# Green Technology Innovations for the Rejuvenation of Plant and Animal Species

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**Abstract:** ***The intersection of technology and wildlife conservation has opened new avenues to protect Earth's biodiversity. While the natural world faces numerous challenges in the modern age, technology serves as a powerful ally in the fight against habitat and wildlife loss. Green science technology is revolutionizing global conservation efforts by introducing innovative solutions to rejuvenate endangered plant and animal species. This interdisciplinary approach combines biotechnology, ecological restoration, and sustainable practices to address biodiversity loss driven by habitat destruction, climate change, and overexploitation. The paper highlights various green technologies and their innovations in monitoring and revitalizing flora and fauna. Notable advancements include genetic engineering techniques like CRISPR-Cas9 to enhance genetic diversity, tissue culture methods for propagating rare plants, and de-extinction technologies aimed at reviving extinct organisms. Precision tools such as drone-based habitat assessments and AI-driven ecological modelling support proactive and efficient conservation strategies. Additionally, green energy solutions, such as solar-powered wildlife sanctuaries, promote sustainable ecosystems with minimal environmental impact. Scaling and ethical implementation of these technologies require collaboration among scientists, policymakers, and local communities. This study explores the integration of green science into conservation initiatives, showcasing successful case studies while addressing challenges like resource constraints and ethical considerations. By leveraging these technological innovations, humanity can make meaningful strides toward preserving Earth's biodiversity and ensuring ecological balance.***

**Keywords:** Rejuvenate, AI Tools, restoration, CRISPR-Cas9

## 1.Introduction

The earth is gifted with an enormous diversity of natural ecosystems comprising a vast range of wild flora and fauna species. Nonetheless, global environmental changes such as climate change, deforestation, desertification, and land use impact negatively on plant and animal life. In the present day, the animal world is under severe attack; more than 1210 species of mammals, 1469 of birds, 2100 reptilians, and 2385 species of fish are threatened [1]Activities such as illegal wildlife trade, spread of invasive species and diseases, and the human impact on the Earth's climate is changing the nature of wild habitats. On account of this, various conservation strategies, initiatives, and technological solutions have been at the lead during the past couple of decades [2]. Green Technology, characterized by its emphasis on sustainable and ecofriendly emerges as a transformative tool in addressing these challenges. The ability of humans and other animal species to self-regulate and adapt to their natural environments is significantly hampered by the presence of various technologies that are more prevalent in our world. Destruction of the environment and turn these technologies into alternatives that are less harmful to the natural world in order to preserve a pristine environment for future generations[3]. According to the IPBES Global Assessment, 75% of land worldwide has been significantly changed, 66% of ocean area is experiencing increasing negative impacts, and over 85% of global wetlands have been lost. Between 2010 and 2015, around 32 million hectares of primary or recovering forest were lost in mega diverse tropics. Faced with the unprecedented degradation of the natural world, ecosystem restoration is more important than ever. However, restoration efforts cannot be effective unless we protect keystone species within these ecosystems, especially those that are endangered. The world is in the middle of a green technology innovation (GTI) revolution. It is predicted that this is going to be the biggest wave of innovation ever, and it is going to change everything-the way we work, the way we live, and how this planet is populated forever.

## 2.From 'Extinct' to 'Least Concern'

The International Union for Conservation of Nature and Natural Resources (IUCN) Red List uses a hierarchical structure of nine categories for assigning threat levels for each species or subspecies. These categories range from 'Extinct' to 'Least Concern' (Figure 1). At the highest levels of threat, taxa are listed as 'Critically Endangered, ' 'Endangered, ' or 'Vulnerable, ' all of which are given 'Threatened' status. A series of quantitative criteria is measured for inclusion in these categories, including: reduction in population size, geographic range size and occupancy of area, total population size, and probability of extinction. The evaluation of these criteria includes analyses regarding the number of mature individuals, generation time, and population fragmentation. Each taxon is appraised using all criteria. However, since not all criteria are appropriate for assessing all taxa, satisfying any one criterion qualifies listing at that designated threat level[4].

