IEEE Tunisia Section

IEEE Tunisia Section Student Activities Committee

TSYP13

IEEE TEMS/SSIT TUNISIA JOINT CHAPTER

IEEE SIGHT Special Interest Group on Humanitarian Technology IEEE Tunisia Section SIGHT

TECHNICAL CHALLENGE REPORT

IEEE TEMS Technology & Engineering Management Society

IEEE SSIT Society on Social Implications of Technology

IEEE TEMS/SSIT TUNISIA JOINT CHAPTER

IEEE SIGHT

SPECIAL INTEREST GROUP ON HUMANITARIAN TECHNOLOGY

IEEE Tunisia Section SIGHT

First Phase Submission

Prepared for:

TSYP 13 CHALLENGE

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Problem Statement

No Eyes. No Data. No Safety.

The ocean covers more than 70% of our planet, yet we have explored less than **5% of it**. Beneath the surface, changes happen silently, species migrate, habitats shift, and threats appear long before anyone notices. In the Mediterranean, this hidden crisis is **accelerating**. **Climate change**, **pollution**, and invasive species are transforming **ecosystems** faster than researchers can track them.

Over **900 non-native species** have already entered the Mediterranean, and Tunisia alone has recorded **more than 200 exotic species**, some of them toxic or aggressive. In certain regions, invasive crabs now represent up to **70%** of the catch, while harmful fish and algae pose real risks to public health and local fishermen. Without continuous monitoring, these dangers remain **invisible, leaving communities vulnerable.**

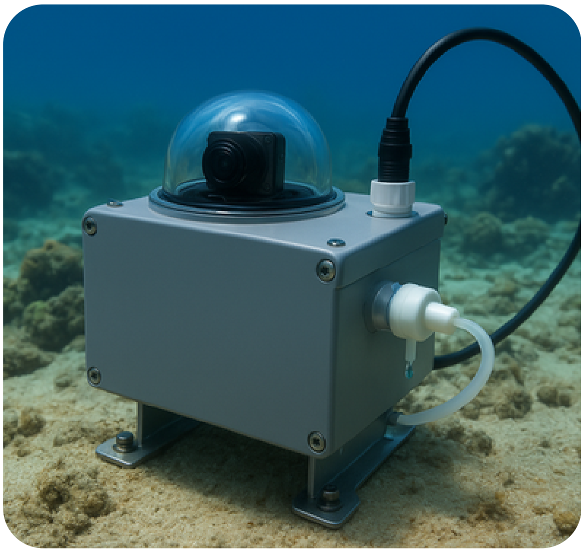
200+ Exotic species in Tunisia's waters, many undetected

No continuous marine surveillance = no alerts for fishers or public

ECO lack of a continuous, affordable system to track ecosystem changes.

SOLUTION: AQUA SENTINEL

An Autonomous AI-Powered Underwater Monitoring System



A fully **autonomous** underwater station that continuously observes marine life **using AI**, **sensors**, and **smart power management**, all connected to a surface solar buoy for long-term operation.

How It Works

Underwater Observation Unit
- High-resolution waterproof camera
- Bait dispenser for species attraction
- Environmental sensors (temp, turbidity, salinity)
- Pressure-resistant enclosure

AI Detection & Classification
- YOLOv11-based species recognition
- Tracks abundance, diversity, and invasive species
- Works locally with ultra-low-power processing

Solar-Powered Surface Buoy
- A floating solar panel powers the system
- A waterproof high-speed Ethernet cable connects the buoy to the underwater unit
- Stores data + sends it to the cloud during sync intervals

MarineGuard Application
- Displays species logs, alerts, and trends
- Visual dashboards for researchers, NGOs, and fishers
- Sends notifications about toxic/invasive species

Project Mission

To enable continuous, intelligent, and inclusive monitoring of marine ecosystems through affordable AI technology, empowering coastal communities, researchers, and policymakers to protect the ocean sustainably.

Project Vision

A future where oceans are no longer mysterious or vulnerable, where every coastline has access to real-time environmental intelligence that preserves biodiversity, supports sustainable fishing, and builds harmony between humanity and the sea.

Project Values

- **Sustainability**: Designing technology that respects and protects marine ecosystems.
- **Scientific Integrity:** Ensuring data accuracy, transparency, and credibility in every analysis.
- **Community Empowerment**: Making information accessible to all, from fishers to researchers.
- **Innovation**: automated Bruvs, Merging AI, renewable energy, and design to create practical environmental solutions.
- **Transparency & Equity:** Promoting open access to knowledge for shared responsibility in ocean preservation.

Risk mitigation

Category	Risk	Solution
Technical	Corrosion, biofouling, low light, power outages	Use of marine-grade materials, anti-fouling coatings, low-light cameras, solar power + backup battery
Operational	Storms, device displacement, loss or breakage	Secure anchoring, retrieval GPS, selection of protected deployment areas
AI & Data	Classification errors or lack of data	Gradual improvement of the model through new videos (active learning)
Social & Community	Distrust or misunderstanding by local fishers	Clear communication + free access to local data + involvement of communities in installation

SWOT

SWOT Analysis

STRENGTHS

- Fully autonomous system
- Modular & scalable
- High-value scientific insight

WEAKNESSES

- Environmental challenges
- Limited underwater mobility
- Periodic maintenance required

OPPORTUNITIES

- Collaboration with NGOs
- Tourism & aquaculture needs
- Data monetization
- Early detection of threats

THREATS

- Harsh marine conditions
- Low-Cost Market Competition
- Varying regulatory requirements across countries

PESTEL

P E S T E L

Politics

- Supportive Tunisian marine conservation policies.

Economy

- Growing eco-tech investment opportunities.

Society

- Increased awareness of marine protection.
- Ensuring Harmless Sea Creatures (Food, Health

Technology

- dvances in IoT, AI, and solar energy.

Environment

- Rising marine pollution and invasive species.
- Decreasing Biodiversity loss

Law

- Compliance with marine data protection and ethical research.

Market Segmentation

Client Segment	Their Identity	Their Problems	Why They Would Pay
Fisheries Authorities & Marine Surveillance Agencies **Purchase estimate:** **+10** units/ Agencie	Government departments responsible for regulating fishing activities and ensuring species safety.	Lack of continuous underwater visibility, illegal fishing detection, and species migration updates.	Imporves regulation accuracy, reduces field inspection costs, and enhances enforcement.
Aquaculture Companies **Purchase estimate:** **+20** units/ Farm	Private companies that raise fish in controlled marine environments.	Species contamination, predator fish attacks, invasive species entering cages, and poor water ecosystem knowledge.	The system helps predict biological risks and surrounding wildlife, and improve production yield.
Ports and Marine Tourism Operators **Purchase estimate:** **+ 2** units/ key spot	Private tourism operators offering marine experiences.	Lack of monitored data to show wildlife richness, absence of digital content for customers, weak environmental branding.	Access to real underwater footage, species analytics, and dashboards to promote tourism revenue.
Smart Coastal Cities & Municipalities **Purchase estimate:** **+8** units/port	Local governments investing in smart-environment solutions.	Need for digital ocean monitoring, pollution detection, and marine reserve protection.	Supports smart city objectives with autonomous underwater environmental intelligence.
Universities & Research Institutes **Purchase estimate:** **+3** units/ institute	Institutions needing reliable underwater data for scientific research.	Manual BRUV footage analysis takes months; no long-term data sources.	The system reduces analysis time and provides AI-labeled datasets.

