

Emerging technologies to combat poaching

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Abstract

Like traditional crimes that harm human society, wildlife crime threatens the animal population. In the present scenario, it is increasing at an alarming rate daily, ultimately leading to their extinction and an imbalanced ecosystem. Wildlife crime is committed in variable forms such as hunting, illegal wildlife trading, animal trafficking, as well import and export of medicinal plants and their products, but out of them, cases of Poaching were reported increasingly and thus need special attention as the poachers are increasing day by day. Their urge for monetary gain is also enhancing. Although traditional methods were already implemented to reduce the numbers, these methods had certain limitations and required modification and advancement. By keeping this in mind, the current review deals with the techniques that can be utilized to combat such crimes, with special emphasis on the promising potential of new emerging techniques, including hardware and software-based methods.

Keywords: Traditional crimes, Hunting, Wildlife Crime

Introduction

Wildlife mainly refers to the various animal species that inhabit their native ecosystems, including forested regions, arid landscapes, and tropical rainforests (Abotsi *et al.* 2016). Wildlife primarily encompasses animal species that are not domesticated but involve all species that thrive or inhabit natural environments that are far in reach from human impact. In a broad sense, animals are categorized mainly on three bases (Al-Zohairi *et al.*, 2022). i) Body covering, which (is hair, fur, feathers, scales, and shells) ii) Appendages (arms, legs, wings, fins, and tails) iii) Movement

(walking, crawling, flying, and swimming) (Table 1). Wildlife crime involves a broad spectrum of illicit activities not only limited to the illegal trade, possession, and consumption of flora and fauna but also unlawful hunting, poaching, and animal trafficking (Anagnostou *et al.*, 2022). The overexploitation of keystone species leads to an ecological imbalance and a significant threat to the ecosystem (Auliya *et al.* 2016). The primary driving force of wildlife crime is economic; however, secondary motivations may include amusement and leisure (Ballantyne *et al.* 2007). Wildlife conservation is the systematic approach to safeguarding the diverse plant and animal species and their habitats. Wildlife is crucial in maintaining equilibrium and stability within natural resources as an integral ecosystem component (Balls *et al.* 2018). Wildlife conservation is of utmost importance in ensuring the existence of these species and the protection of their natural habitats (Begum *et al.*, 2022). Educating individuals on the significance of wildlife and promoting sustainable development is crucial for fostering a more favourable future for the entire ecosystem (Begum *et al.*, 2023). The Red Data Book, issued by the International Union for Conservation of Nature (IUCN), provides a record of rare and endangered species of animals, plants, and fungi, along with local subspecies found within the country (The species were grouped into nine categories namely (a) Not Evaluated (b) Data Deficient (c) Least Concern (d) Near Threatened, (e) Vulnerable (f) Endangered (g) Critically Endangered (h) Extinct in the Wild and (i) Extinct (Biggs *et al.* 2019). Several agencies are actively working for wildlife conservation, such as the Wildlife Crime Control Bureau (WCCB), Wildlife Protection Society of India (WPSI), Wildlife SOS, World Wide Fund for Nature (WWF), Wildlife Trust of India (WTI), Wildlife Conservation Society (WCS), Rhino Conservation of India and many more (Table 2) (Black *et al.* 2022).

Poaching: A Serious Threat to Wildlife World

Poaching is commonly defined as the unlawful practice of hunting or capturing wildlife (Burkart *et al.* 2017). In legal terms, poaching refers to the illegal act of shooting, trapping, or possessing wild animals, fish, or plants from privately owned land or areas designated explicitly as protected (Carter *et al.*, 2020). The act of poaching causes a substantial risk to a wide range of wild organisms globally and is a notable factor in the decline of biodiversity (Chandran *et al.* 2017).

