SYNTHETIC BIOLOGY IN CONSERVATION – ENVIRONMENT

NEWS: With global biodiversity facing critical threats due to habitat loss, climate change, and species extinction, the 2025 IUCN Congress debate over Motion 133 has brought synthetic biology's role in conservation science into sharp focus.

WHAT'S IN THE NEWS?

What is Synthetic Biology?

- **Definition and Scope**:
  Synthetic biology refers to the interdisciplinary field that combines biology, engineering, and information technology to **design and construct new biological parts, systems, or organisms**, or to **re-engineer existing biological systems** for useful purposes.
- **Relation to Genetic Technologies**:
  It involves advanced manipulation of **DNA, RNA, and proteins**, which are used to analyze, modify, or recreate biological structures and functions. These tools are essential for **biodiversity monitoring, conservation, and species recovery programs**.

II. Potential Benefits of Synthetic Biology in Biodiversity Conservation

- **1. Rescuing Endangered or Extinct Species**
  - Techniques like **CRISPR-Cas9** gene editing can correct harmful mutations in endangered species to improve their viability.
  - **De-extinction technologies** aim to resurrect extinct species (e.g., woolly mammoth, northern white rhino) by combining ancient DNA with genomes of closely related living species.
  - Can be used for **genetic rescue**, where individuals with low genetic diversity are supplemented with new alleles to increase adaptability and resilience.
- **2. Controlling Invasive Species and Disease Vectors**
  - **Gene drives** are synthetic tools that bias the inheritance of a particular gene, allowing rapid spread through populations. These can be used to suppress **invasive alien species** (e.g., rats, mosquitoes) that pose threats to native biodiversity.
  - For instance, genetically engineered **Aedes aegypti mosquitoes** have been released to reduce the spread of dengue, chikungunya, and Zika, demonstrating a model for ecological application.
- **3. Ecosystem Restoration and Environmental Stress Response**
  - **Engineered microbes or plants** can be deployed to restore degraded ecosystems. These organisms can break down pollutants, **fix nitrogen**, or improve soil fertility.
  - Synthetic biology could help ecosystems adapt to **climate change** by engineering species that tolerate heat, salinity, or drought.
- **4. Sustainable Biomanufacturing for Conservation**

    - Synthetic biology enables **biosynthesis of high-value wildlife products**, like **rhino horn substitutes**, **lab-grown ivory**, or **bear bile alternatives**.
    - This can help reduce illegal wildlife trade by offering **ethical and traceable alternatives**, thereby **lowering poaching pressure** on endangered species.
- **5. Monitoring Biodiversity Using Environmental DNA (eDNA)**
    - eDNA techniques detect species' presence in an ecosystem by analyzing fragments of genetic material shed in water, soil, or air.
    - Helps in **non-invasive monitoring** of endangered species, early detection of invasive species, and understanding **ecosystem dynamics** without the need for physical sightings or captures.

III. Challenges and Concerns

- **1. Ethical and Moral Dilemmas**
    - Concerns exist about the **ethics of cloning or de-extinction**, especially in cases where natural extinction was due to ecological or human pressures.
    - The idea of "playing God" by redesigning life raises philosophical and **bioethical debates**, especially when species are created or modified for human goals.
- **2. Risk of Genetic Homogenization**
    - Genetic rescue efforts may inadvertently **erase local adaptations** if genes are introduced from genetically distant populations.
    - This can **reduce long-term evolutionary fitness**, particularly in species adapted to unique ecological niches or microhabitats.
- **3. Regulatory and Legal Gaps**
    - There is a **lack of national and international frameworks** to govern the use of tools like CRISPR, gene drives, or synthetic organisms in wild ecosystems.
    - Disagreements among countries on how to classify and regulate these tools hamper **global conservation collaboration**.
- **4. Biosecurity and Data Sovereignty Issues**
    - Nations may be concerned about **biopiracy**, where genetic material from native species is used by foreign entities without permission or benefit-sharing.
    - Risks of **misuse** of genetic data include creation of harmful organisms or **biological weapons** through synthetic reconstruction.
- **5. Ecological Risks of Genetic Interventions**
    - Reintroduction of genetically altered or cloned species may result in **unexpected ecological consequences**.

- These species could develop **invasive traits**, outcompete native species, or disrupt existing **food webs and ecological balances**.

IV. Way Forward

- **1. Scientific and Ecological Rigor**
    - All applications of synthetic biology must be **evidence-based**, preceded by thorough **ecological impact assessments**, and subjected to **peer-reviewed scrutiny**.
- **2. Ethical and Community Involvement**
    - Engage **ethicists, indigenous communities, and the public** in decision-making, especially in areas where interventions may affect natural habitats or local livelihoods.
- **3. Robust Regulatory Frameworks**
    - Formulate **clear guidelines and standards** for the use of synthetic biology in conservation, ensuring alignment with **CBD (Convention on Biological Diversity)** and other global treaties.
- **4. Multidisciplinary and Precautionary Approach**
    - Encourage **collaboration across disciplines**—ecology, genetics, law, bioethics, sociology—to balance innovation with responsibility.
    - Adopt the **precautionary principle** to minimize unintended consequences.
- **5. International Cooperation and Capacity Building**
    - Promote **technology sharing, joint research**, and **capacity building** in developing countries to ensure equitable access and shared benefits.
    - Develop platforms for **transparent genetic data sharing** while respecting national sovereignty.

Source: https://www.downtoearth.org.in/science-technology/debate-over-synthetic-biology-in-conservation-divides-scientific-community-ahead-of-iucn-meet