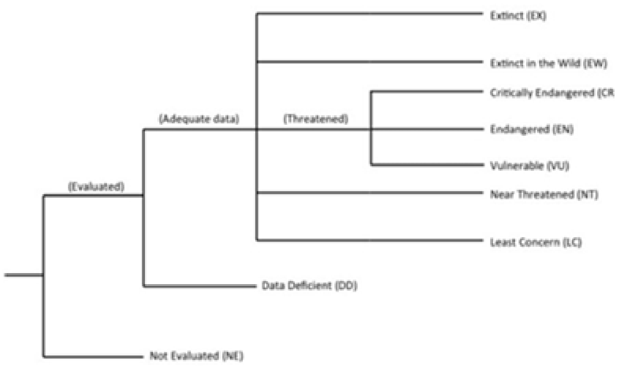


**Figure 1:** IUCN Categories

The Species Threat Abatement Restoration (STAR) metric uses IUCN Red List of Threatened Species data to estimate the potential reduction in species extinction risk that could be achieved at a site, across a corporate footprint, or within a country. It can also be used to set local or global species extinction risk targets, and measure progress towards those targets. The STAR methodology 4 draws on the Red List data to produce estimates of the potential for species extinction risk reduction broken out over a global 5 x 5 km² grid. For each pixel within this grid, STAR estimates the contribution of the threats affecting species present in the grid to the total value for the pixel. Values of pixels can be added up to enable assessment for larger polygons representing corporate footprints, administrative areas, protected areas, or commodity production zones. The STAR value of a pixel is calculated using the number of threatened species that occur in a pixel, their level of threat (from 100 for a Near Threatened species, up to 400 for a Critically Endangered species), and the proportion of all threatened species' Area of Habitat represented by the pixel.

STAR also estimates the amount of species extinction risk reduction that can be achieved by restoring habitat where threatened species used to occur. The restoration STAR value is discounted compared to the threat abatement value, to reflect the longer timescales of restoration impact.

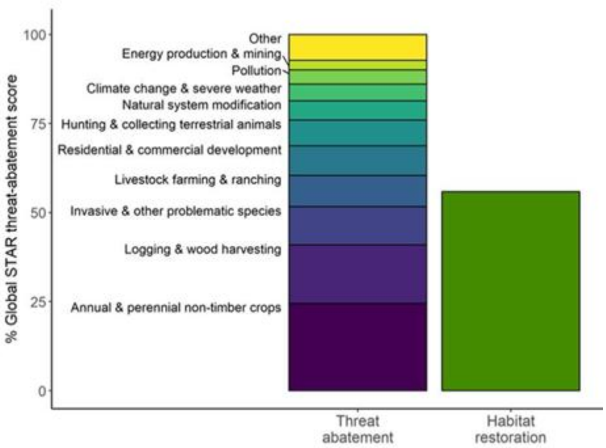


**Figure 2:** The contribution of different threats to the global STAR threat-abatement score, and the potential contribution of habitat restoration. (Mair et al. (2021) Nature Ecology & Evolution.)

## 3.Technology-based wildlife in situ conservation

### 3.1 Bio-logging and bio-telemetry

Bio-logging and bio-telemetry have different forms of collecting information, but both comprise the monitoring of physiological, behavioural, or environmental information of organisms that are difficult to observe or often otherwise unattainable [5, 6]. Bio-logging technology records and stores the information in an animal-borne device (archival logger), and the information is downloaded once the logger is retrieved, unlike the bio-telemetry technology, which sends the information to a receiver that is emanated from the device carried by the animal [6]. For instance, block states that the integration of environmental data with animal collected data has been simpler with the use of emerging electronic tagging and the remote sensing satellites, which provide a more precise and rapid environment sampling and higher resolutions of global views. New approaches using both technologies are changing the capacity to conduct ecosystem-scale science and to improve the capacity of scientists to explore unanswered ecological questions [7]. The technology of Global Positioning System (GPS) allows scientists to obtain precise movement patterns of an animal through GPS telemetry where the animal location and its distance to survey sites can be quantified [8]. Such technology has helped to identify, for example, the use of unpredicted habitats [9], to explore the social dynamics of reintroduced species[10] and to reveal unfamiliar life history characteristics of threatened species [13]. Animal-borne technology (referred to as animal-borne video and environmental data collection systems-AVEDs) gathers high-resolution datasets that can measure the animals' physiology, behaviour, demographics, community interactions, and the environment animal inhabits[11]. A vast variety of these sensor types to collect data on wild animals' internal and external states have been packaged into lightweight units[11].

