A Swarm Robotics Approach to Rebuilding Natural Habitats

Master’s Project Exploration

# Problem Definition

* **Wildlife populations have plummeted by 73% in half a century** […] with habitat degradation and loss being the most reported threat to vertebrates, followed by overexploitation, invasive species and disease (Caton, 2024)
* The region that recorded the steepest decline was **Latin America and the Caribbean with a 95% decline**
* **Habitat loss** and degradation driven mainly by our food system was the most reported threat to wildlife
* As we rely on healthy ecosystems for clean water, food and carbon storage, these declines can significantly damage the benefits these environments provide for local communities
* An average decline of **61% across chinstrap penguin** colonies is thought to be linked to changes in sea ice and a shortage of krill
* **17% of Amazon forests have been wholly lost, and an additional 17% are degraded** (WWF, 2022) […] 47 million people live in the Amazon region and depend upon it for their livelihoods. This includes 2.2 million Indigenous peoples from more than 500 different groups
* The Amazon is home to a stunning array of the world’s species: 9% of mammals; 14% of birds; 8% of amphibians; 13% of freshwater fish species; and 22% of vascular plant species. Many of these species are found nowhere else in the world, and scientists estimate there are places in the Amazon where up to 90% of the species are yet to be discovered
* But man-made climate change means the **Arctic** has warmed over the past few decades – nearly **four times faster than the global average** <https://www.wwf.org.uk/where-we-work/arctic>
* Only 4.7% of the Arctic Ocean was protected as of 2016, highlighting the urgent need for conservation efforts
* Scientific estimates show **that 64 % of the world’s wetlands have disappeared** since 1900 […] 35% lost globally since 1970
* The global value of wetland ecosystem services for human health, wellbeing and security is estimated to be £35.5 trillion a year

## WWF Living Planet Report (2024)

* Globally, over half of GDP (55%) – or an estimated US$58 trillion – is moderately or highly dependent on nature and its services. Yet our current economic system values nature at close to zero, driving unsustainable natural resource exploitation, environmental degradation and climate change (Abdelli, et al., 2024)
* It is no exaggeration to say that what happens in the next five years will determine the future of life on Earth (Abdelli, et al., 2024)

### Tipping Points

* In the biosphere, the mass die-off of coral reefs would destroy fisheries and storm protection for hundreds of millions of people living on the coasts (Abdelli, et al., 2024)
* The Amazon rainforest tipping point would release tonnes of carbon into the atmosphere and disrupt weather patterns around the globe (Abdelli, et al., 2024)
* In ocean circulation, the collapse of the subpolar gyre, a circular current south of Greenland, would dramatically change weather patterns in Europe and North America (Abdelli, et al., 2024)
* In western North America, a combination of pine bark beetle infestation and more frequent and ferocious forest fires, both exacerbated by climate change, is pushing pine forests to a tipping point where they will be replaced by shrubland and grassland (Abdelli, et al., 2024)
* Although the Great Barrier Reef has shown remarkable resilience to date, we will likely lose 70–90% of all coral reefs globally, including the Great Barrier Reef, even if we are able to limit climate warming to 1.5°C (Abdelli, et al., 2024)

## Opportunity Areas

1. Rebuilding barrier marshes and planting marsh grasses can help restore wetland
   1. 40% of the world’s species live or breed in wetlands (RAMSAR, 2023)
   2. Specific types of wetlands, especially peatlands, mangroves, intertidal marshes and seagrass beds are exceptionally efficient carbon sinks (RAMSAR, 2023)
2. Burn control in forestry areas to prevent fires spreading
3. Establish wildlife corridors between fragmented forest ecosystems
4. Sustaining manageable grazing patterns
5. Protecting Sundarbans from coastal erosion (protect the Bengal Tiger)
   1. Four million people rely on the ecosystem services of the Sundarbans, with wild fisheries the second biggest employment source within the region (Gosh, 2020)
6. Coral reef protection (replanting healthy coral, building parks etc.)
   1. Cold water coral dendrite collection

<https://www.bbc.co.uk/news/business-66656369>

1. Drainage control in the tundra for minimising permafrost melting
   1. raising the surface [of the permafrost] delayed the runoff from the plot by up to eight days, and decreased the maximum daily drainage to 72% <https://www.sciencedirect.com/science/article/pii/S0165232X23001295>
2. Recontouring in the tundra following abandonment of decommissioned mining sites (bryophyte seedling transplantation)
3. Rehabilitating wetlands
   1. Ditches are usually dredged through wetlands to promote irrigation and move water. The dredged material is often piled along the edge of the ditch in piles, known as spoil banks. These can block sheet flow
   2. Reconnecting wetlands can improve biodiversity <https://www.fisheries.noaa.gov/feature-story/after-environmental-disasters-noaa-works-restore-habitat-all>
4. Resting platforms for polar bears

* Protecting endangered species – we can’t wait for large scale investment/change we need to implement a solution now, even if it is temporary

