FROM NASA SATELLITES TO OCEAN DEPTHS.

FIN TRACK

NASA INTERNATIONAL SPACE APPS CHALLENGE

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CONTENT:

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Intro on Challenge:

The "Sharks from Space" challenge in the 2025 NASA Space Apps Challenge is a cutting edge exploration of how the latest space technology and data science can assist us in better being able to understand one of the planet's most intriguing but mysterious predators: sharks.

Even though the ocean is widely studied based on satellite data for tracking photosynthesis and health of ecosystems, tracking apex predators such as sharks is one of the most significant challenges in oceanography.

This project challenged scientists to go beyond the normal course of research by creating a mathematical model that would be able to identify sharks and predict where they feed from NASA satellite images. Essentially, the project is not only tracking where sharks are but developing a more enhanced knowledge of their habits, ecological role, and impact on the balance of marine ecosystems.

In addition, the challenge initiated the invention of a new conceptual tag model a small electronic device that could be attached to sharks to track their movement, feeding, and immediate activity. With such a device, in combination with satellite information, we could transform ocean predator research by transmitting instant vital information that would enable scientists to create predictive models and contribute to global conservation.

Last but not least, the "Sharks from Space" challenge embodies the intersection of space science, info tech, and sustainability, pushing us to think creatively about how technology can bridge the gap between the unknowns of the deep ocean and the tech of the times.

SHARKS RESEARCH:

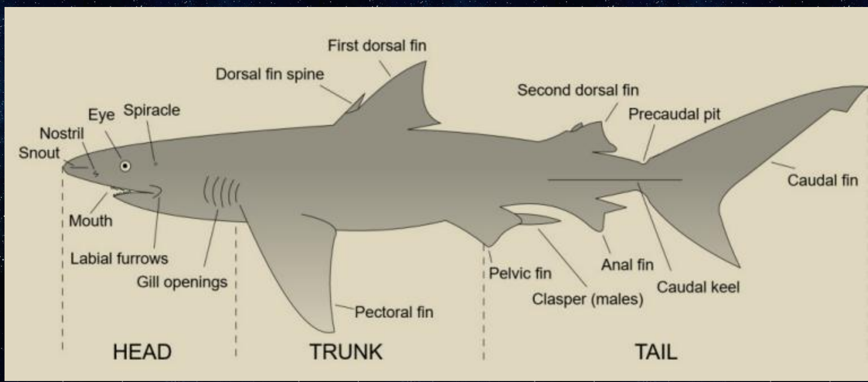
Orectolobiformes:

Traits:

• **43 Species**
• **8 Families** (Families have different genera inside of them)
• **Size Range:** Small to very large (from 25 cm to 12 m)
• **Body Shape:**

1. Generally broad, flattened heads with short snouts.
2. Many species are bottom-dwelling with mottled or camouflaged patterns.
3. Some have distinctive projections or lobes around their mouths (e.g., wobbegongs).

• **Fins and Gills:**



o Two dorsal fins (without spines).
o Have **anal Fin**
o 5 gill slits, with the last 2 often located in front of pectoral fins.

• .**Reproductive Method:**
They reproduce through different strategies depending on the family; some, like bamboo sharks, are oviparous and lay eggs, while others, such as nurse sharks and whale sharks, are ovoviviparous or viviparous, giving birth to live young.

Movement:
Most of them are slow swimmers, adapted to ambush or filter-feeding. Their tails are generally not crescent-shaped, reflecting their benthic or slow cruising habits. The whale shark is a strong but gentle swimmer, capable of long-distance migrations.

ood Sources:

• Mostly carnivorous, though diet depends on family:

1. **Benthic species** (like wobbegongs, bamboo sharks): feed on Ʊsh, crustaceans, and mollusks.
2. **Pelagic species** (like whale shark): filter-feed on plankton, small Ʊsh, and krill.
3. Nurse sharks: suck prey from crevices using strong suction feeding.

Habitats:

• Distributed mainly in **tropical and warm temperate waters**.