In birds, lightweight geo locators or satellite transmitters have allowed practical reconstruction of the migratory routes and wintering areas for large and small birds, which can give opportunities to test predictions about migration strategies[12]. Animal-borne devices are also advantageous for testing hypothesis about drivers of habitat use. For example, a study on southern elephant seal (Mirounga leonina; [13] in the Southern Ocean, which looked at the geographic distribution of core foraging areas and behaviour and assessed the relative quality of the habitats regionally, demonstrates clear advantages of using satellite tracking systems and their assistance to understand more about the animal's response to varying environmental conditions and population viability.

### 3.2 Camera traps

Camera traps are remote devices equipped with a motion or infrared sensor that automatically record images or videos [14]. They have become an important wildlife research tool; the decreasing cost gives researchers additional opportunities to monitor and reach a larger number of wildlife populations. Traditional approaches, such as visual, capture and trapping methods, can be labor-intensive and can require hundreds or thousands of person hours; whereas, camera traps can multiply the number of observers and make them more cost efficient[15]. The use of this technology has increased to address questions of species' distribution, activity per terns, population densities [[15, 16]], and among other questions. Camera traps offer a practical approach to answer many questions about wildlife besides the density or estimation of animal populations. Behavioural studies using camera traps, such as the first ever done by Gysel and Davis (1956) where they essentially described a simple system to photograph wildlife, help us understand how different species use their habitat[17]. For instance, Bauer *et al.*1[8] examined scavenging behaviour of puma in California through camera traps and telemetry. While puma are known to be opportunistic predators, their results indicated that pumas are also opportunistic scavengers. A more recent study in chimpanzees Pan troglodytes; [19] examined community demographic changes (births, deaths, emigrations, immigration's) and community composition (age/sex structure). The authors found that camera traps allowed for a practically accurate approximation of demographic composition and variation within and among social groups. They also highlight that such technology may provide more accurate and precise measures of fine-scale group abundance

**3.3 Additional technologies**

The emerging technology of synthetic biology is rapidly expanding and currently applied to conservation. This field is capable of editing natural genomes in an extremely precise manner, through deleting a target gene and/or inserting a synthetic one (CRISPR/Cas9 technology), which can bring the efficacy of genetic modification to a new level[20].

Endangered species often have genetic diseases and functional defects due to population decline and loss of genetic diversity. Gene editing technology can improve the health and adaptability of endangered species by repairing harmful gene mutations or introducing new functional genes. For example, in carnivores such as snow leopards (*Panthera uncia*), reduced genetic diversity caused by inbreeding may lead to immune system defects or reduced reproductive capacity. Through gene editing, exogenous functional genes can be introduced or mutant genes can be repaired to improve the health and reproductive capacity of individuals [22] proposed a strategy to repair the genes of endangered species using CRISPR/Cas9 technology. They pointed out that by repairing the genes of endangered birds, their immune function can be effectively improved, enabling them to better resist the invasion of foreign pathogens. At the same time, the advantages of CRISPR technology in gene repair also include the ability to accurately locate specific gene mutation sites and use DNA repair mechanisms to repair them. Dudek *et al.*2[2] proposed that gene editing technology can help restore the functional genes of marine mammals, such as improving hereditary immunodeficiency diseases. CRISPR technology can also be used to enhance the expression of functional genes. For example, by regulating gene expression levels, the reproductive capacity of birds, mammals and fish can be improved. This method can achieve better adaptation of species to environmental pressures by precisely regulating gene expression levels, helping their populations expand and stabilize.