Potential Partners

Environmental Associations & NGOs :
System Deployment in marine reserves, provide field access, and raise public awareness.
Exemple: Notre Grand Bleu, UN, WWF Tunis, TunSea, UICN med.

Academic & Research Entities:
Scientific collaboration & Ecological interpretation and data analysis, AI training datasets, and scientific validation.
Exemple: INSTM, Engineering, biology, and environmental faculties and labs.

Government Institutions:
Ministry of Environment, Maine Coast Guard, Marine Research Centers will facilitate authorization, integration with national monitoring programs, and funding.

Private Technology Firms:
Provide hardware components, solar technologies, and maintenance support.
Example: IoT device manufacturers, renewable energy companies

International Cooperation Programs:
Mediterranean sustainability initiatives, global oceanic networks will be helpful for funding, knowledge transfer, and scaling to regional projects.
Example: UICN invasive species funds, EU invasive species Funds....

Local Communities & Fishing Cooperatives:
Ensure community participation, safeguard equipment, and spread local awareness.
Example: Fishermen's unions and youth clubs.

Project Phases & Timeline

Month 1-3
Research & Design

Conduct field research, define system specifications, finalize technical design, and identify local suppliers.

Month 3–4
Prototype Development

Assemble the first complete underwater monitoring unit, including Raspberry Pi, camera, sensors, solar buoy, and cable systems.

Month 5–7
AI & Software Integration

Train and deploy the fish detection model (YOLOv11-based), integrate mobile app dashboard and cloud data sync.

Month 7–8
Field Deployment & Testing

Install the system in a coastal area for real-environment testing. Evaluate sensor accuracy, solar autonomy, and underwater durability.

Month 9–12
Expansion & Community Partnership

Scale up production (5 units), engage with academic and NGO partners, launch educational campaigns, and secure long-term funding.

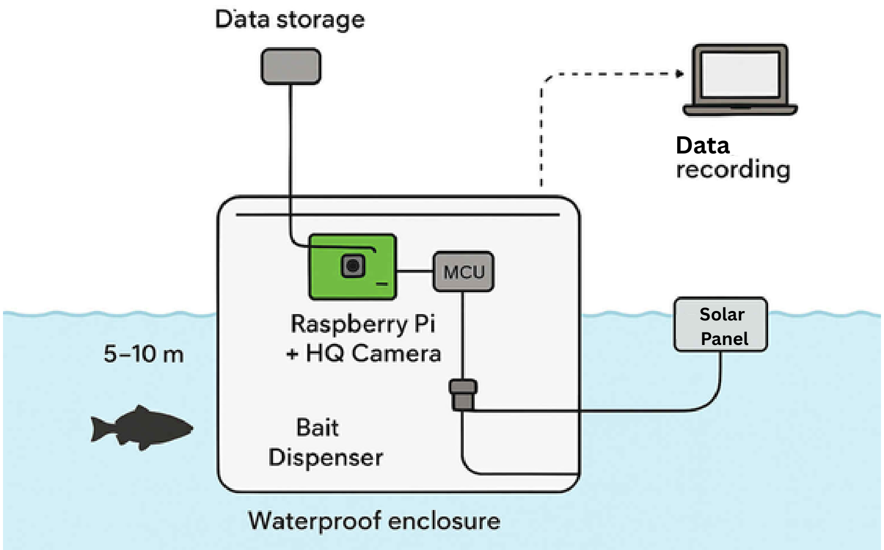
Note: Project International Growth is Showen on Page 25
(Scaling to Mediterranean Expansion)

Team Roles

Role	Responsibilities
Project Lead (Management + Finance + Operations)	- Oversee project execution and timeline adherence - Coordinate communication across teams and stakeholders - Manage budget, procurement, and financial reporting
AI & Software Officer	- Supervise development of AI fish detection system and software - Oversee dataset preparation, labeling, and model optimization - Ensure integration of mobile, cloud, and backend systems
Hardware & Systems Officer	- Oversee design and deployment of hardware systems (Raspberry Pi, cameras, solar) - Ensure technical feasibility, reliability, and maintenance of devices
Marine & Environmental Officer	- Advise on marine species, ecosystem behavior, and biodiversity protection - Ensure monitoring activities follow ethical research guidelines
Marketing and LAW Officer	- Oversee partnerships and NGOs' collaborations - Lead public relations and community engagement initiatives -Oversee legal compliance, permits, and regulatory requirements

Hardware Architecture

System Overview



The system is designed as a compact and intelligent underwater monitoring unit capable of recording, analyzing, and transmitting marine data autonomously. It operates quietly beneath the surface, continuously observing marine ecosystems with minimal human intervention. Once deployed, it captures underwater activity, processes the collected data, and identifies or classifies fish species while detecting any unusual or invasive presence.

The system automatically adjusts its operation according to environmental conditions, ensuring optimal visibility and minimal disturbance to marine life. It also releases small amounts of bait at regular intervals to attract species naturally, enhancing observation without disrupting the ecosystem.

All collected data are securely stored and periodically transferred to the surface for analysis.

This integrated architecture creates a self-sustaining and intelligent monitoring ecosystem capable of long-term operation in harsh underwater environments, supporting marine research, biodiversity tracking, and environmental protection efforts.

Hardware Architecture

System Components

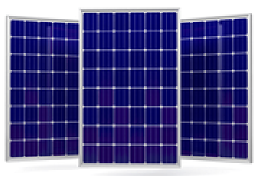
Central Processing Unit – Raspberry Pi 4 (4 GB RAM)
Acts as the system's brain, managing all operations including camera control and bait dispensing. Captures video locally and runs AI models to identify and analyze fish species.

Protective Waterproof Enclosure
Durable, corrosion-resistant housing protects all components from water pressure, saltwater exposure, and leaks, ensuring reliable long-term underwater operation.

Raspberry Pi HQ Camera v3
Captures clear, high-resolution video to provide accurate visual data for marine observation.

Local Data Storage (MicroSD Card)
Stores recorded videos securely for multiple days, preventing data loss between transfers to the surface.

Waterproof High-Speed Ethernet Cable
Delivers both power and fast, stable data transmission between the underwater unit and the surface buoy.