1. Wobbegongs: demersal, found in shallow coral reefs and rocky seabeds of the Indo-Pacific.
2. Bamboo sharks: shallow coastal waters, often among reefs.
3. Nurse sharks: tropical Atlantic and eastern PaciƱc, resting on sandy bottoms and reefs.
4. Whale shark: open tropical oceans, migrates thousands of kilometers across pelagic zones.

Reasons for Choosing Habitat:

• **CamouƲage and feeding strategy:** Benthic species rely on blending with reef or seabed environments for ambush.
• **Food availability:** Coral reefs provide abundant Ʊsh, crustaceans, and cephalopods. Whale sharks follow plankton blooms.
• **Temperature tolerance:** Adapted to warm seas; not common in cold or deep polar regions
• **Reproductive safety:** Reef crevices and shallow lagoons provide protected areas for eggs and pups.

Carcharhiniformes (Ground Sharks):

Carcharhiniformes, also known as *ground sharks*, represent the largest order of living sharks. They include more than 270 species that inhabit oceans worldwide. This order contains many of the most familiar shark species, such as tiger sharks, bull sharks, blue sharks, blacktip reef sharks, and hammerhead sharks.

Distinctive Features

Nictitating membrane: A protective third eyelid covering the eyes when attacking prey.
Two dorsal fins: Both without spines.
Anal fin: Present, unlike some other shark groups.
Five gill slits: Standard for most modern sharks.
Elongated snout: Often with grooves connected to the nostrils.
Teeth diversity: Some species have serrated cutting teeth, while others have long slender teeth for grasping.

Size and Diversity

Smallest: Catsharks (Scyliorhinidae) measuring about 30 cm
Largest: Tiger sharks (Galeocerdo cuvier) reaching up to 5 meters
Total: Over 270 species across several families

Habitats:

Found in all oceans worldwide
Occupy habitats ranging from shallow coastal areas to the open ocean
Some species, like the bull shark, can live in freshwater rivers and lakes

Families within Carcharhiniformes

Carcharhinidae – Requiem sharks (Tiger shark, Bull shark, Blue shark).
Scyliorhinidae – Catsharks (small, bottom-dwelling).
Triakidae – Houndsharks.
Hemigaleidae – Weasel sharks.
Proscylliidae – Finback catsharks.
Sphyrnidae – Hammerhead sharks

Ecological Role:

Ground sharks are apex predators or mesopredators, regulating populations of fish and other marine organisms, thus maintaining ecosystem balance

Reproduction:

Mostly viviparous (give birth to live young), but some are oviparous (egg-laying).
Litter size varies greatly, from a few pups to dozens.

Examples of Famous Species:

Tiger shark (Galeocerdo cuvier) – Large, aggressive predator.
Bull shark (Carcharhinus leucas) – Can live in freshwater.
Blue shark (Prionace glauca) – Known for speed and wide distribution.
Hammerhead sharks (Sphyrna spp.) – Characterized by their hammer-shaped head

Hexanchiformes (Frilled & Cow Sharks):

Hexanchiformes is a small and primitive order of sharks, often called frilled sharks and cow sharks. Unlike most modern sharks, which have five gill slits, members of this order usually have six or seven gill slits, making them unique among living sharks. They are considered some of the most ancient surviving shark lineages, with fossil records dating back to the Jurassic period (over 170 million years ago).

Distinctive Features

Six or seven gill slits (instead of the usual five).
Elongated, eel-like body (especially in frilled sharks).
Single dorsal fin, located far back.
No nictitating membrane (unlike ground sharks).
Long jaws with many needle-like teeth adapted for gripping slippery prey.
Primitive skeletal and muscular structures compared to modern sharks.

Size and Diversity

The order includes only a few species (around 6 recognized species).
Frilled shark (Chlamydoselachus anguineus) can reach 2 m.
Bluntnose sixgill shark (Hexanchus griseus) can reach up to 5.5 m, making it the largest in the order.

Habitats

Found mostly in deep waters (200 – 2000 meters depth).
Distributed in temperate and tropical oceans worldwide.
Rarely seen by humans because they live in deep-sea environments.