# Existing Measures

1. Rebuilding barrier marshes and planting marsh grasses can help restore wetland
   1. Romu Harvard robot is designed to implant steel sheets into the sand to protect from coastal erosion ([Romu](https://wyss.harvard.edu/media-post/romu-a-robot-for-environmental-protection/))
2. Burn control in forestry areas to prevent fires spreading
3. Establish wildlife corridors between fragmented forest ecosystems
4. Sustaining manageable grazing patterns
5. Protecting Sundarbans from coastal erosion (protect the Bengal Tiger)
6. Wildlife Corridors
   1. In the past four decades, insufficient land use planning led to the loss of 60% of elephant habitat in Sabah to large-scale plantation development

<https://www.worldwildlife.org/stories/why-connectivity-matters-to-wildlife-and-people>

1. Coral reef protection (replanting healthy coral, building parks etc.)
   1. Coral Maker: Using robotics to manufacture the living coral reefs by sticking ‘sprigs’ to blocks of limestone
   2. Researchers have discerned that by listening to coral reefs you can determine their health
   3. Coral clip is a little metal spring for securing healthy coral strips to rock facesDrop-Sphere monitoring deep sea habitats
   4. Larval bot disperses larvae on struggling reefs to accelerate growth <https://www.qut.edu.au/engage/giving/support-research/great-barrier-reef>

## Critical Analysis

### Wetlands

* <https://www.wwt.org.uk/our-work/threats-to-wetlands/>

### Rain Forests

### Coral Reefs

* The best measures seem to be in collecting samples from healthy coral plants, repotting them in nurseries and then fixing to degraded coral reefs
* It is not possible to build structures from materials available on the sea floor because you risk disrupting the ecosystem
* The space is highly saturated, but the problem is extremely pressing
* Two-thirds of reefs are threatened by algal overgrowth, reducing their resilience to environmental stressors

<https://www.ioes.ucla.edu/article/sea-urchins-help-tropical-coral-reefs-recover-study-finds/>

## Tundra

* Disturbed areas extend rapidly due to erosion, further reducing resilience. “Rain and wind wash away and spread the sand, and the roads and paths turn into deep gullies,” Yulia explained. “The disturbed area grows ever larger. Now you can see it from space.” <https://news.mongabay.com/2021/07/nine-principles-of-ecosystem-restoration-for-the-russian-tundra-commentary/>

## Key Opportunity Area

# Animals At Threat of Habitat Destruction

* Upon leaving their nesting beaches, most hawksbill hatchlings enter pelagic (open sea) habitat, where they take shelter in floating algal mats and drift lines of flotsam and jetsam for approximately 1 to 5 years. Eventually, juveniles migrate to shallower coastal feeding grounds, including their preferred coral reef habitats, where they mature to adulthood and spend the remainder of their lives

<https://www.fisheries.noaa.gov/species/hawksbill-turtle>

* The ledges and caves of coral reefs provide shelter for resting hawksbills during the day and at night. Hawksbills are also found around rock formations, high energy shoals (sand bars in shallow water), and estuaries that provide good habitat for sponge growth

# Case Study Identification

1. Rebuilding barrier marshes and planting marsh grasses can help restore wetland
   1. Chesapeake Bay Watershed (USA): This area has seen significant wetland loss due to agriculture and urban development. Restoration efforts aim to create or restore 85,000 acres of wetlands by 2025 to improve habitat quality and water filtration

## Economic Advantages

# Technology

* Robotics have several advantages compared with human labour when considering mass habitat restoration projects:
  + Ability to navigate and survive in extreme environments (icy tundra, arid deserts, deep forests etc.), contaminated sites (post-disaster zones, toxic waste etc.) and remote locations (deep underwater, mountain tops etc.)
  + Precision and accuracy
  + Cost effectiveness
  + Operating speed/efficiency
  + Data collection
  + Scalability
  + Customisation

# Potential Solutions

* Carving out new waterways in areas of diminishing water supplies (wetlands during times of drought)
* Attaching living coral supplements to underground rigs to accelerate reef reconstruction further
* Repurpose habitat structures for wildlife, such as deadwood piles that provide shelter for insects, small mammals, and birds. Robots could also use these materials to stabilize soil or create erosion barriers
* Moving living moss in the tundra to create effective wildlife corridors
* Robotic recontouring the tundra (returning the natural environment to original landscape to guide water flow)
* Sea urchin deployment to protect coral reefs

# Proposed Solution

# Finalised Project Brief

55% of the world’s GDP, an estimated US$58 trillion, is dependent on nature or its services, and yet over the last 50 years we have seen a 73% in wildlife populations. Entire ecosystems are collapsing, with massive ramifications for animal welfare and extinction, the climate and worldwide industry. Whilst this problem requires a massive effort to overcome, in the meantime we can leverage advances in robotics and AI to address isolated instances.

# Useful Links

[Towards new ecologies of automation: Robotics and the re-engineering of nature](https://www.sciencedirect.com/science/article/pii/S0016718523001513)

[Tundra Drainage](https://ess.science.energy.gov/highlight/new-model-rapidly-predicts-rates-of-soil-drainage-in-complex-tundra-landscapes/)

# Other Ideas

* Build underwater structures to replace the coral reefs for sapping energy from waves in tropical storms etc. – flood defence measures
* Artificial ice bergs
* Vertical cattle pasture lands

# Questions to Answer

* What is the best way to stop deforestation for building new cattle pasture