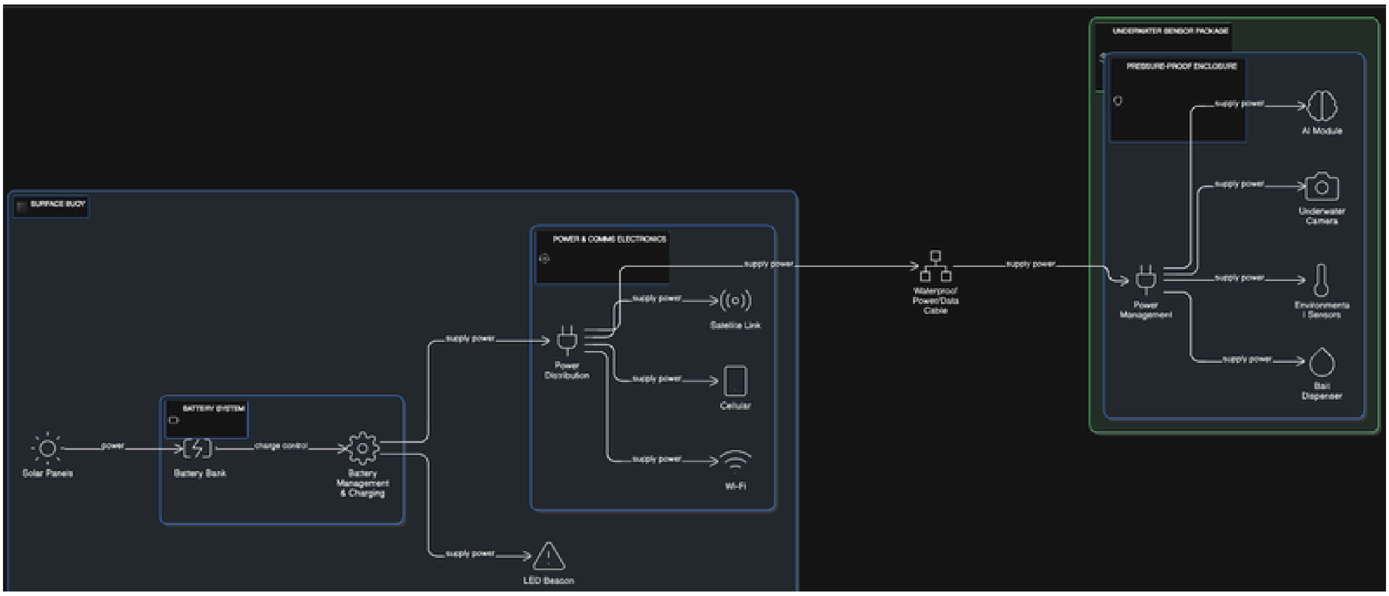


Solar-Powered Surface Buoy Module
Contains solar panels and communication hardware, providing continuous renewable power to the underwater system and uploading collected data at regular intervals.

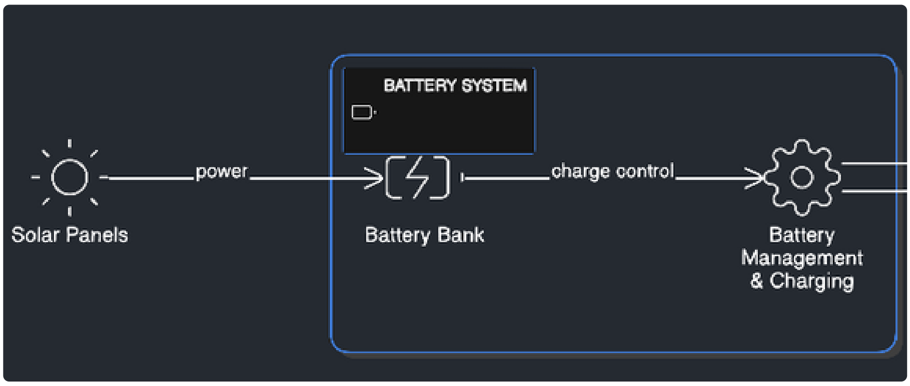
Automated Bait Dispenser
Incorporates a small DC motor or pump with a bait reservoir that releases controlled bait portions on preset schedules, attracting marine life without altering natural behavior.