Families within Hexanchiformes

1. Chlamydoselachidae – Frilled sharks (Chlamydoselachus anguineus).
2. Hexanchidae – Cow sharks (Sixgill and Sevengill sharks).

Ecological Role

Ground sharks are apex or mesopredators in deep-sea ecosystems. They feed on fish, squid, other sharks, and carrion. They are important for maintaining population balance in deep-sea food chains.

Reproduction

Most are ovoviviparous: embryos develop inside eggs within the mother’s body and hatch before birth. Frilled shark has one of the longest gestation periods in vertebrates up to 3.5 years.

Examples of Famous Species

Frilled shark (Chlamydoselachus anguineus) – 'Living fossil' with eel-like body.
Bluntnose sixgill shark (Hexanchus griseus) – Large deep-sea predator.
Broadnose sevengill shark (Notorynchus cepedianus) – Unique with seven gill slits.

Squatiniformes :

Traits:
• 23 Species
• 1 Genera (Genera has different species inside of it)
• 1 Families (Families has different genera inside of them)
• Size range: mostly small to medium size (80 cm to 2.4 m)
• Body Shape:
1. flat, ray-like body with broad pectoral and pelvic fins
2. eyes and spiracles on top of the head
3. large mouth positioned forward for ambush strikes
4. two small dorsal fins near the tail, no anal fin
5. camouflaged with sandy or mottled patterns to blend with the seafloor
• Have 2 small dorsal fins near the tail
• no anal fins
• 5 gill slits
• Reproductive method: Ovoviviparous (eggs are laid inside the mother and hatch there then are live birthed)

Movement:
• Mostly sedentary, lie buried in sand or mud
• Use pectoral and pelvic fins to shuffle and bury themselves
• Sudden explosive strike when prey comes close, using powerful suction feeding
• Swim with slow, undulating movements of body and tail when relocating

Food Sources:
• Mostly Carnivores Predators
• prey includes:
1. Bony fish (cod, herring, lanternfish, grenadiers)
2. Squids and octopuses
3. Crustaceans (shrimp, crabs)

Habitats:

• Sandy or muddy bottoms of continental shelves and slopes, shallow coastal to 1,300 m, mostly temperate and tropical seas.

Reason For Choosing Habitat:

• Sandy or muddy bottoms provide camouflage for ambush hunting
• Shallow coastal and continental shelf zones have high prey density (fish, crustaceans, cephalopods)
• Soft substrates allow easy burial for concealment and protection from predators
• Moderate depths (0–1,300 m) give stable conditions for feeding and reproduction

Squaliformes :

Traits:
• 125 Species
• 27 Genera (Genera has different species inside of it)
• 7 Families (Families has different genera inside of them)
• Size range: mostly small to medium size (20 cm to 6 m)
• Body Shape:
1. Slender to stout, depending on family
2. many are deep-sea adapted: softer bodies, larger livers for buoyancy, slower swimming
3. **head shape** varies:

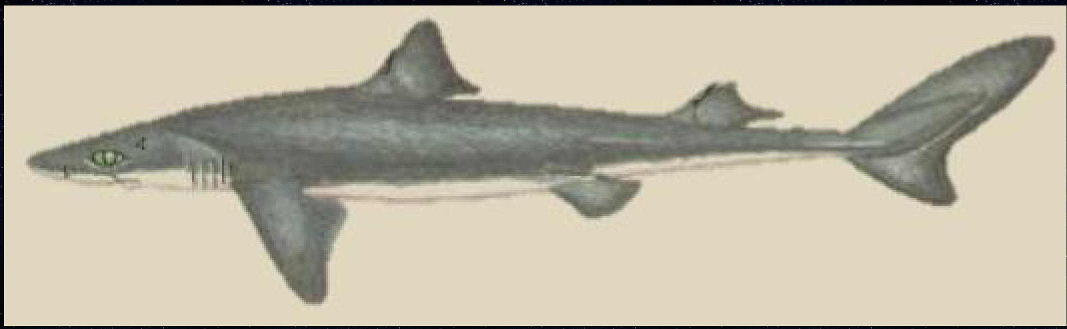
a. Squalus (spiny dogfish): pointed snout, slim body

b. Somniosus (sleeper/Greenland shark): bulky, large body, blunt snout

c. Oxynotus (rough sharks): compressed, triangular body, humpbacked

d. Isistius (cookiecutter): small, cigar-shaped body

• Have 2 dorsal fins with spine infront of them
• no anal fins
• 5 gill slits except Hexanchiformes which have 6 to 7
• Reproductive method: Ovoviviparous (eggs are laid inside the mother and hatch there then are live birthed)