Methods Employed for Poaching

a. Snare Ware – In this particular technique, cables are tied around the two vertical supports of a tree to constrict the neck of an animal as it travels along its pathway

b. Pitfalls- The poachers excavate a pit and conceal it with the help of shrubs and bushes to make an animal fall into it and kill it.

c. Pin Board Traps – This method utilizes a large board covered with numerous iron nails and positions it on the path to kill an animal.

d. Spears- In this process, an animal was chased by canines to fall into the pit, ultimately resulting in its demise.

e.Arrow and Bow- This method utilizes arrows and bows to kill the animals.

f. Shooting- Poachers use firearms to assassinate the targeted animals.

g.Poisoning- In this method, animals are killed by administering toxic substances.

h.Poisoned Arrows- This process involves administering the Poisons via the arrow to kill the animals.

i.Electrocution- This method employs high-voltage electrical cables for killing animals.

j.Netting- In this method, Nets capture and kill animal species.

k.Harpooning- This involves capturing and killing aquatic animals with traps.

l.Bird Trapping – This method employs nets to capture flying bird species.

2.1 Reasons Behind Poaching

There are the following reasons behind Poaching:

More legislation is needed to combat wildlife crime effectively.

Insufficient stringent legislation fails to effectively convict individuals engaged in unlawful trading and poaching, enabling them to evade legal consequences for their activities (Chen *et al.* 2022). The penalties for these offences are comparatively low, considering the gravity of the crimes being perpetrated (Chirisa *et al.*, 2020). In India, the prescribed penalties for the offences mentioned above include an amount of around ten thousand to twenty-five thousand rupees, along with a custodial sentence of seven to ten years (Droissart *et al.* 2021). A three-year conviction for a poacher was very rare. Nevertheless, a significant proportion of those engaged in poaching activities are acquitted due to the ineffectiveness of the prosecution process (Eikelboom *et al.*, 2020). The conviction rate in India for cases reported during the preceding three and a half years is a mere 10% (Fernando *et al.* 2020). The permissive nature and susceptibilities of regulatory systems have facilitated the ability of poachers to exploit and evade enforcement mechanisms, notwithstanding the existence of legislation designed to safeguard endangered species and uphold biodiversity conservation efforts (Harmsen *et al.* 2021).

The process of transferring illicit trade commodities into lawful marketplaces.

Wildlife items often find their way into legitimate marketplaces despite their illicit origin. In the past, there was a prevalent belief that wildlife products obtained through illegal trade and poaching were solely marketed within clandestine markets (Harvey *et al.*, 2021). However, several investigations have concluded that a significant portion of animal products that are trafficked illegally are being sold inside legal marketplaces. These products include peacock feathers, oak, sea pearls, cuttlefish, and other trinkets and jewelry crafted from ivory (Huang *et al.*, 2021).

Huge money on offer

Based on available records, it has been observed that wildlife materials exhibit exorbitant costs in both domestic and global markets (Hutchins *et al.* 2016). This prevailing circumstance catalyzes poachers, motivating them to intensify their efforts in pursuit of financial gain. The perpetuation of avarice, a prominent contributing factor to poaching, has consistently provided sustenance to the poaching industry (Hutchison *et al.* 2021). The illicit wildlife trade is a lucrative industry with a significant economic value of billions of dollars. Consequently, various entities such as criminal organizations, high-ranking government officials, and authorities responsible for wildlife regulation derive financial gains from this trade (Ibrahim *et al.* 2021).

The legal commerce of undocumented species

In contrast to prevailing national legislation, many undocumented species were traded legally within the market worldwide (Kays *et al.*, 2022). Despite facing imminent extinction, certain species are subjected to extensive exploitation due to unclear documentation of their economic value (Kelly *et al.* 2012).

The diverse demand and usage

The animals were used for a wide range of applications, ranging from medicinal purposes to the production of carpets and rugs. In the context of India, several commodities utilize a wide range of items, namely Mongoose hair, Rhino horn, snake skins, Tiger and Leopard claws, bones, skins, and whiskers, Elephant tusks, Deer antlers, Shahtoosh shawls, Turtle shells, Musk pods, Bear bile, Medicinal plants, timber, and avian species such as Parakeets, Mynas, Munias, and so forth (Keskin *et al.* 2022). Most of these unlawfully acquired products are intended for the global market and are in direct demand within India.

