because not relevant by abstract/missing abstract. A final 79 of the articles were further screened by full text and excluded 33 because not relevant by study design and content. Finally, forty-six (46) articles met the inclusion criteria for the tertiary, full-text, review.

Results and discussion

To begin with, "Robotic jellyfish" technology was identified been used to protect endangered coral reefs and other aquatic animals. This robot is specially designed with soft, flexible rubber material and uses small but powerful propellers to swim. The idea is to begin using robot jellyfish in the place of divers to observe, explore, and even restore delicate coral reefs. Coral reefs are structures in oceans that form the basis of heavily populated and diverse ecosystems. Unfortunately, coral reefs face many jeopardies and can be damaged by the effects of climate change, pollution, unsustainable fishing practices, and human exploration. Coral reef ecosystem degradation has increased dramatically during the last three decades due to enhanced anthropogenic disturbances and their interaction with natural stressors (Hussein A. El-Naggar, 2020). For instance, the Great Barrier Reef of Australia, the world's largest coral reef with an area of 349,000Km2 contains about 400 species of coral, 1500 species of fish, 4000 species of molluscs and 6 species of turtles. It provides a breeding site for around 250 species of birds and covers only 0.1% of the ocean but has about 8% of the world's fish species. There are thousands of species which are yet to be discovered and described (Poulami A.M, 2021). Tropical cyclones, coral predation by crown-of-thorns starfish (COTS), and coral bleaching accounted for degradation of the site. Other anthropogenic activities have led to increase in water temperature that affects corals. For instance, Algal blooms (as result of a nutrient, like nitrogen or phosphorus from fertilizer runoff, entering the aquatic system and causing excessive growth of algae which affects the whole ecosystem) and Sediment plumes are also causes by anthropogenic activities that affect corals.

Another latest advancement in assisted reproduction is the development of an artificial "biobag" womb that can be used to carry developing fetuses through to full term. Although still in early stages, such a device would potentially be used to increase reproductive capacity of endangered mammals in instances where the availability of females to gestate the next generation is a limiting factor to recovery. The "Biobag" technology could be considered for reproducing critical and endangered mammals' species. For example, The African forest elephant (Loxodonta cyclotis) is now listed as critically endangered and the African savanna elephant (Loxodonta africana) as endangered on the

IUCN Red List of threatened species before it completely goes extinct. This would help sustain conservation efforts in protected biosphere reserves, national parks, and sanctuaries.

Also, environmental deoxyribonucleic acid (eDNA) monitoring is another evolving technique, especially useful for tracking community composition in freshwater systems (Biggs *et al*., 2015; Valentini *et al*., 2016). It is the hereditary material in organisms that contains the biological instructions for building and maintaining them. The samples are usually collected from the environment (typically from skin, scales, mucous, gametes, and carcasses) and thus non-invasive is particularly helpful in searching for rare aquatic species and determining fish community diversity, which is difficult to survey manually. Environmental DNA (eDNA) is used to identify species in both aquatic and terrestrial ecosystems for inventory and monitoring, improved detection of native species and early detection of invasive species towards conservation efforts against extinction. The chemical structure of DNA is the same for all organisms, but differences exist in the order of the DNA building blocks, known as base pairs. According to the application of Environmental DNA for inventory and monitoring of aquatic species report, in aquatic environments, eDNA is diluted and distributed by currents and other hydrological processes, but it only lasts about 7-21 days, depending on environmental conditions. Exposure to UVB radiation, acidity, heat, and endo-exo nucleases can degrade eDNA. Species, where threatened and endangered been identified are taken out and given full protection and kept in special reserves like ponds, botanical gardens, wildlife safari and others to prevent extinction of the species through eDNA. Some of the species are later reintroduced into the wild for continuity. Cameras fitted to blimps have been used to monitor river dolphins (e.g., Oliveira *et al*., 2017), and monitor coastal habitats in MPAs (Castellanos-Galindo *et al*., 2019). However, technology alone cannot be used to monitor all species (Stephenson, 2019a), and in many cases more specialized methods are needed. For example, tests using environmental DNA to detect manatees suggests the technique "may be effective for population monitoring," especially in sites where they are in low densities or difficult to spot (Hunter *et al*., 2018). Valentini *et al.* (2016) used eDNA metabarcoding techniques to detect amphibians and bony fish and found that, "when compared with traditional surveys or historical data, eDNA metabarcoding showed a much better detection probability overall."

Other techniques that have been tested for monitoring aquatic species, including fecal DNA (Fernández-García and Cedillo, 2017) and artificial shelters (tested on desmans; González- Esteban *et al*., 2018), also need to be used more widely for smaller species. Techniques for lesser-known species need to be integrated into standardized protocols, as has been done recently for taxa such as invertebrates and plants (e.g., van Swaay *et al*., 2015; Borges *et al*., 2018) that are often neglected.