Movement:

• Built for slow speeds
• tails are less crescent-shaped, suited for steady cruising in deep or cold waters

Food Sources:

• Mostly Carnivores Predators
• prey includes:

1. Bony fish (cod, herring, lanternfish, grenadiers)
2. Squids and octopuses
3. Crustaceans (shrimp, crabs)
4. Sometimes carrion (dead whales, large fish)

• **Cookie Cutter Shark** (Isistius) is unique: it takes circular bites out of whales, dolphins, and even submarines.

Habitats:

• Most species live in **deep-sea habitats** (200–2,000 m), but some live in coastal zones
1. Spiny Dogfish: found in temperate shallow waters and continental shelves
2. Greenland Shark: Arctic and sub-Arctic, one of the only sharks adapted to near-freezing waters
3. Sleeper Sharks: deep, cold Arctic and temperate seas, 200 m to 2,000+ m.
4. Cookie Cutter Sharks: tropical and subtropical oceans, 85–3,500 m, migrate nightly to the surface.

Reason For Choosing Habitat:

• Food availability (schools of midwater fish, deep-sea cephalopods)
• Temperature tolerance:
1. Greenland shark survives at –1 to 10°C
2. others prefer temperate deep waters
• Reproductive safety: deep waters are safer for slow-growing pups
• Some species (spiny dogfish) form large schools for migration and hunting

Heterodontiformes :

There are nine recognized species of Heterodontiformes, the most significant species are:

- Port Jackson shark (Heterodontus portusjacksoni): found in southern Australia.
- Horn shark (Heterodontus francisci): Native to the eastern Pacific (California to the Gulf of California), well-known for its specialized diet and nocturnal habits

Heterodontiformes (bullhead sharks) have different types of teeth in their jaws.

• The front (mesial) teeth are small and pointed for grasping soft prey.
• The back (distal) teeth are large and molar-like, adapted for crushing hard-shelled prey such as mollusks and crustaceans.

Body Structure:

They have a robust body, a blunt head with prominent ridges above the eyes, and two dorsal fins, each with a spine.
The pectoral fins are large, and the pelvic fins are set further back compared to some related groups.Size range: from about 60 cm to 165 cm in adult length, with
most species under 1.5 meters.

Reproduction:

Oviparity (Egg-Laying): Females lay eggs in protected crevices, and the young emerge after a long incubation period.
Egg Cases: Heterodontiformes lay distinctive spiral-shaped egg cases, often with tendrils or flanges, which are unique among sharks.

Main Prey and Food Sources:

Heterodontiformes sharks primarily feed on hard-shelled invertebrates

Prey: The horn shark (Heterodontus francisci), mainly consumes anomurans (a group of crustaceans), which make up about 66% of its diet.

Other Important Prey:
- Cephalopods (such as octopuses) (7.2%)
- lobsters (4.7%)
- Fish (4.2%), and sea urchins (2.3%) are also part of the diet, though in much smaller proportions.

(The horn shark is considered a specialist predator with a narrow trophic niche, focusing on a few key prey types rather than a wide variety)

Feeding Mechanisms:

These sharks use a combination of suction and crushing to capture and process prey. They can generate strong suction to extract prey from crevices and use their molariform teeth to break hard shells.