Unsubstantiated Religious, Aphrodisiac, and Medicinal Benefits

Certain animal species have been targeted for religious purposes and materials used in rituals and holy ceremonies (König *et al.* 2020). These materials involve various body parts, including hooves, tails, skin, feathers, fangs, heads, fur, horns, and ivory. Some animal species, such as rhinoceroses, turtles, orangutans, snakes, seahorses, and pangolins, are targeted due to the perception that their body parts possess medicinal properties capable of curing various ailments, including cancer. It has been found that the scales of pangolins and turtle blood are pulverized into fine powder and employed for the alleged therapeutic properties (Kyriakidis *et al.* 2021). There is a prevailing belief that buffalo horns, freshly obtained serpent blood, and the reproductive organs of tigers possess qualities that can potentially enhance aphrodisiac effects and promote virility (Lamichhane *et al.*, 2020).

Delicacy Food Items

Certain wild creatures, including zebras, lions, hippos, elephants, gazelles, snakes, and giraffes, were killed to obtain their flesh, which was commonly referred to as "bush meat" in customary practices (Losavio *et al.* 2018). In specific regions, the consumption of some animal species, such as apes and snakes, is regarded as a culinary delicacy.

Organized Criminal Networks

Certain kinds of wildlife species are targeted by criminal networks that are involved in activities such as people trafficking, money laundering, and drug cartels (Lam *et al.*, 2023). The criminal network exhibits significant scale, enabling the act of slaughtering the animals inside the sub-Saharan African region and afterward exporting its various body parts to Asian destinations (Louchouart *et al.* 2021). Organized criminal groups unlawfully capture certain animals to showcase their dominance, whereas others are traded as domesticated companions. Humans are currently recognized as the sole documented natural predators of the rhinoceros species (Marescot *et al.*, 2020).

Habitat loss, logging, and the expansion of human settlement areas.

The continuous growth of the human population necessitates the encroachment of human settlements into areas designed for wildlife conservation. The act of killing animals is carried out to facilitate human activities such as urban expansion, road construction, settlement, and agricultural practices (Mestanza *et al.*, 2020). The destruction of animal habitats results in famine, compelling animals to encroach upon agrarian land or livestock. Furthermore, logging creates roads and pathways that link the untouched areas of the wilderness, providing poachers with entry points to the more remote sections of the forest, which serve as habitats for diverse wildlife species (Mudumba *et al.* 2021).

Effects of Poaching

Extinction

Certain animal species are considered extinct, but others are classified as endangered due to wildlife crime (Narayanan *et al.* 2010). Moreover, it is worth noting that the annual mortality rate of rhinoceros exceeds one thousand due to the illegal hunting of these animals for their valuable horns. Tigers are currently facing a critically endangered status as a result of illicit poaching activities. Due to the scarcity of pangolins in Asia, pangolins from other regions have become the targets of poachers.

The Animals Suffer

Many animal species need ample space for movement, suspension from branches, and aerial locomotion. Confinement in cages, luggage, sacks, or crates generally hinders their ability to thrive (Pérez *et al.* 2021). At times, human populations establish themselves in areas that animals previously inhabited. This phenomenon compels animals to occupy areas with restricted spatial availability, posing challenges to their survival (Pilz *et al.*, 2022).

The amalgamation of criminal network activities contributes to escalating global health risks.

The underreported instances of homicides of forest rangers, poaching, and the subsequent illicit ivory trade are associated with further criminal activities, including money laundering, human trafficking, and corruption (Pires *et al.* 2017).

An Imbalance in the Ecosystem

Predators and prey within an ecosystem are crucial for maintaining its overall balance. Keystone species, typically exemplified by apex predators, predate populations to curtail their expansion and uphold the overall biodiversity (Pusparini *et al.* 2018). Hence, numerous wild animals play a crucial role in upholding the equilibrium of the food chain and food web within the natural environment. Consequently, the elimination of these species would result in a disturbance to the whole ecosystem. The exponential proliferation of certain species may lead to the depletion of other animal and plant populations, perhaps resulting in the extinction of further species (Rees *et al.*, 2018).

Disruption in the Food Chain

Poaching can alter the food chain by causing the extinction of predators. This can alter the transfer of energy by organisms. People hunt animals that consume plants and eat animals that feed on other animals in every corner of the globe (Robinson *et al.* 2015).