Some examples of the main conservation problems with possible solutions through the application of synthetic biology are as follows: (a) habitat conversion by creating or modifying microorganisms that consume hydrocarbons in order to clean up oil spoils [23] or by using systems to produce man-made palm oil and so reducing tropical forest alteration [24]; (b) over exploitation, where production of materials that can substitute rhino horn ivory or deep sea shark squalene [26]; and (c) invasive species, where the use of chromosome alterations and gene drives to stop reproduction in these species. The latter is yet associated with aesthetic, moral, and ethical issues in which Piaggio and colleagues [25] call for a robust decision-making and a risk-assessment framework in the application of synthetic biology to conservation concerns.

Biotechnological approaches such as tissue culture and micropropagation facilitate the conservation of rare plant species, while genetic rescue and CRISPER-based gene editing support the revival of endangered animal populations. Seed banking and cryo preservation of plant germplasm and animal gametes offer long-term genetic preservation strategies.

In recent years, seed banks have been preserving seeds of rare and endangered plants by storing them in low-humidity, low-temperature environments. This practice slows down the seeds' metabolic processes, effectively placing the embryos in a state of suspended animation to extend their lifespan.

However, for species that have already become extinct, our only remaining samples are often found in herbaria-collections of dried and pressed plant specimens. These herbaria were originally intended for documentation and study, not for preserving seeds for future growth. Only a few of these specimens include mature seeds, as it was a matter of chance whether a plant was bearing fruit at the time of collection.

Even when seeds are present in herbarium specimens, determining their viability is challenging. It's difficult to ascertain whether the embryos inside are still alive and merely dormant, awaiting the right conditions to germinate, or if they have perished over time.

Despite these challenges, there have been instances where seeds from herbarium specimens have successfully germinated. For example, researchers have explored the potential for germinating seeds from critically endangered plant species endemic to the Hawaiian island of Kaua'i using herbarium specimens. (CONBIO. ONLINELIBRARY. WILEY. COM)

Additionally, seeds from herbarium specimens of Bupleurum tenuissimum, aged over 100 years, have been successfully germinated, highlighting the potential of herbaria as a resource for conservation efforts. (RESEARCHGATE)

To assess seed viability without damaging these precious specimens, non-destructive methods like X-ray imaging can be employed to check for intact embryos. Chemical tests, such as the tetrazolium chloride test, can also be used to determine viability, though they require sacrificing the seed. (SAVEPLANTS. ORG)

While herbaria were not designed for seed preservation, they may hold untapped potential for reviving lost plant species, especially as our understanding of seed dormancy and germination improves.

Efforts to rejuvenate extinct plant species have seen notable successes in recent years.

Toromiro Tree (*Sophora toromiro*)

Native to Rapa Nui (Easter Island), this tree became extinct in the wild by the 1960s due to overexploitation and environmental changes. Recent scientific initiatives have focused on cultivating seedlings using compatible soil bacteria and fungi to reintroduce the species to its native habitat. (THE GUARDIAN)

Judean Date Palm (*Phoenix dactylifera*)

Once prevalent in ancient Judea, this date palm vanished centuries ago. Remarkably, scientists have successfully germinated seeds dating back 1, 900 to 2, 300 years, leading to the growth of several trees and the harvesting of dates. (WIKIPEDIA)

Snowdonia Hawkweed (*Hieracium snowdoniense*)

Endemic to North Wales, this plant was believed extinct in the early 1950s due to overgrazing. It was rediscovered in 2002, and conservation efforts, including habitat protection and cultivation, have been implemented to support its resurgence. (WIKIPEDIA)

'Sheba' Tree (*Commiphora* sp.)

Germinated from a 1, 000-year-old seed found in the Judean desert, this tree belongs to a potentially new species within the Commiphora genus. It may be the source of the biblical balm, 'tsori, ' known for its medicinal properties. (THE TIMES)

York Groundsel (*Senecio eboracensis*)

Discovered in York, England, in 1979, this plant was declared extinct by 2000. Seeds stored at the Millennium Seed Bank were successfully germinated, leading to its reintroduction in 2023-the first recorded instance of a plant's extinction and subsequent revival in its native range. (WIKIPEDIA)

These examples underscore the potential of combining seed preservation, scientific research, and conservation efforts to restore plant species once thought lost forever.