(Their diet reflects their benthic (bottom-dwelling) habitat, where hard-shelled invertebrates are abundant and accessible)

Movement Patterns and Strategies:

- Nocturnal Activity: Heterodontiformes are primarily active at night. During the day, they rest in shelters like caves or crevices, emerging after sunset to forage

- Area-Restricted Search (ARS): These sharks use an area restricted search strategy, traveling between multiple reefs at night to locate dense patches of prey. They spend extended periods in specific areas where food is abundant

- Movement Range: Individuals traverse a range of depths (2–112 m) and temperatures (10–24°C) during nightly movements.

- Site Fidelity: Both horn sharks and Port Jackson sharks show strong preferences for particular reefs, often returning to the same sites across nights and seasons. Males tend to be more site-attached, while females may roam more, especially during breeding seasons

- Some Heterodontiformes sharks, especially the Port Jackson shark, do migrate seasonally, often returning to the same sites each year.

Habitats:

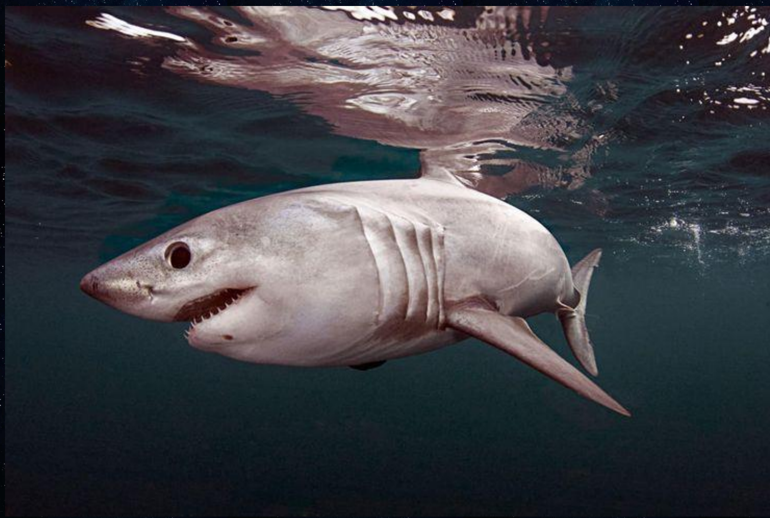
- Shallow Reefs and Rocky Substrates: These habitats provide abundant crevices, caves, and fissures.
- Modern species are distributed mainly in warm-temperate to tropical regions of the Pacific and Indian Oceans

Reasons for Habitat Selection:

- Shelter and Protection: The abundance of caves and crevices in rocky reefs offers daytime refuge from predators and strong currents.
- Breeding and Egg Deposition: Females lay eggs in rock fissures or crevices, which protect the auger-shaped egg cases from predators and environmental hazards.

- Food Availability: These habitats are rich in benthic invertebrates (e.g., crustaceans, mollusks, sea urchins), which are the primary food sources for Heterodontiformes.

Lamniforms:



Traits:

• 15 Species
• 10 Genera (Genera has different species inside of it)
• Size range: (sand tiger shark ~3 m to basking shark ~12 m)
• Body Shape: Fusiform for speed
• Have 2 dorsal fins, 1 anal fin and 5 gill slits
• Reproductive method: Ovoviviparous (eggs are laid inside the mother and hatch
there then are live birthed)

Movement:

• Streamlined bodies built for long-distance travel and bursts of speed
• Species like shortfin mako are among the fastest sharks (up to 70 km/h)
• Powerful crescent-shaped tails (heterocercal caudal fin) for propulsion

Food Sources:

• Mostly Carnivores Predators
1. Great White Sharks: seals, sea lions, dolphins, large fish and carrion (a type of birds)
2.Shortfin Mako: tuna, swordfish and squid
3.Sand Tiger Shark: bony fish, rays and smaller sharks
4.Goblin Shark: deep sea fish, squid and crustaceans (Shrimp, Lobster, Crab and Cray Fish)
5.Basking Shark: plankton and small fish

• Hunting Methods:
1-great while shark:ambush
2.Makos: Pursuit
3.Basking: Filter Feeding

Habitats:

• wide distribution, found in both deep and shallow oceans
• prefer temperate and tropical waters