Table 1. List of Anti-Poaching Organizations

S. No	Name of the Organization	Year of Establishment	Headquarter
1.	WCS (Wildlife Conservation Society)	1895	New York, USA
2.	National Wildlife Federation	1936	Reston, Virginia, USA.
3.	Defenders of Wildlife	1947	Washington, D.C
4.	IUCN (International Union of Conservation of Nature)	1948	Gland, Switzerland
5.	WWF (World Wildlife Fund for Nature)	1961	Gland, Switzerland
6.	IFAW (International Fund for Animal Welfare)	1969	Washington D.C
7.	CITES (Convention on International Trade of Endangered Species of Wild Flora and Fauna)	1975	Geneva, Switzerland
8.	TRAFFIC (Trade and Record Analysis of Flora and Fauna in Commerce)	1976	Cambridge, UK
9.	WII (Wildlife Institute of India)	1982	Dehradun, India
10.	WPSI (Wildlife Protection of Society)	1994	New Delhi, India
11.	Wildlife SOS	1995	New Delhi, India
12.	WTA (Wildlife Trafficking Alliance)	1998	Noida, India
13.	WTI (Wildlife Trust of India)	1998	Noida, India
14.	WCCB (Wildlife Crime Control Bureau)	2006	New Delhi, India
15.	Biglite Foundation	2010	Tanzania, Africa
16.	ICCWC (International Consortium on Combating Wildlife Crime)	2010	Cambridge, UK

Prevention of Poaching

Engage the Public

Law enforcement agencies predominantly prevent and mitigate poaching activities. Nevertheless, it is imperative to provide the general public with comprehensive education regarding the significance of wildlife conservation and the detrimental effects of poaching on local economies (Ruiz *et al.*, 2022). By doing so, individuals will be motivated to oppose poaching and promptly and actively report any instances. Furthermore, this educational initiative will enhance public awareness regarding the importance of preserving animal habitats. It is worth noting that dispelling misconceptions surrounding the purported medicinal, aphrodisiac, and religious applications of animal parts is an integral part of this educational endeavour (Shamsuzzaman *et al.*, 2022).

Recruit More Wildlife Scouts

To ensure the protection and welfare of wildlife, employing more forest rangers and scouts is crucial.

Make Tougher Laws

The existing legal frameworks have been established already to prohibit this behaviour. Nevertheless, poaching persists, indicating that it reinforces existing legislation (Serfass *et al.* 2017). Strict action is required to effectively mitigate the demand and sale of animal parts and commercialize wildlife as exotic pets. The implementation of strict legislation entails the imposition of more severe convictions against poachers and individuals involved in wildlife-related offences, hence enhancing the protection of a more significant number of species (Sherman *et al.* 2022).

Provides Sanctuaries to the Animals

Certain animal species are currently under the imminent threat of extinction, necessitating their protection within designated sanctuaries. Using this conservation approach, including a wide range of animal species, will likely increase the population of these species (Shuffler *et al.* 2018).

Zoning (Demarcate Land for The Wild Animals)

More efforts need to be made to outline where wildland begins and ends. In doing so, humans will not encroach into such land for construction, settlement, or agricultural purposes. Those found inside such lands should be treated as poachers, regardless of why they enter, and will face the consequences of violating the law (Munaweera 2022).

Put More Trackers and Sensors in the Wild

Utilizing innocuous and imperceptible trackers is crucial in wildlife tracking, as it facilitates the acquisition of precise data regarding animal populations, spatial distribution, and potential hazards (Pires and Moreto 2017). This enables people sitting in control rooms to monitor and assess the welfare of this animal. One effective method for addressing the challenges of poaching, logging, and other illicit wildlife operations is employing strategies that do not necessitate the continuous presence of rangers with the animals in their natural habitats (Pimbert and Pretty, 2013).

Outlaw the Purchase and Sale of Animal Parts and Products

Implementing legislation prohibiting the trade of wildlife products, particularly inside animal markets, can substantially reduce poaching activities (MacKenzie 2017). If the trade of animal parts were to be prohibited, there would be a decrease in demand for these products, resulting in the closure of many businesses involved in this industry. As a result, this will decrease the quantity of animals being slaughtered for their body parts (Lorimer 2015).