In addition, the rate of deforestation is rapidly escalating because of climate change, human destruction, and global food production. Repopulating trees lost to deforestation is essential to help regulate and decrease global carbon emissions and encourage biodiversity. Considering this uncontrollable effect, the use of Drones that fire seed pods into the ground have become the fastest and most effective way to plant many trees.

In 2020, Canadian company Flash Forest used drone technology to plant seeds in an area where trees had burned down in a wildfire. Flash Forest plans to plant 40,000 trees a month and aims to have planted 1 billion trees by 2028. According to the company, using drones to plant trees is 10 times faster than manual plantation by humans. To fight deforestation, a UK-based startup is using aerial drones that can plant seeds 60 times faster than humans can. The world's forests lose an area equivalent to 48 football fields every minute, according to the World Wildlife Fund. This effort helps in restoration of the forest ecosystem species richness which makes an ecosystem able to respond to any catastrophe.

Apart from that, GIS and remote sensing are used to detect and monitor the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft). Cameras on satellites are used to make images of temperature changes in the oceans. Remote sensing plays a particularly important role in helping to understand where species live and in providing measures of diversity such as species richness. E.g., Coral reefs, fishes, sea grass, Coral bleaching (warmer water temperatures can result in coral bleaching). The importance of measuring species diversity as an indicator of ecosystem health has been recognized by major initiatives worldwide (Skidmore *et al.*, 2015). Remote sensing, whether through satellites or drones, is increasingly applied to wildlife monitoring, land-cover classification, and as a mitigation tool for early warning for poaching activities (Wich 2015).

Especially over vast areas or in remote areas with rugged terrain. With sharks threatened by overharvest, researchers compared simultaneous locations of satellite-tracked fishing vessels and tagged shark locations to examine proximity and potential threat to sharks from accidental or deliberate catch. 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 (Hussey *et al.*, 2015; Kays *et al.*, 2015). In forest diversity, it's been used in research linking high-resolution imagery to detect high-carbon tropical forests with camera trap photo data to assess species presence. Ugandan park rangers who used GPS units to assess accuracy of Global Land Analysis & Discovery (GLAD) alert locations found that the satellite-based alerts could make field patrols more effective. Conservation scientists have recently started using satellite imagery to keep track of elephants. Elephant populations in parts of Africa are continuously decreasing, classifying them as vulnerable. Meanwhile the Asian elephant population has dropped by 50% over the last three generations and today the animal is considered endangered. Scientists have begun by tracking elephants in Africa and are aiming to use satellite technology to track threatened elephant populations internationally. According to the BBC, the images come from an Earth-observation satellite that orbits 600 km (372 miles) above the planet's surface. This technology can capture up to 5,000 sq. km of elephant habitat on a single clear day. Infrared sensors provide the potential to identify individual animals either at traditional camera-trap stations; from sensors directly connected to smartphones; or aerially from drones. Multispectral sensors are being trialed for their ability to identify aerial-census species from pelage reflectance characteristics. Increasing sensor sophistication and deployment by citizen scientists, recreational visitors, or indigenous expert trackers could hugely augment both the quality and volume of data collected.

Furthermore, the use of automated bioacoustics monitoring devices and camera traps have improved the study of the production, transmission, and reception of animal sounds. This includes not only the vocalizations of animals such as birds and mammals (Lachlan RF, *et al.*, 2016), but also the sounds that can be produced by insects. E.g., Bee. Acoustic sensors can play a role like that of camera traps by recording the presence of animals through their sounds, at relatively low cost, and storing them in a web-based platform for users to manage and analyze the data. Camera traps, hidden in some of the world's remote and inaccessible locations, are activated by infrared sensor when body heat or movement from an animal is detected. The camera automatically triggered by a change in some activity in its vicinity, like presence of an animal. For example, researchers in Mexico detected the decreasing number of vaquitas through acoustic monitoring of their home in the Gulf of California. Camera trap records nest ecology, detection of rare species, estimation of population size and species richness, as well as habitat of species in the wild. Camera traps are remote cameras that take photos when a sensor is triggered by the movement of an animal or person and, increasingly, send the image in real-time to the operator. The installation of camera traps in trees, for example, has successfully documented canopy use by arboreal mammals (Rovero and Zimmermann, 2016).

Data from the devices has been used to make conservation decisions and check extinction towards attaining sustainable development. Acoustic sensors can also detect human sounds and alert authorities or local indigenous groups in near real-time when chainsaws are detected in their forest. (Alvarez-Berríos *et al.*, 2016) and unmanned aerial vehicles or drones (Wich and Koh, 2018). These sensors can enhance the quality and volume of monitoring data, reduce the fieldwork involved in data collection and, if used in systematic ways (Beaudrot *et al.*, 2016), help fill data gaps in high biodiversity tropical countries (McRae *et al.*, 2017). Successful uses of such devices in Africa include the use of camera traps in monitoring cryptic water-bird species (Colyn *et al.*, 2017) and acoustic monitoring of frogs (Measey *et al.*, 2017).