1. Great Whites: coastal and offshore
2. Makos: open ocean, pelagic zones
3. Goblin Sharks: deep sea, below 100 m up to 1,200 m
4. Basking Sharks: temperate coastal waters, often near plankton blooms

Reason For Choosing Habitat:

• prey concentration
• temperature tolerance and partial warm-bloodedness, ex:

1. great white shark (Carcharodon carcharias)
2.shortfin mako shark (Isurus oxyrinchus)
3.longfin mako shark (Isurus paucus)
4.salmon shark (Lamna ditropis)
5.porbeagle shark (Lamna nasus)

• reproductive needs: sand tigers often stay near shallow coastal regions for pupping
• migration: many lamniforms travel huge distances (basking sharks migrate seasonally following plankton)

Other solution:

Existing Solutions for Tracking and Understanding Sharks

1-SPOT Tags (Smart Position and Temperature Transmitting Tags)

Technique:

Installed on the dorsal fin of the shark and works with satellites (Argos system). Whenever the shark ascends to the surface, the crown sends a signal of its location and water temperature.

Data you collect:

• Geographical location with high accuracy.
•Surface temperature.
•Patterns of movement and migration.

Features:

•Availability of almost instant data.
•Can be used for years.
•Very accurate in location tracking.

Defects:

• It only works when the shark goes up to the surface.
•Do not provide data from large depths.

Actual use:

It is used by global projects such as OCEARCH Global Shark Tracker, which displays shark locations directly on an interactive map for the public and scientists.

2-PSAT Tags (Pop-up Satellite Archive Tags:)

Technique:
Installed on the shark for a specific period, storing depth, temperature, and level of light data. After a while, it separates and floats to the surface to send the data to the satellites.

Data you collect:
•Depth.
•Temperature.
•Diving patterns.
•Approximate location.

Features:
•Work even with sharks that do not go up to the surface.
•It gives a three-dimensional perception of diving behavior.

Defects:
•Don't send data in real time.
• You can check some data if the crown is not extinguished or damaged.

Actual use:
It is used in the research of deep-diving sharks, such as the mako and the Tiger, to understand their movements in the depths.

3-Acoustic Telemetry Systems

Technique:
It relies on sound waves sent from a shark-mounted crown and picked up by underwater receivers.

Data you collect:
• Location within specific areas (such as beaches or reserves).
• The length of time the shark spends in each region.

Features:
•Very accurate in small areas.
•Useful for the study of local behavior and interaction with the environment.

Defects:
•Cannot be used in the open environment (need a receiver network).
•Do not send data via satellites.

Actual use:
It is used by Ocean Tracking Network (OTN) and Australian Integrated Marine Observing System (IMOS).

4-Drone & AI Detection Systems (like SharkEye):

Technique:
Drones equipped with high-resolution cameras and artificial intelligence programs that recognize the shape of a shark from aerial images and videos.

Data you collect:
• Instant location.
•The number of sharks near the beach.
•Surrounding environmental conditions.

Features:
•Ideal for coastal monitoring and human protection.
•Quick to discover sharks in real time.
•Do not require devices on the shark itself.

Defects:
•Limited by the area covered by the drone.
• Ineffective in the depths or in turky water.

Actual use:
Project SharkEye (California) and Airsight (Australia) use it to protect the beaches.

5-AUVs (Autonomous Underwater Vehicles) – such as REMUS SharkCam:

Technique:
Underwater robots equipped with cameras and sensors that track the signals of the shark-mounted crown to photograph and observe its behavior.

Data you collect:
•Live underwater video.
• Shark behavior while fishing or diving.
•Interact with other sharks.

Features:
•Provides rare visual data from the depths.
•It reveals normal behavior in its true environment.

Defects:
•Very expensive.
•You need prior planning and knowledge of the initial location of the shark.

Actual use:
REMUS SharkCam project from the Woods Hole Oceanographic Institution.

6-Automated Video & Image Analysis (e.g. SharkTrack, Sharkbook)

Technique:
Software that uses artificial intelligence and CNN networks to analyze videos and photos and automatically identify and track sharks.

Data you collect:
•Identify the types of sharks from photos.