Anti-poaching methods

The Anti-Poaching Methods are classified into two types: -

Traditional Anti-poaching Methods

a) Dehorning

The technique involves forest authorities removing an animal's horn.

b) Community-based Conservation

The protection and conservation of wildlife need the involvement of the local population.

c) Strong Policies

Laws and policies are enacted to safeguard wildlife along with the regulations associated with the treatment and preservation of wildlife.

d) Shoot to Kill Policy

The implementation of this policy involves the use of lethal actions against individuals who are apprehended in the act of poaching.

e) Making the Wildlife Products Illegal

The substantial demand for wildlife items increases the illicit supply and trafficking, hence fostering the killing of animals. Hence, it is necessary to enact global legislation to prohibit the trade of items, particularly those derived from endangered species.

Table 2. List of Highly Poached Endangered Animal Species in India

S.NO	ANIMAL SPECIES	PRODUCT USED FOR TRADE	USES
1.	Indian Tiger	Bones, Meat, Teeth, and Skin	Medicine and Ornamental
2.	Leopard	Fur, Skin, and Bones	Medicine
3.	Indian Rhino	Horn	Medicine
4.	Indian Elephant	Ivory	Medicine and Ornamental
5.	Lion	Teeth, Claw, and Bone	Medicine and Ornamental
6.	Pangolin	Meat, Scales, and Blood	Medicine and Ornamental
7.	Kashmir Red Stag	Meat, Antlers, and Skin	Medicine
8.	Ganges Dolphin	Flesh and Oil	Medicine

3.2 Emerging Technologies

The Emerging Technologies are of two types: -

- a. Hardware Based
- b. Software Based

3.2.1 Hardware-Based Methods

a. e-Eye System

The e-Eye system is an extensive intelligent technology and surveillance system for wildlife monitoring. It can operate continuously, regardless of weather conditions, providing real-time video records of wildlife activities in areas prone to vulnerability and within sanctuary perimeters. The system's primary function is to gather and analyze data related to wildlife crime, enabling it to notify the forest authorities. The system operates by using solar energy. Electronic surveillance cameras can perform a complete 360-degree scan and effectively monitor the movements of both animals and humans. This application serves as a valuable tool for monitoring and analyzing poaching and investigating specific species' migratory patterns. These devices can also detect the movement of poachers or any other form of human activity, such as habitat destruction, grazing, and cutting of trees within the vicinity, by activating an alarm system when required. In addition, it can emit auditory signals about ailments, irregularities, and fatality of fauna, accompanied by a comprehensive report. The device can be outfitted with either infrared cameras for short-range detection or thermal cameras for long-range detection, depending on the situation's specific needs. Additionally, the system is equipped with remotely operated cameras and Wi-Fi gadgets.

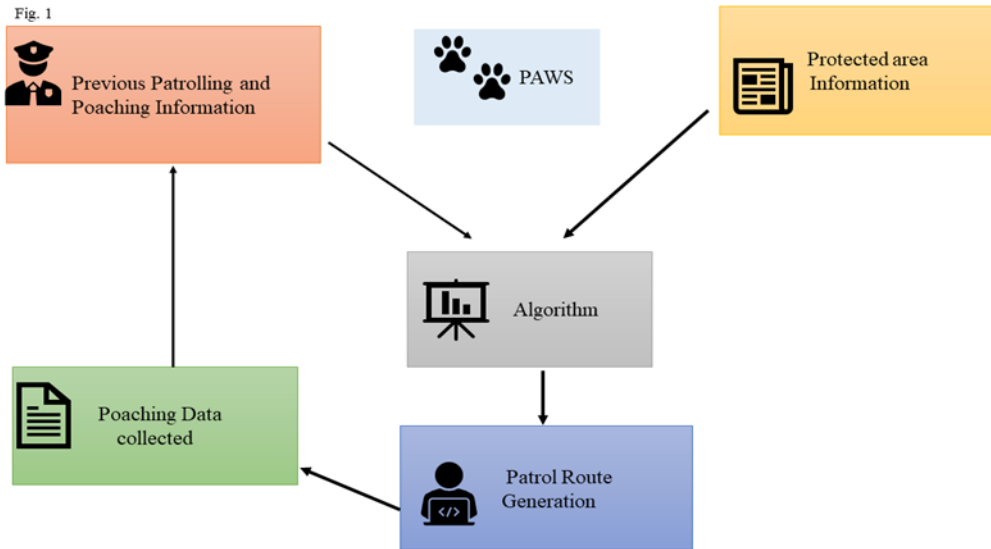


Figure 1. E-eye system to monitor the activity of poachers and human activity in prohibited zones.

