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Geospatial analysis of microplastics risk to endangered species

Every year, oceans are flooded with millions of tons of plastic, threatening marine ecosystems and species, especially affecting sea turtles, whales, and dolphins. They can accidentally eat and get tangled in the plastics, and over time, the plastics affect the wider ecosystem, including us.

Research Question: Does microplastic pollution influence how certain species travel or migrate?

For my innovation project, I'm creating an interactive map to view how animals, like blue whales, dolphins, and green sea turtles, move across the ocean, and whether microplastic pollution affects their migration. I wanted to find out if these animals adjust their routes or stay on their long-established paths, even as the growth of pollution increases.

I'm building a website that lets people explore real-life data from the past years, showing both plastic and animal migration. By layering these datasets on a map, judges can see how pollution overlaps with the migration paths and get a better picture of what's happening in the ocean. This website allows us to view data from the past year all the way back to 1970, showing where animals reside yearly, and gives us a zoom in and out function to observe the overlap between these species. Although we have the data individually on both marine animal and microplastics movement, there's no simple way to compare this data side by side. This tool can help researchers and conservation groups in understanding and visualizing the impacts of microplastic pollution on marine animals. The goal of this project is to fill in the gap by creating a website that is an interactive tool that visually compares these datasets. By viewing this complex information in a clear and understandable map, users and judges can visually notice the relationship between animals and plastics.

Animals migrate for multiple reasons, including food, breeding, and climate change. Pollution may affect the feeding and the survival of this species. I decided to focus on sea turtles, blue whales, and bottlenose dolphins.

Green sea turtles have one of the largest habitat ranges in the entire world, nesting in approximately 80 countries and travelling through the waters of 140 countries. Their migration patterns are very complex; adults typically migrate every 2-5 years from different shorelines back to the place where they initially hatched.

These migrations can reach from hundreds of thousands of kilometers across the entire ocean. Green sea turtles highly rely geomagnetic fields for navigation, using it as a GPS (global positioning system) to determine where in the ocean the turtle is, relative to the latitude and longitude, guiding them through the water, Since seawater conducts electricity, it interacts with the magnetic field, allowing turtles to sense the geomagnetic changes as they travel. Green turtles feed in globally significant areas such as the Great Barrier Reef, Shark Bay in Australia, the East China Sea, and the Red Sea. At the beginning of the sea turtle's life, hatchlings usually feed on drifting oceanic life, but as they grow older, their diet starts turning into a more herbivorous diet. Their breeding is very widespread and includes major sites like Tortuguero in Costa Rica, Colota Beach in Mexico, and Raine Island in Australia, along with many other locations through the Atlantic, Caribbean, and Florida. At the moment, sea turtles are listed as of least concern, but their population sizes are slowly decreasing. The reason I chose a turtle is that it is a well-known fact that turtles follow sea currents, which are the same currents plastic flows in. Therefore, turtles are especially vulnerable to microplastic pollution because they might resemble their natural food source, causing ingestion. Turtles may also accidentally consume plastics mixed with microplastics cause intestinal blockage, internal injuries, and increased mortality.

Bottlenose dolphins have a wide habitat range that includes coastal water, bays, and offshore regions, based on two regions. They generally fall into two groups: coastal (inshore) and offshore dolphins.

Coastal dolphins remain close to shore, usually within five miles of the coastlines, and are slimmer and usually reach up to 8 feet in length. They often hunt in seagrass and sandy coastal environments. Offshore dolphins are typically larger, reaching up to 14feet, weighing nearly 1,00 pounds. Their darker coloration and body structure allows them to live in colder environments. Offshore dolphins typically follow prey and may be either migratory or non-migratory. Non-migratory dolphins travel about 24 kilometers per day, while migrating dolphins can travel over 32 kilometers per day, with some exceeding 50 kilometers per day, depending on prey movement. Bottlenose dolphins feed primarily in estuaries, bays, and near-shore waters using specialized techniques. They do not have a single breeding area, and they reproduce across a much longer area. Although their conservation status is currently listed as least concern, dolphins can ingest microplastics directly or indirectly through prey, which may lead to internal injuries, chemical exposure, and starvation due to blockage.

Blue whales are the largest animals to have ever lived on earth, reaching up to a length of 30 metres(100 feet) and weighing as much as 180,000 kilograms (400,000 lbs). To put that into comparison, there tounge can weigh as much as an elephant, and their heart can weigh up to a small car. Even with their immense size and length, they still face significant threats from humans. They rely on tiny prey like krill for food, so even the smallest microplastics can affect them. Microplastics pollution, climate change, and shipping traffic can have serious impacts on their well-being.