•Track individuals by unique signs.
• Control the distribution and number.

Features:
• Reduces time and effort in video analysis.
•Can be combined with drones or divers cameras.
•You don't need devices on sharks.

Defects:
•It depends on the quality of the images and lighting.
•You need extensive training for artificial intelligence.

Actual use:
Projects such as SharkTrack (AI tracking) and Sharkbook (photo identification).

7-Enhanced Biologging Tags (Low-stress attachment systems)

Technique:
Crown-optimized fixing systems using soft materials and comfortable clamps to reduce stress on the shark.

Data you collect:
It depends on the type of crown, but it aims to increase the traceability period with higher accuracy without harm.

Features:
• Safer for animals.
• Higher long-term accuracy.

Defects:
• It's still experimental and expensive.

8-NASA Ocean Data Modeling

Technique:

Analysis of satellite data (e.g. PACE, MODIS, and AQUA) to monitor temperatures, chlorophyl, and ocean color to predict shark feed areas.

Data you collect:

• Water temperature.
• Phytoplankton.
• Biological production areas.

Features:

•You don't need to install devices.
•It gives a comprehensive environmental perception.

Defects:

• Don't provide individual fish locations.
• It needs to be combined with other data from crowns or direct sensing.

OUR TECHNOLOGIES:

‘The FinTrack system represents a complete technical and analytical framework designed for advanced wildlife monitoring. Project development was preceded by essential strategic analysis, including the application of SWOT and PACE methodologies, to ensure project viability and address potential implementation challenges. The core data acquisition component, centered on the ESP module, operates as a robust, cost-effective field device. Critical to its functionality is the integration of an accelerometer and gyroscope. These inertial sensors are calibrated to detect signature feeding events by analyzing characteristic movement patterns and vibrations. This high-resolution temporal data, when combined with precise GPS location, is then cross-referenced against a curated marine species database to accurately infer the consumed prey species, thus establishing a detailed dietary profile. This rich, multi-sensor dataset is subsequently utilized by a dedicated Python-based predictive model. This model employs machine learning to analyze historical patterns, enabling the forecasting of future migratory paths and generating alerts for notable deviations. Ultimately, FinTrack serves as an integrated solution that translates raw sensor data into actionable ecological intelligence necessary for informed conservation strategies.

CONCULSION:

The “Sharks from Space” challenge represents a groundbreaking step toward understanding the hidden lives of one of Earth’s most powerful predators through space-based innovation. By integrating satellite remote sensing, AI-driven behavioral modeling, and real-time data collection, our project bridges the gap between marine biology and space technology. Traditional shark tracking techniques often focus only on movement or location, but our conceptual system goes further — it decodes behavior, identifies feeding events, and predicts potential prey types using environmental and sensor-based data.

This approach not only enhances marine research but also supports ocean conservation by providing scientists with continuous, non-invasive, and high-resolution data on shark activity and ecosystem dynamics. The fusion of technology and biology opens new possibilities for protecting marine life, maintaining ecological balance, and deepening our understanding of the ocean from a truly global — even extraterrestrial — perspective.

In essence, this project embodies the spirit of NASA’s mission: using innovation beyond our planet to better understand and protect life within it.

OUR SOURCES:

PACE: https://pace.gsfc.nasa.gov/
Usage: We used PACE to find the sustainability of the current locations of our tracked sharks and to predict the future locations of the sharks after the yearly migration

SWOT: https://podaac.jpl.nasa.gov/SWOT
Usage: We used SWOT to predict the next location of the shark and analyze the current location depending on the depth of the shark, each shark needs a different depth in order to find there food sources

MODIS: https://modis.gsfc.nasa.gov/data/
Usage: We used MODIS to find if the location is of the shark is actually in a marine body or on land due to an error in the gps tracker or the shark has been injured and drifted to a beach

Eddies: https://www.pnas.org/doi/abs/10.1073/pnas.1903067116
https://www.nature.com/articles/s41598-018-25565-8
Usage: We used Eddies to find the perfect location for the shark after migration according to the temperature of the ocean at the predicted depth and to follow positive temperature anomalies