Track plates offer a further efficient method to detect wildlife, and they have been used in an array of ways to monitor several animal species. Originally, track plates were developed to monitor rodents' abundance, and were subsequently adapted for use with carnivores [26]. Back in the 1980s, such tools commonly comprised an aluminium plate in a plywood box, and usually, a bait was placed near the back of the box. The negative track impressions were created after the underlying plate surface was revealed, when the animal's foot removed soot [26]. Other tracks of mammals were and are created by using, for instance, smoked monograph paper [27] sand, ink-coated tiles [29,] mineral oil mixture and carbon black [30], or contact paper and dispersed printer toner [31]. Track plates are considered economical and reliable devices that can provide robust measurements of animal's abundance. For example, Connors *et al.*3[2] used track plates to measure abundance and local predation risk created by white-footed mouse (*Peromyscus leucopus*) foraging activity, and they conclude that such devices were a trustworthy means of quantifying local risk of attack by terrestrial mammals without significantly modifying the spatial distribution of risk. A more recent study by Smith *et al.3*[3] confirms that a well-designed trap to enclose the track plate can be fairly inexpensive, non-intrusive, and an easy monitoring tool. They specifically looked at whether breeding phenology of a generalist predator was associated with human responses to climate change. For this, they assessed seasonal abundance of small mammals using presence/abundance data collected from track plates, along with motion-activated trail cameras to obtain visual corroboration of the identity of small mammals visiting traps.

## 4.Case study of Rejuvenation

### 4.1 Timba: Gujrat

Timba is located about 110 km south east of Ahmedabad, Gujrat India. Here the geological track forms the part of Pavagdh basalt deposits and has been in the past several decades. A Completely barren basalt quarry up to depth of 15 to 20 m was done on the site. The exhausted quarry tract is spread over an area of forty-one hectares (Fig.1). The quarry operation has not only distributed the natural ecological environment but also created large unused barren and degraded land. The vegetation was in poor condition because of the poor soil strata. The forty-one hectares Basalt quarry land had deteriorate very badly.

**Image:** Site location, Timba

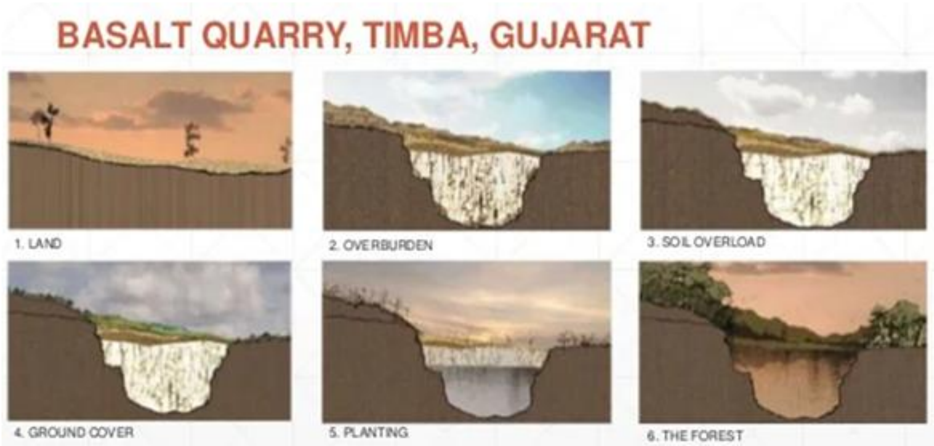


**Figure 3**

**Rejuvenation method**

The only existing vegetation was at the site was marginal scrub formation with a extremely sparse distribution of Neem trees. The first step in the processes was to enable humus formation to make the soil rich in order to sustain further vegetation cover. The ground cover would help in covering the soil moisture, rain water; keep the soil in summer months and so help to plant growth. In order to encourage this growth, weeds from nearby areas were developed on the site. With the first shower much of the desired effect was achieved and by second year and entire area was covered with a carpet of vegetation. At the same time a list of trees was made and seedlings raised in the nursery at the site. These trees were planted in the shallow pits approximately 30 cm x 30 cm and available organic matter was used to fill the pits. The pits were watered for a very short duration in the summer months. Soil working and mulching was done to encourage growth of plants.