The IUCN Green List of Species (Akçakaya *et al.*, 2018) is a new tool to assess species recovery and conservation success that may also be relevant for many freshwater species. Early pilot testing has provided useful results for fish and amphibians, as well as aquatic mammals and birds (Stephenson *et al.*, 2020). One advantage of the tool is that it encourages conservation planning and status monitoring across the historic indigenous range (Stephenson *et al.*, 2019a). Species distribution modeling (SDM) may also be able to assist monitoring efforts by, for example predicting range shifts of species due to climate and land use or predicting the advance of alien invasive species, and monitoring those hotspots identified in models (Bazzichetto *et al.*, 2018). SDM has the potential to focus monitoring efforts on key sites or species, saving time and effort. WET-Health is a method developed in southern Africa for assessing the current and projected ecological condition of a wetland by measuring hydrology, geomorphology, and vegetation (Kotze *et al.*, 2018). The scope to use this tool for monitoring trends over time should be explored.

Artificial intelligence to track wildfires: The International Telecommunication Union (2020) Artificial Intelligence (AI) for Good Global Summit, organized in partnership with the XPRIZE Foundation, the Association for Computing Machinery (ACM) and more than 26 UN agencies, was the first event to initiate global dialogue on AI's potential to act as a force for good. The 2017 summit sparked the first-ever inclusive global dialogue on beneficial AI, which was followed by 2018's action-oriented summit that focused on impactful artificial intelligence solutions able to yield long-term benefits by identifying applications of AI capable of improving the quality and sustainability of life on Earth. The summit also formulated supporting strategies to ensure trusted, safe, and inclusive development of AI technologies and equitable access to their benefits. The 2019 summit took place from 28-31 May 2019 in Geneva, Switzerland. Wildfires such as those recently seen in California in the US, Queensland in Australia, and Brazil's Amazon rainforest are a danger to ecosystems, can cause a loss of vegetation, and emit large amounts of air pollution. A US-based company called Descartes Labs has been using artificial intelligence to detect and track wildfires. By using satellites to capture imagery roughly every few minutes, the software uses indicators of fire such as smoke and thermal infrared sensors to detect whether a fire has ignited and to track it were about.

Anti-poaching transmitters are used for preventing poaching in protected areas by means of collecting, analyzing, and reporting data from the field. These are devices that can be fitted on a collar or directly onto an animal in danger from poaching. They monitor an animal's movements through a sensor and track their location. These transmitters which are being used to monitor rhinos and other endangered animals in most African conservations can send real-time information on the whereabouts of an animal and can even sense when they are in distress. The movement sensor will even trigger an alarm if an animal is in physical distress and in the case of rhinos, can detect if its horn is in danger of being severed by poachers.

Finally, technologies constantly collect data and information to create a shorter feedback loop that could, in theory, enable better decision-making overtime.

Conservation technology have helped researchers and conservationists to better understand species diversity and ecological structure and systems of interest, monitor their status, and take actions to protect biological diversities. More diverse ecological structures tend to be more productive. Species diversity is an important part of life on earth. The vast diversity and density of interactions between species keep our ecosystems operative. Due to anthropogenic activities a million species of plants and animals are now at risk of extinction. This is a severe threat to the ecosystems that people around the world depend on for their survival (Meng *et al*., 2019).

Ecological niches of many plant and animal species are degraded, and opportunistic and invasive species have invaded to empty ecological niches due to their high tolerance to stress conditions (Lemos *et al*., 2019). For instance, majority of the problems threatening coral reefs are the direct (and indirect) result of human activities on land, and in the marine environment. Marine debris, water pollution, sedimentation, overfishing, careless recreation, and global warming are some examples of human-caused threats to the coral reef habitat. Each of these threats has a significant impact on the health of coral reefs. The Convention on Biological Diversity (CBD's) Aichi target 15 called for the 'restoration of at least 15% of degraded ecosystems' by 2020 and a recent study estimated that at least 1.9 million km 2 of land in 114 countries will need to be restored to meet the area component of Aichi target 11 (Mappin *et al*., 2019). In response to this notable decline in abundance of species diversity and their ecological systems, technologies have been employed to restore and or protect this phenomenon.

Conclusion

Species diversity and ecological protection require data on species status and threats to inform decision-making and adaptive management using technology. However, there are key challenges in Africa around the availability, usability and quality of species diversity data, willingness to use data, and capacity (Stephenson *et al*., 2017a). Consequently, many decision makers do not have access to the data they need (Stephenson *et al*., 2017a). Meanwhile, species diversity and ecological structures are significant for nature conservation and human well-being. To enhance conservation of this threating loss, technology should be advanced to restore the ecosystem.

Conflict of interests

The authors have not declared any conflict of interest.

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