Power Architecture

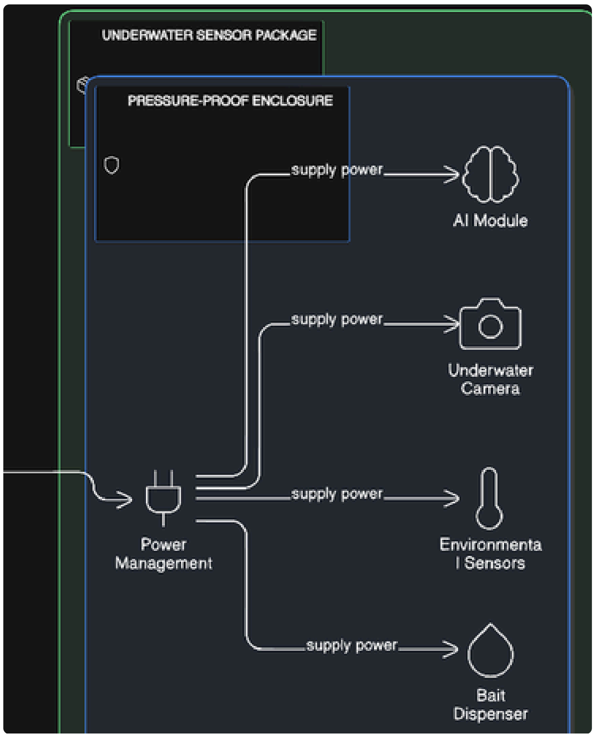
Architecture Overview



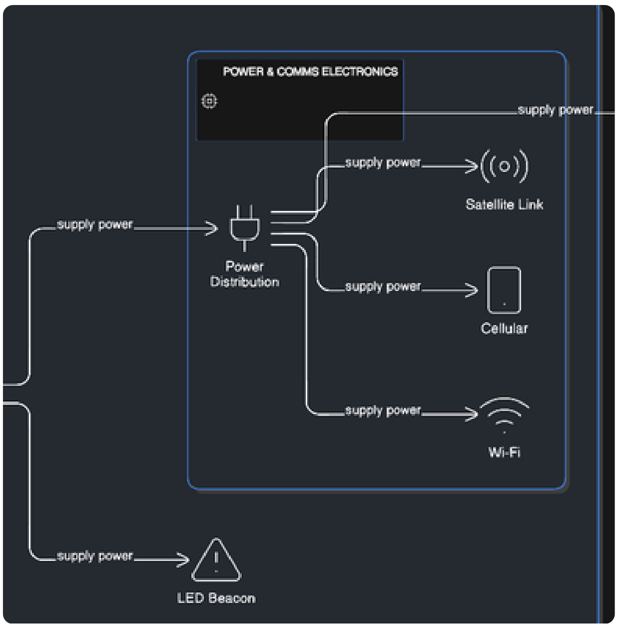
Surface Buoy: Battery System



Underwater Unit



Surface Buoy: Power and Comms electronics



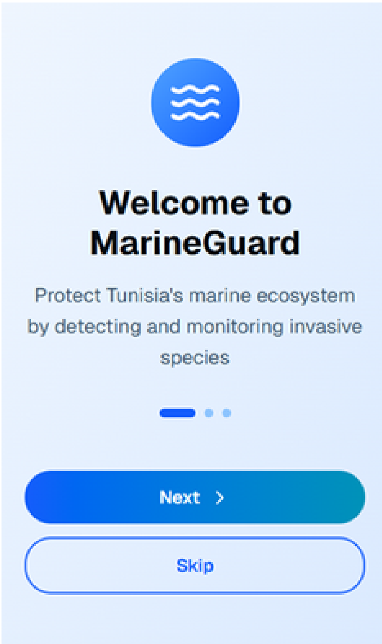
Software Architecture

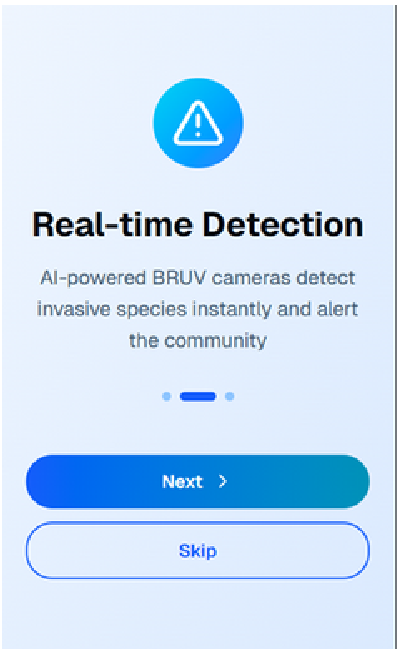
APPLICATION DETAILS

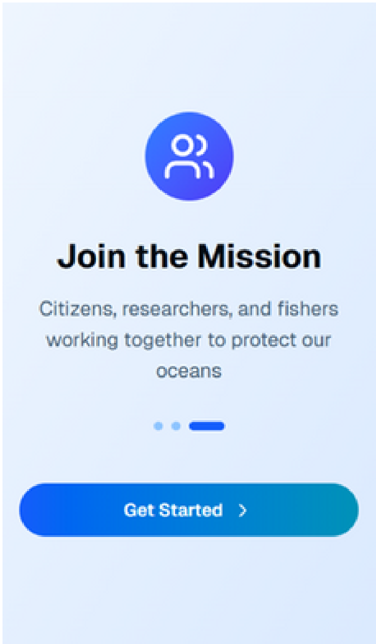
What is MarineGuard?

MarineGuard is a comprehensive mobile application designed to detect, monitor, and combat invasive marine species in Tunisia's waters.

It combines real-time underwater surveillance technology, AI-powered species identification, and community-driven data collection to protect Tunisia's marine ecosystem and support sustainable fishing practices.







Note: all screenshots are from the real APP developed by our team, not design prototypes

Software Architecture

APPLICATION DETAILS

How does it work?

Data Collection:
BRUVs cameras deployed across Tunisia's coastline record live marine footage, while users contribute species photos through the AI identifier tool for automated identification and threat assessment.

Real-Time Monitoring:
The app displays live feeds, invasive species alerts, oceanographic data, and interactive maps showing detection hotspots and camera locations.

Community Collaboration:
Citizens, researchers, and fishers share findings in the community forum and access educational resources to collectively combat invasive species threats.

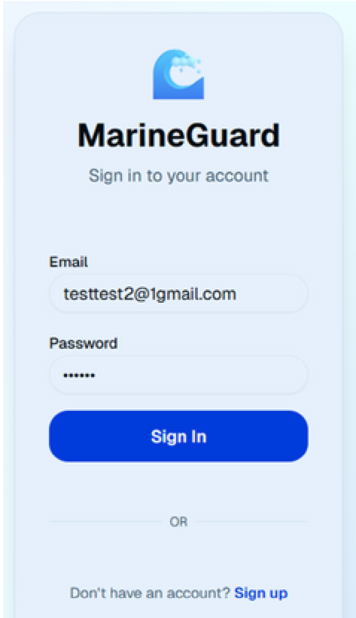
Actionable Results:
Researchers access detailed analytics and reports, fishers receive zone-specific safety alerts, and citizens learn about marine conservation while contributing to monitoring efforts.

Software Architecture

APPLICATION DETAILS

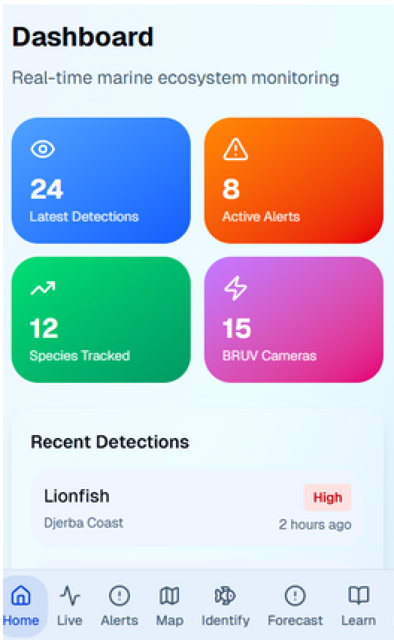
Features Descriptions

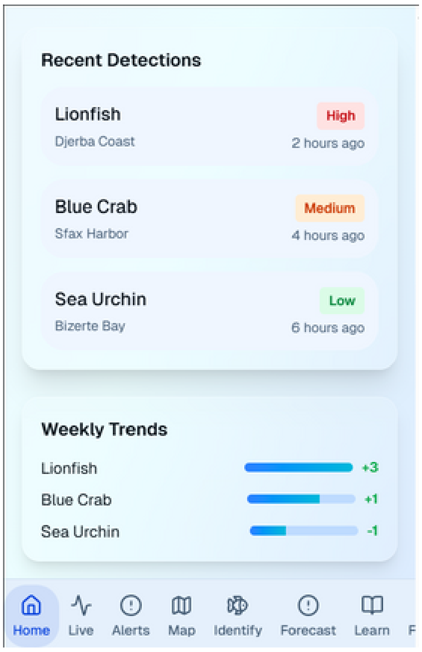
- **Authentification Screens (LOGIN & SIGNUP):**



- **Dashboard Screen:**

The Dashboard is the central hub displaying real-time monitoring statistics including total detections, active cameras, alerts count, and weekly trend charts. Interactive cards show recent invasive species detections with species names, locations, and severity levels. Quick action buttons provide immediate access to critical features like alerts and the live feed.

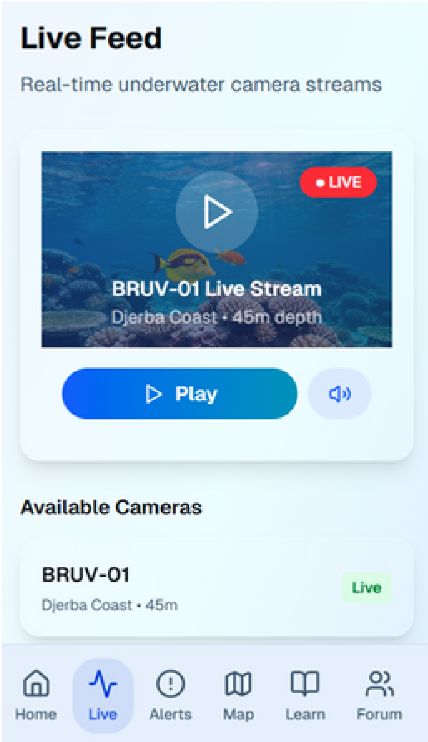




Software Architecture

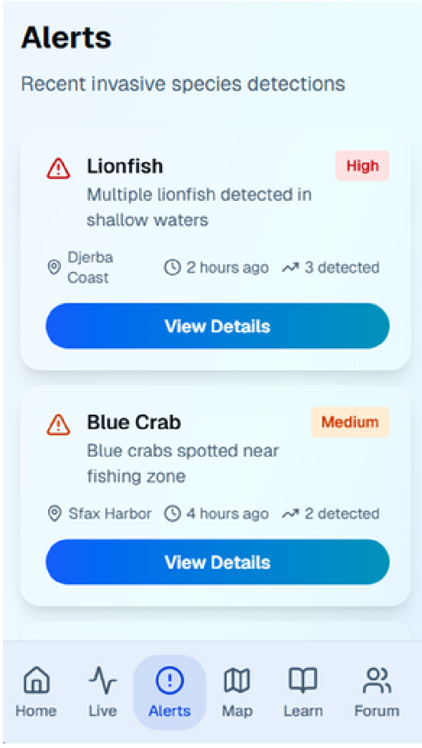
APPLICATION DETAILS

Features Descriptions



- **Most recent feed Screen:**

The streams section allows users to observe marine life as it happens. Users can select between multiple camera locations, view footage with play/pause controls, and monitor environmental data including water depth, temperature, and camera status. Each stream displays location coordinates and continuous recording indicators



- **Alerts Screen:**

A centralized notification system for invasive species detections throughout Tunisia's waters. Each alert displays the species name, detection location, severity level (Critical, High, Medium, Low) with color coding, and timestamp. Users can filter alerts by severity or location to manage and prioritize monitoring efforts effectively.