To develop the project, I use several tools and technologies, which are:

- Python to clean, process, and merge a large dataset
- CSV and GeoJSON files store and display animal migration and species tracking data
- Global plastics pollution databases to generate plastic density heat map layers.
- Web-map-based mapping, using Leaflet, Mapbox, or Streamlit map for interactive visualization.

The main idea is to stack different layers on one map, like the migration routes and the plastic pollution. Seeing everything together makes it easier to compare the two and see how these factors affect each other.

Map layer includes:

1. Plastic pollution density (heat map)
2. species migration and sighting data (points and paths)

Currently, large datasets exist for both marine animal migration and plastic pollution, but these datasets are usually stored and analyzed separately.

- species tracking data exists as points,
- plastic pollution exists as density maps

There is no simple, visual way to view these datasets together in one place.

The purpose of this projects aim to close the gap by creating a website that helps users observe whether marine animals move through or avoid plastics.

Does plastic pollution change where these species travel?

Do they avoid areas with high pollution zones or pass through them?

To actually start this project, these are the necessary steps:

1. collect animal tracking and migration datasets
2. obtain global plastic pollution maps
3. clean the datasets to retain

- latitude
- longitude
- data
- species

4. Merge datasets into a single format

5. Export cleaned datasets into map-ready layers.

Steps to create the base map on the website include:

-> set up base map

-> add species tracking layer

-> add plastic heat map

-> add filtering tools

-> add pop-ups with simple species info

-> add legend + instructions

A comparison of our microplastic disturbance maps from 2005 to 2020 reveals a relationship between the spread of microplastic pollution and marine animal migration patterns. While the migration of marine animals such as blue whales, bottlenose dolphins, and green sea turtles remains relatively the same over time, the intensity of microplastic pollution has increased greatly over the years, leading to an overlap of these species' populations.

In 2005, microplastics seemed to be closer to the shoreline and less intense, primarily concentrated in oceans such as the North Pacific, the Indian Ocean, and parts of the Atlantic. During this time, many animal migration routes pass near or through these areas, but the overlap between these layers is not that much. This shows that even though marine animals were exposed to microplastics, the exposure was less.

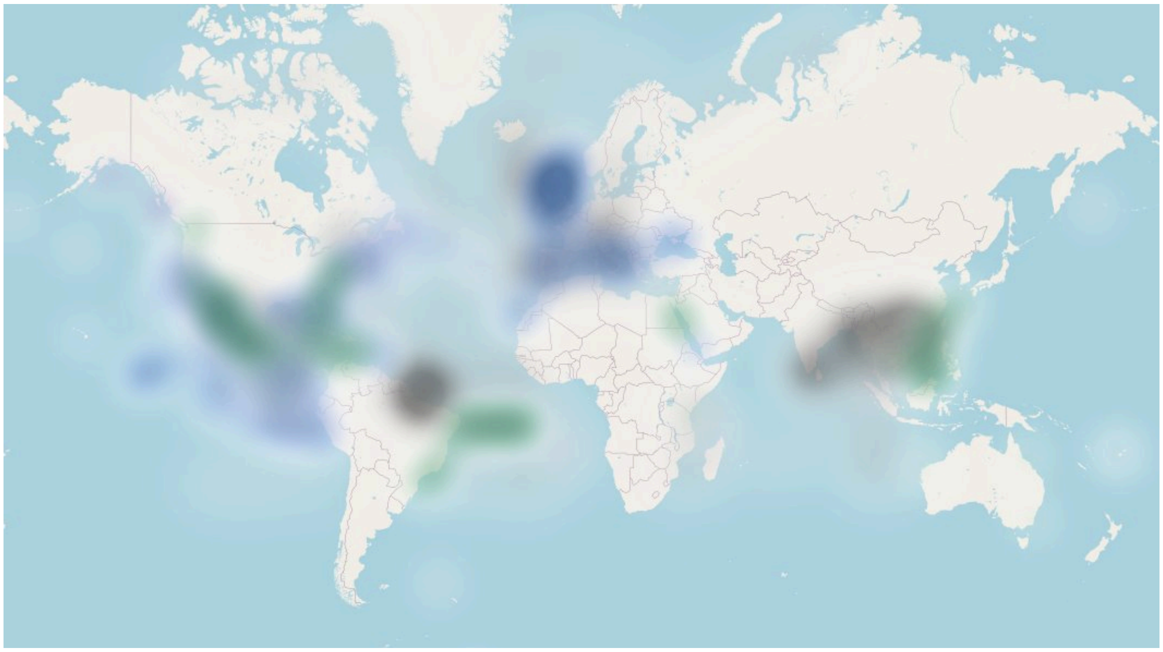
In 2020, the situation changed noticeably. Microplastic pollution became far more widespread and much more noticeable. These polluted areas expanded to regions that were less affected, include feeding grounds of these species.