Harnessing water resources within the quarry was also a critical area of work. Land contours are studied to divert rain water Shallow & big depressions. The lake (fig.3) formed by rain water was stoked with popular varieties of fish. III. Findings: Today the entire area has become a natural environment (Fig.4) with several varieties of insects etc. approximately 140 varieties of birds visit it every year.

**Result:** Today the entire area has become a natural environment (Fig.4) with several varieties of insects etc. approximately 140 varieties of birds visit it every year.

**Figure 4:** Rejuvenated site

**4.2: Restoration of the Indian Vulture Population by Green Science**

**Problem**

In the 1990s, more than 95% of India's vulture population perished due to the widespread use of the veterinary drug diclofenac, which induced fatal kidney failure in vultures consuming treated livestock carcasses.

**Green Science Solution:**

1. **Diclofenac Ban:** The Indian government prohibited the veterinary use of diclofenac in 2006.
2. **Vulture Breeding Centres:** Organizations like the Bombay Natural History Society (BNHS) and the Haryana Forest Department established breeding and conservation facilities, including the Jatayu Conservation Breeding Centre in Pinjore.
3. **Reintroduction Programs:** Captive-bred vultures were released into safe habitats with carefully monitored food sources devoid of diclofenac contamination.
4. **Ecological Innovations:** "Vulture restaurants" were created, comprising carcass dumps with safe food, ensuring vultures access uncontaminated sustenance.

**Impact:** Recent studies report population stabilization in several vulture species, including the white-rumped vulture and the slender-billed vulture, in northern and western India.

**4.3: Restoration of the Kashmiri Stag (Hangul) in Jammu & Kashmir**

**Problem:** The Hangul (*Cervus hanglu hanglu*), a critically endangered red deer subspecies native to Dachigam National Park and its surroundings, experienced a dramatic population decline due to habitat loss, poaching, and inbreeding, with fewer than 200 individuals recorded in the 2000s.


**Figure 5:** Vital statistics of the Kashmir Stag [Infographic Wildlife SOS/ Kewal Nawariya]

**Green Science Solution:**

1. **Habitat Restoration:** The Wildlife Department of Jammu & Kashmir implemented afforestation initiatives and removed invasive plant species, establishing corridors to reconnect fragmented habitats.
2. **Community Involvement:** Local communities were engaged in anti-poaching initiatives and incentivized to reduce livestock grazing in key Hangul habitats.
3. **Genetic Studies:** DNA fingerprinting and other green science technologies were utilized to monitor genetic diversity and design effective breeding programs.
4. **Technology in Monitoring:** Tools like camera traps, GIS mapping, and drones were deployed to monitor populations, detect threats, and protect critical habitats.

## 5.AI Tools

Automatic Species Identification: Image recognition using AI will be applied to track species from images taken with camera traps or drones. This would help track the size of populations and movements without disturbing them.