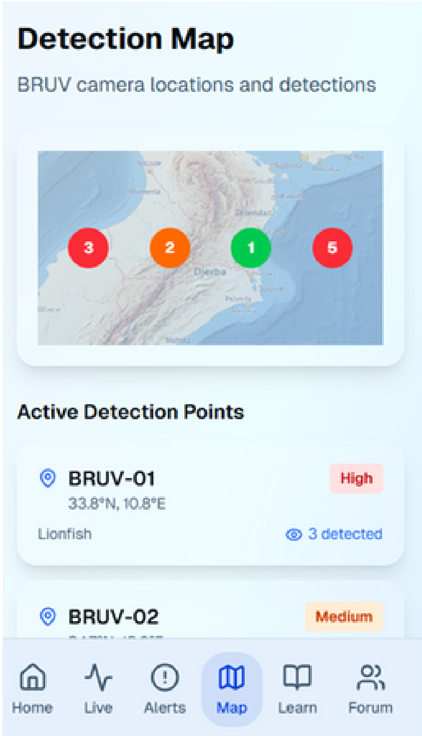
Software Architecture

APPLICATION DETAILS

Features Descriptions

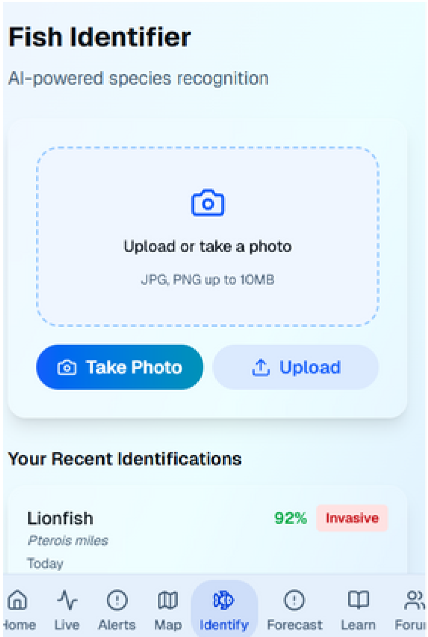
- **Map Screen:**

An interactive geographical map of Tunisia's coastline displaying all BRUV camera locations and invasive species detection hotspots. Users can zoom and pan to explore detection patterns across different marine zones. Color-coded markers indicate severity levels, helping identify high-risk areas requiring immediate attention.



- **Fish Identifier Screen:**

An AI-powered tool enabling users to identify marine species by uploading photos or capturing them with their device camera. The system analyzes images and provides species identification, scientific name, common name, and invasive status. Users can save results to their profile and contribute to the community species database.



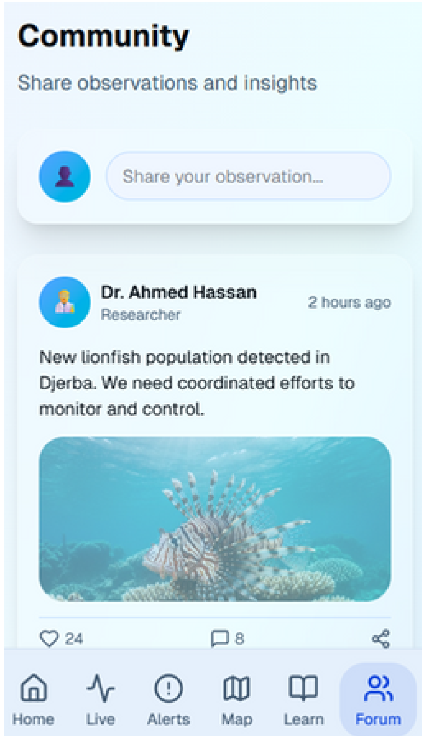
Software Architecture

APPLICATION DETAILS

Features Descriptions

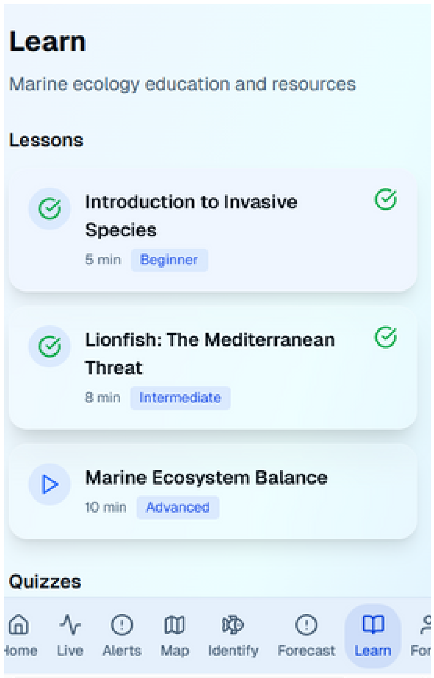
- **Community Forum**

A collaborative platform where citizens, researchers, and fishers share observations, research findings, and marine conservation insights. Users can create posts, comment on discussions, and engage in topic-specific conversations about invasive species and monitoring techniques. The forum fosters community engagement and enables crowdsourced data collection from diverse perspectives.



- **Educational Section**

Comprehensive marine ecology resources including structured lessons on invasive species threats, Tunisia's marine ecosystem, and conservation importance. Interactive quizzes test knowledge retention and provide immediate feedback. Engaging marine facts and statistics inspire community participation in conservation efforts and raise awareness about ocean health.



Software Architecture

AI SYSTEM:

Fish Detection and Growth Prediction

System Overview

This part objective is to design and implement an artificial intelligence system capable of analyzing underwater footage captured by BRUVs. The system is composed of two major models: “fish detection and classification” model, and “growth prediction” model. The first model detects and identifies fish species from raw videos, while the second predicts species growth patterns such as size, biomass, and rate of increase based on detection outputs and environmental variables.

Dataset Description

Model 1: Fish Detection and Classification:

The dataset was derived from our BRUVs deployments that recorded extended underwater footage across multiple marine sites. Each video captures a range of fish species under varying lighting and depth conditions. Individual frames were extracted and annotated using Roboflow, where fish were labeled with bounding boxes and classified by species. Annotations were exported in YOLO-compatible formats for model training.

Model 2: Growth Prediction and Ecological Forecasting :

This dataset builds upon the outputs of the fish species detection model. For each detected species, supplementary environmental variables(such as water temperature, depth, visibility, and site location) were integrated.

All data were verified for consistency and split at the video level to maintain independence across training, validation, and test sets.