b. Camera Traps and Acoustic Recorder

A camera trap is a practical and widely used tool to study wildlife. It is generally considered non-invasive; it can gather information on an extensive range of species simultaneously and continuously over wide areas for months. Camera traps are best for shy species or obscure species, such as snow leopards, for example, or nocturnal species, such as striped hyenas. Camera traps are also useful for detecting the activities and behaviours of animals that are not easily observed. Acoustic recordings capture sound-producing species (e.g., birds, insects, vocalizing mammals) but cannot detect non-vocal or silent animals.

Fig. 2

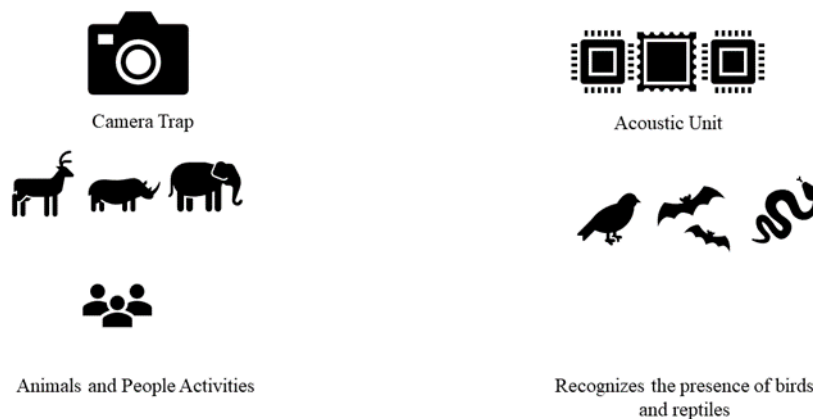


Figure 2. Camera traps to access the various animal activities easily.

c. Satellite-Based Wildlife Conservation

The use of satellite remote sensing technique, which involves the detection of emitted and reflected light from satellites, along with the application of machine learning, specifically neural networks processing, geographic information systems (GIS), and global positioning systems (GPS), has significantly broadened the scope of possibilities for gathering data, conducting analysis, developing models, integrating information, and producing satellite maps in the field of wildlife monitoring and assessment. Satellite enhanced-resolution imaging provides scientists and researchers with the most recent geospatial data through network processing. Monitoring relies on statistical data to track wildlife migrations and map habitats and endangered species in remote regions where on-site surveillance is impossible. These activities aim to support authorities and conservation initiatives. The utilization of the WorldView-3 satellite sensor, which possesses a panchromatic resolution of 30cm and an 8-band multispectral resolution of 1.2 meters, has emerged as a valuable tool in the field of wildlife monitoring. When spectral signatures are accessible for the animal species that are to be observed, seasonal statistics can be acquired through neural network processing, resulting in high levels of trust.