This growing overlap is significant because marine animals don't seem to change there pattterns in response to the pollution. The species I researched relies on long establish pathway. As microplastics spread into these pathways, animals are more exposed to plastic particles through ingestion, respiration, and contact with contaminated water and prey. Over time, this can lead to something called bioaccumulation, where the plastics can start with a tiny fish and slowly but surely build up within a food chain, potentially affecting animals' health, reproducation and more.

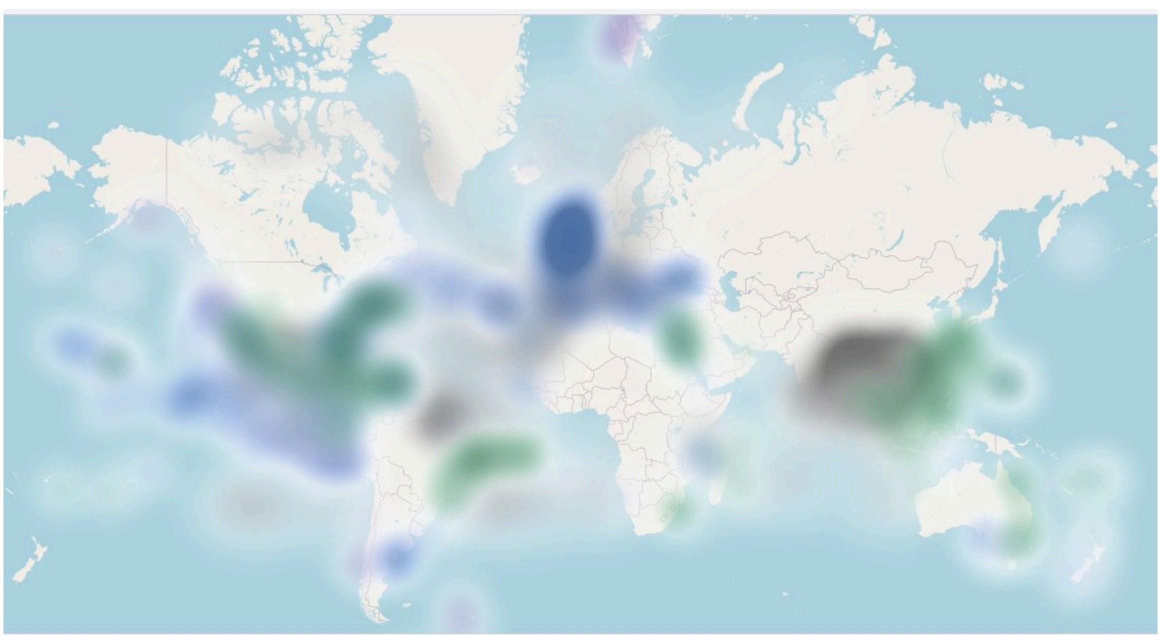
Maps show that regions with high human activity and major ocean currents have the greatest microplastic concentration. Ocean currents trap debris, piling it in more biologically important places.

Looking at the maps from 2005 to 2020, it's clear that microplastic pollution has grown faster than the oceans can absorb. Many migration routes of whales, dolphins, and turtles now cross the heavily polluted areas. These overlaps make it obvious that these animals are at high risr than we thought, and it highlights the need for better conservation.

2005 map: (blue= dolphins, purple = whales, green = sea turtles, gray= mircoplastics)



2020 map: (blue= dolphins, purple = whales, green = sea turtles, gray= mircoplastics)



In conclusion, the geospatial analysis of microplastics and marine animal migration shows that near this time period, plastic pollution is increasing rapidly and overlaps significantly with the pathways of these species (blue whale, bottlenose dolphins, and green sea turtle). Despite the growth of microplastics, these animals continue to follow the long-established migration paths, increasing their risk of exposure to microplastics. This overlap depicts the urgent need for more data analysis and visual information to inform conservation and policy decisions.