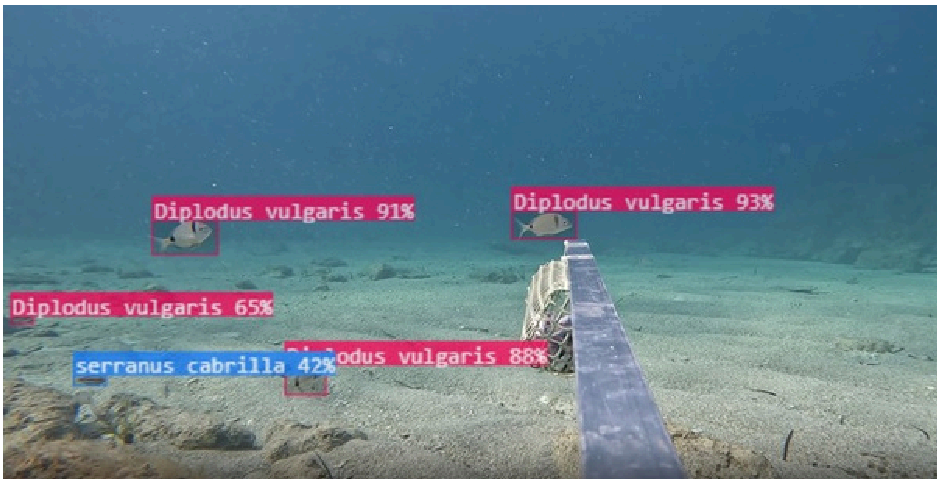
Software Architecture

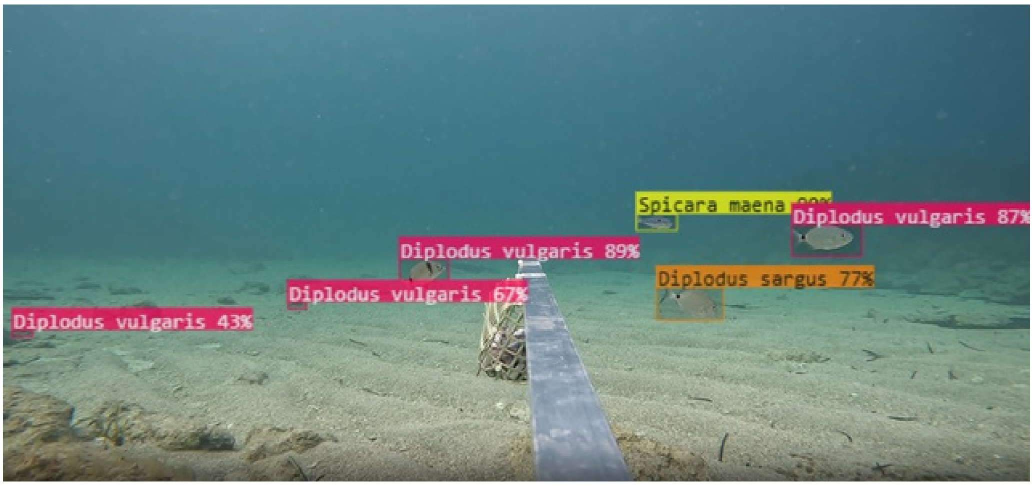
AI SYSTEM:
Fish Detection and Growth Prediction

AI Models Architecture

<u>Model 1: Fish Detection and Classification</u>

The first component of the system employs a YOLO-based object detection architecture optimized for underwater environments. This convolutional neural network processes individual frames to identify fish, locate them within bounding boxes, and assign species labels with associated confidence scores. The YOLO detection head enables real-time inference while maintaining high accuracy.





Note: These screenshots come directly from our first working AI model

Software Architecture

AI SYSTEM:

Fish Detection and Growth Prediction

Model 2: Growth Prediction and Ecological Forecasting:
The second model builds on the structured outputs of the detection stage, integrating detected species counts and environmental variables to estimate growth-related metrics such as size and biomass over time. It employs data-driven regression and sequence learning techniques to capture temporal and ecological dependencies.
The resulting forecasts provide actionable insights into population dynamics and ecological changes, offering a scalable tool for long-term marine resource management.

Evaluation and Future Prospects

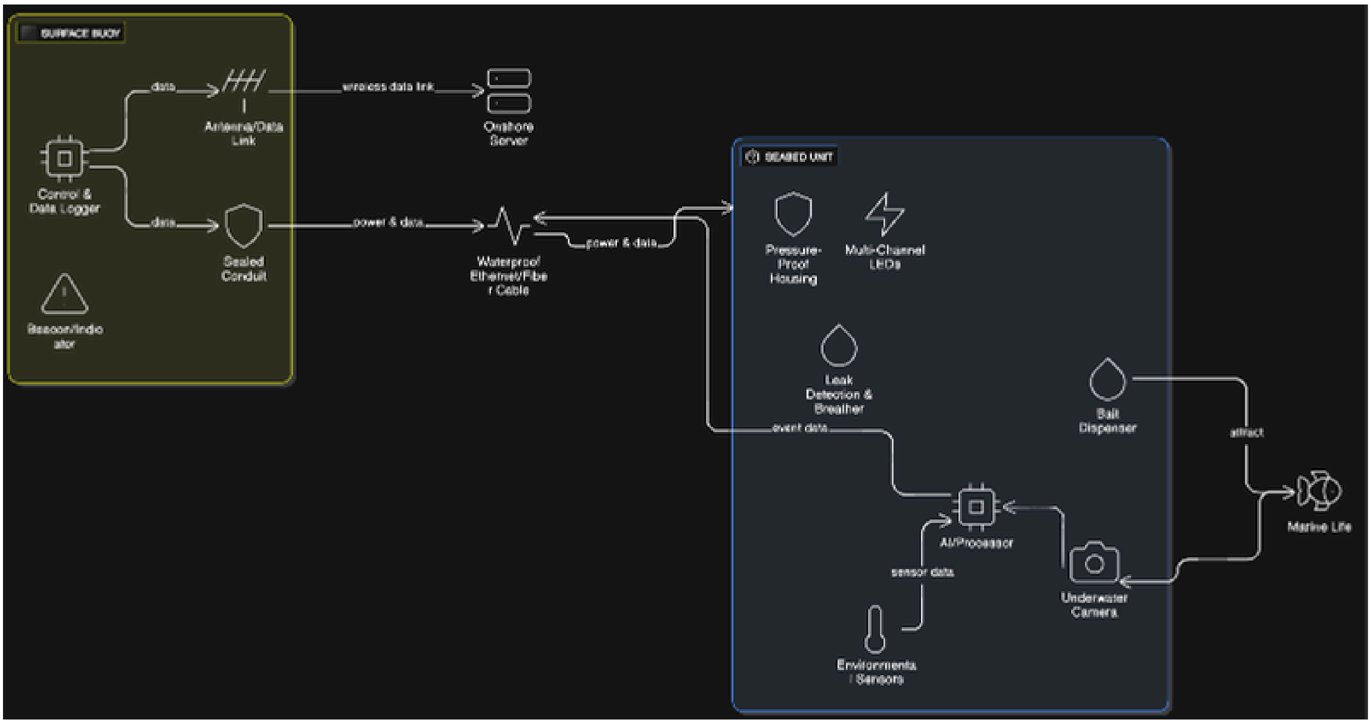
The two-model architecture presents a comprehensive framework for automated marine observation. The YOLO-based detection model provides rapid and accurate species identification, establishing a robust foundation for ecological data acquisition. The growth prediction model builds upon this by offering predictive insights into species dynamics, effectively linking visual AI with environmental modeling.