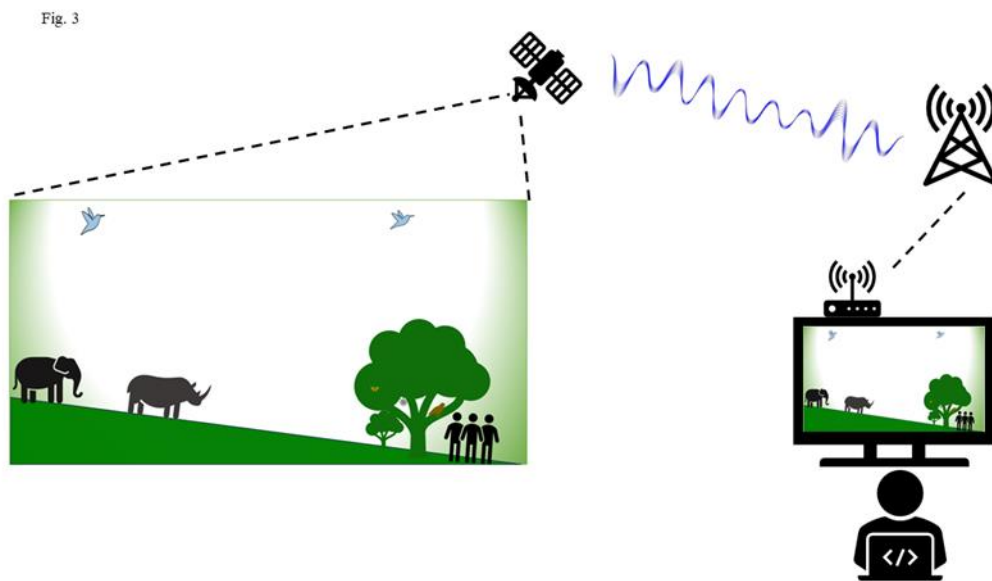


Figure 3. Satellite monitoring to track wildlife migrations and location mapping.

b. Software Based

i) CAPTURE (Comprehensive Anti-Poaching Tool with Temporal and Observation Uncertainty Reasoning)

The CAPTURE framework involves the following features:

- a. The density of animals
- b. The measurement of distances for rivers, highways, and villages.
- c. Net primary productivity (NPP) refers to the amount of energy produced by plants through photosynthesis minus the energy used for respiration. It is an important measure of an ecosystem's productivity and biomass accumulation.
- d. Habitat refers to the specific environment in which a particular animal resides.

Rangers can access the CAPTURE tool to forecast poachers' behavior and develop the most effective patrol schedules. CAPTURE is an artificial intelligence (AI)- powered anti-poaching technology that supports conservation authorities by facilitating the identification of high-risk areas for poaching activities and enabling the development of efficient patrol strategies. The CAPTURE system employs an alternative hierarchical paradigm to inform law enforcement agencies about potential actions undertaken by poachers.

ii) Protection Assistant for Wildlife Security (PAWS)

The PAWS system was introduced as a game-theoretic approach, specifically within the domain of security games, to enhance the efficiency of patrol optimization. PAWS represents the pioneering implementation of a comprehensive framework designed to simulate and optimize routine and strategic operations within green security, specifically focusing on wildlife conservation efforts. Its primary objective is to augment the efficacy of human patrol personnel in combating the illegal act of poaching. The PAWS system has been designed as a data-driven approach for classifying regions with a high likelihood of poaching within protected areas. Additionally, it aims to determine the most efficient patrol routes to address the issue of poaching effectively. PAWS employs a novel hierarchical modelling approach to construct a virtual street map integrating comprehensive topographic data.

iii) Spatial Monitoring and Reporting Tool (SMART)

The SMART system is an innovative and sophisticated surveillance tool specifically designed to support field rangers in their efforts to prevent poaching and combat the illicit trafficking of wildlife. The SMART system is an integrated software and programming solution that has been specifically

developed to provide comprehensive analysis and support park rangers in their efforts to save wildlife and preserve their natural habitats. The SMART tools exhibit the following characteristics: they are open-source, non-proprietary, and readily accessible without any cost. The SMART system includes a wide range of technologies that facilitate the user in the compilation, storage, interconnection, and assessment of plant and animal species data, as well as places designed for conservation purposes.

Conclusion

Poaching has now become a massive threat to the stability of biodiversity. Nevertheless, methods to prevent them are widely developed at the ground level, and people have become aware of why they need to reduce wildlife poaching. Emerging technologies in wildlife crime prove to be a windfall in saving wildlife. Widespread networks of technologies considerably reduce certain wildlife crimes like poaching. The main concern is to develop technologies, whether expensive or cheap, as each gadget significantly prevents wildlife crime. Most of the endangered species that are poached are keystone species, and a reduction in these species will inevitably disturb the ecosystem. A change in the mentality is needed towards the medicinal uses of the wildlife products obtained by poaching, as well as keeping an endangered species as a pet. Along with that, less demand for wildlife products means less supply, which consequently leads to a reduction in poaching, which will ultimately lead to an increase in the population of wild animals, and it will help stabilize the ecosystem in a better way.

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