**5.1: Monitoring fish species**

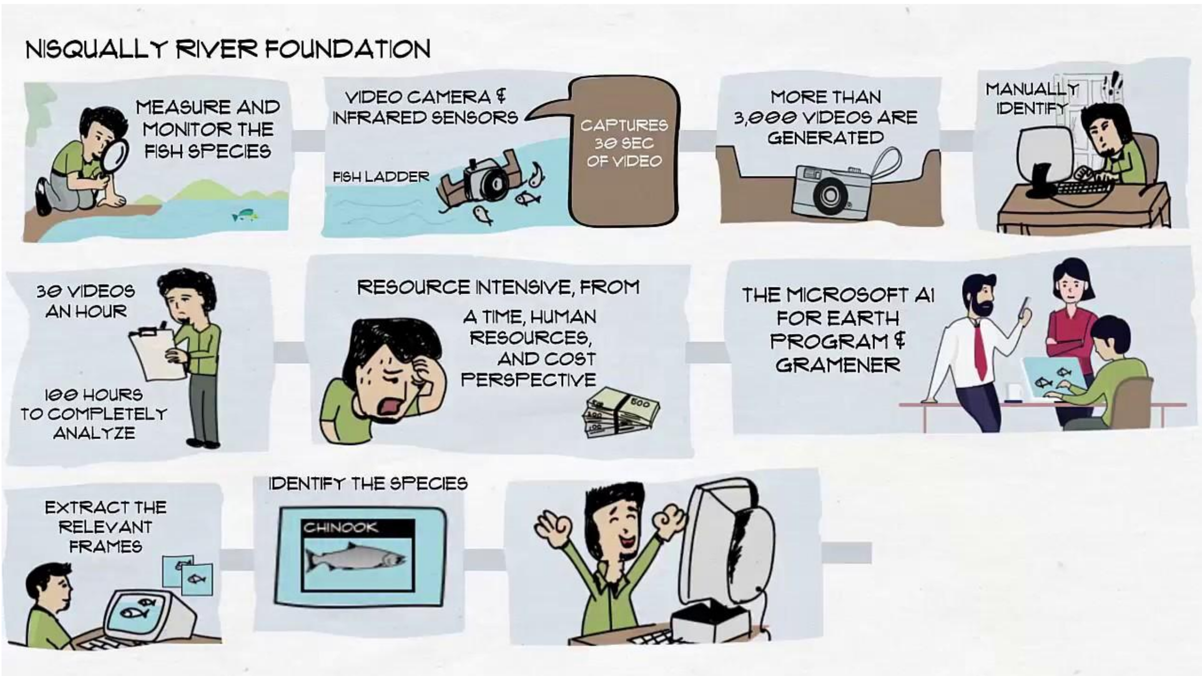


**Figure** "Nisqually River Foundation. " It illustrates the process and challenges of measuring and monitoring fish species in the Nisqually River. **Measure and Monitor the Fish Species**: An illustration of a person kneeling by the river.

**Methodology:**

1. **Video Camera & Infrared Sensors**: An illustration of a fish ladder with a camera capturing 30 seconds of video.
2. **More than 3, 000 Videos are Generated**: An illustration of a camera.
3. **Manually Identify**: An illustration of a person at a computer.
4. **30 Videos an Hour**: An illustration of a person holding a clipboard.
5. **100 Hours to Completely Analyze**: An illustration of a person with a clipboard.
6. **Resource Intensive, from a Time, Human Resources, and Cost Perspective**: An illustration of a person with money.
7. **The Microsoft AI for Earth Program & Gramener**: An illustration of three people discussing fish data.
8. **Extract the Relevant Frames**: An illustration of a person at a computer extracting frames.
9. **Identify the Species**: An illustration of a person identifying a Chinook fish on a computer.

### 5.2 Acoustic Monitoring

Set up AI for the analysis of audio recordings from forests and oceans to identify the presence of particular species, such as birds or marine mammals. This is very useful in monitoring shy or nocturnal animals.

### 5.3 Predictive Modeling

A method of applying concepts of machine learning to forecasts in biodiversity modifications for areas related to environmental data sets. This helps a conservationist take timely actions upon perceived threats targeting their site.

### 5.4 Habitat Mapping

It involves the use of satellite imagery and AI in mapping habitats in detail. This will help in the identification of critical areas for conservation and monitoring changes over time.

### 5.5 Anti-Poaching

AI systems can be implemented to analyze data from sensors and cameras in protected areas to detect and prevent illegal activities like poaching.

### 5.6 Citizen Science

Involvement of the general public in biodiversity monitoring using AI-powered applications would identify the species based on pictures clicked by the users themselves. This would amass considerable amounts of data from diverse locations.

### 5.7 Data Integration

Integrating disparate data from satellite imagery, camera traps, and citizen science into a unified view of biodiversity and ecosystem health using AI.

## 6.Conclusion

The use of technology in rejuvenation should be seen as force that can transform the work of researchers from across all fields interested in the protection of species. There is a serious need to understand the efficacy of both in situ and ex situ approaches to maximize their value for studying remaining populations. Furthermore, collaborations between ex situ and in situ communities can equally provide useful information, and for that reason, both approaches should be complementary rather than discordant

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