Looking ahead, the system can be further enhanced through larger and more diverse datasets, integration with calibrated imaging systems for precise size estimation, and
real-time analysis pipelines.

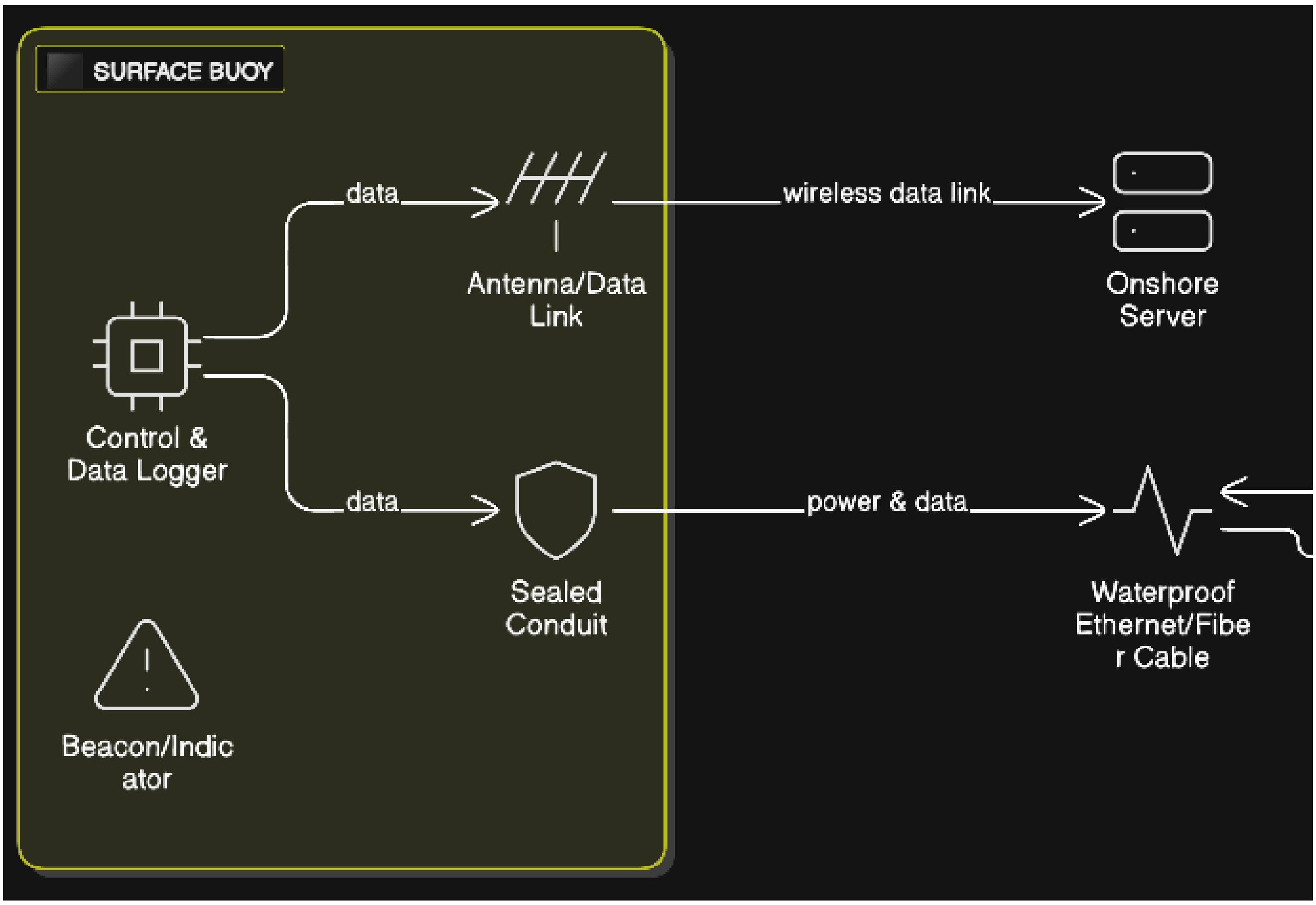
Future developments may also explore multi-modal learning by combining visual, acoustic, and environmental data to improve prediction accuracy. With continued refinement, the approach holds strong potential for scalable, autonomous, and data-driven marine ecosystem monitoring.

DATA Architecture

Architecture Overview

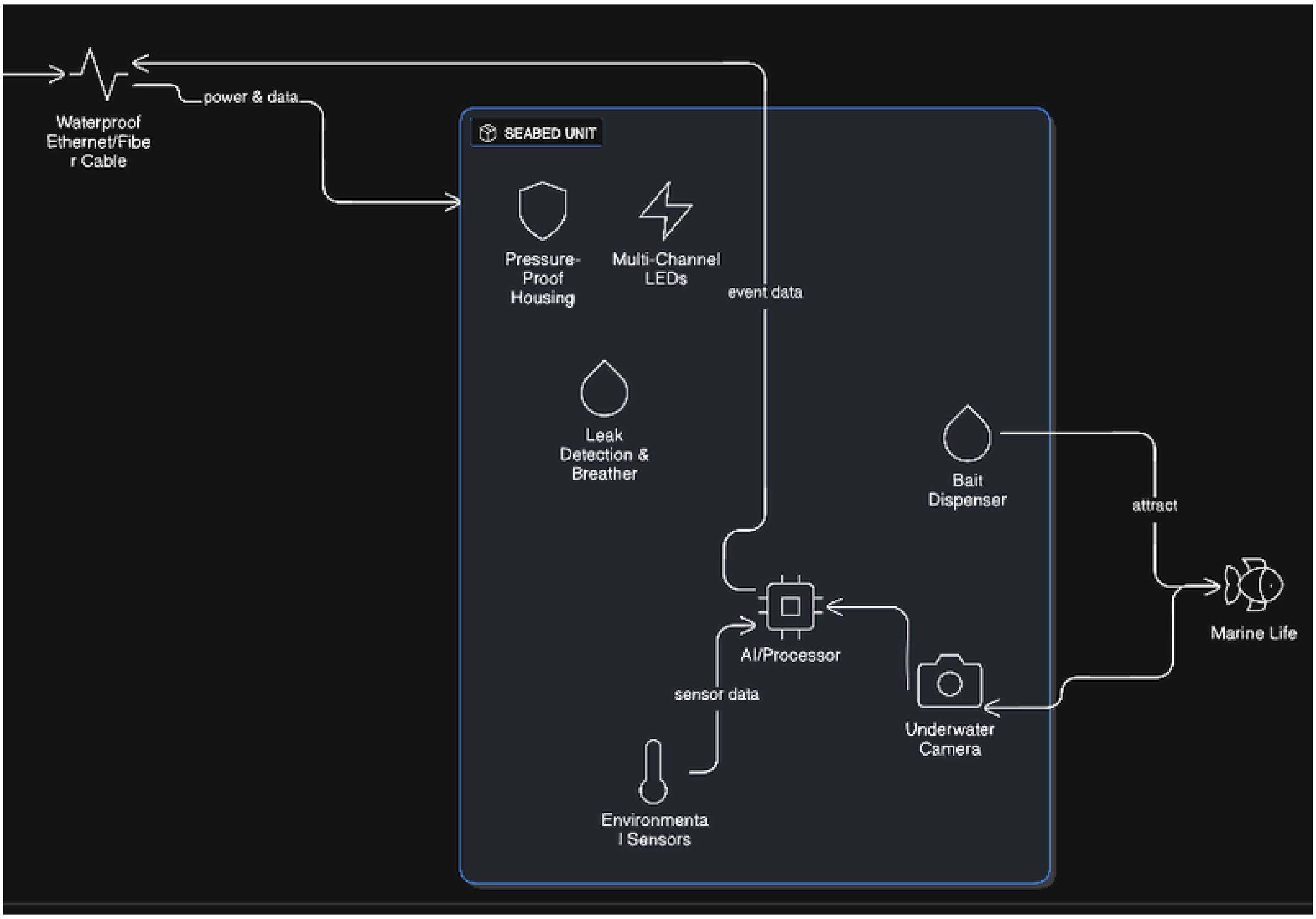


Surface Buoy



DATA Architecture

Seabed Unit



Description:

The underwater camera, environmental sensors, and bait dispenser operate from the seabed unit and continuously collect video and sensor data. This data is sent upward through a waterproof Ethernet/Fiber cable that also carries power from the surface buoy.

Once the data reaches the buoy, the control and data-logging module stores it and can process or forward it as needed. From there, the buoy's antenna establishes a wireless data link that transmits the collected information to the onshore server, where it can be analyzed, monitored, or archived.

In this architecture, the seabed unit is focused solely on capturing raw data, while the surface buoy handles communication, storage, and system management.

Budget and Financial Analysis

Hardware Costs

Component	Quantity	Unit Cost (TND)	Total Cost (TND)	Description
Raspberry Pi 4 (4GB RAM)	1	120	120	Main CPU controlling sensors, camera, AI models
Pi HQ Camera v3	1	160	160	High-resolution camera for underwater imaging
Waterproof Enclosure (IP68)	1	200	200	Durable housing protecting electronics
Automated Bait Dispenser System	1	60	60	Motorized unit to dispense bait on schedule
MicroSD Card (128GB) Storage	1	20	20	Local data storage for video and sensor logs
High-Speed Ethernet Cable (50m)	1	40	40	Tether cable for power/data to surface buoy
Solar Panel (20W)	1	150	150	Provides renewable power to the unit
Surface Buoy & Comms Module	1	300	300	Buoy with radio/satellite modem for data uplink
Total Hardware Cost (per unit)			**1,130**	

Software & Development Costs

Key cost categories include:
AI Model Training and Maintenance: Development of fish detection, species ID, and growth prediction models (including data labeling and cloud resources).
Mobile App and Backend: Engineering for the MarineGuard mobile/web app, server hosting, and database management.
Telecommunications and Hosting: Yearly costs for data services (e.g., satellite comms fees, cloud servers).
Project Team & Overhead: Salaries for developers, project management, testing, and administrative overhead.

Budget and Financial Analysis

These costs are largely fixed or semi-variable with scale. For a 1-year project, we budget approximately **15,000–20,000 TND** for software development and operational setup. This includes 2–3 software engineers, data scientists, and infrastructure costs. Future annual maintenance (cloud hosting, minor updates) is estimated at **5,000 TND** per year.

Pricing Strategy

MarineGuard will use a hybrid hardware/software pricing model. Customers (research institutes, marine agencies, NGOs) are offered:

- **Unit Sale**: One option is an outright sale of the monitoring station. For example, each unit can be sold for **1,500 TND**. Alternatively, a lease (rental) model might charge **150 TND/month** per unit, with a one-year minimum.
- **Subscription Service:** The core value is real-time data. We charge an annual service subscription of 500 TND per unit for data access, alerts, and app features. This includes cloud-hosted analytics and app maintenance. Pricing is set to ensure a healthy margin. As noted in

pricing strategy research, even small price increases can significantly boost profitability. For instance, selling a unit at 1,500 TND instead of 1,130 TND raises gross margin and covers additional costs. The subscription fee covers ongoing costs and generates recurring revenue.

Revenue Projections and ROI

We assume modest initial sales in Year 1: selling 10 units at 1,500 TND each and 10 subscriptions at 500 TND/year. This yields:

- **Hardware Revenue**: 10 units × 1,500 TND = 15,000 TND
- **Subscription Revenue (Year 1)**: 10 × 500 TND = 5,000 TND
- **Other (grants/consulting)**: ~2,000 TND (e.g., one-time funding or service fees.)

Total Projected Revenue (Y1): ~22,000 TND.

Budget and Financial Analysis

Subtracting the initial investment of ~36,000 TND gives a **net profit** of (22,000 – 36,000) = **-14,000 TND** in Year 1 (a first-year loss, typical for R&D).

However, by Year 2, ongoing costs drop (only maintenance), and sales increase. If we deploy an additional 10 units and retain subscriptions, Year 2 revenue might reach ~25,000 TND against operational costs of ~10,000 TND.

Using these projections, we calculate Return on Investment. ROI is defined as **(Net Profit / Total Investment) × 100%.** For example, if Year 2 net profit is 15,000 TND on a 36,000 TND investment,
ROI = (15,000 / 36,000) × 100 ≈ 42%. The actual ROI will improve further in subsequent years as unit sales and subscriptions grow.

ROI Calculation Example:

Description	Value (TND)
Total Investment (Year 1)	36,000
Total Revenue (Year 2)	25,000
Year 2 Net Profit	15,000
ROI = (Net Profit/Investment) × 100	**42%**

Scaling to Mediterranean Expansion

Year	Region	Strategic Partner	Units
2026	Tunisia Full Coast	NGOs + Govermment	40
2027	Algeria + Libya	Regional Marine Protected Network	70
2028	Malta + Italy	EU Research + Horizon	120
2029	Morocco	Fisheries and MPA Authorities	60

Humanitarian Impact

Aqua Sentinel is not only a technological project, it's a **social and environmental movement** designed to empower communities and preserve life below water.

Environmental Protection:

- Enables early detection of invasive and toxic species, reducing ecological damage.
- Supports biodiversity restoration and pollution control through continuous observation.

Public Health & Safety:

- Prevents fish poisoning incidents by providing real-time data and community alerts via the mobile app.
- Educates citizens and fishers on safe consumption and ecosystem balance.

Community Empowerment:

- Involves local fishers, students, and youth clubs in data collection, maintenance, and marine education.
- Creates local employment and research opportunities in marine innovation.

Sustainable Development Goals Alignment:

- **SDG 14** (Life Below Water): Protect marine ecosystems.
- **SDG 7** (Affordable and Clean Energy): Promote renewable power through solar-driven operations.
- **SDG 13** (Climate Action): Monitor and respond to climate-driven changes in marine life.
- **SDG 2** (Zero Hunger): By monitoring fish populations and detecting harmful species, our system helps protect marine food sources and ensures safer, more sustainable fisheries for coastal communities.

Educational Impact:

- Offers open access to marine data for schools and universities, encouraging scientific curiosity.
- Raises awareness through workshops and community programs integrated with the MarineGuard app.

Through its humanitarian dimension, AQUA SENTINEL transforms marine conservation from a technical mission into a collective national responsibility merging science, ethics, and sustainability for a safer ocean.

Conclusion

AQUA SENTINEL brings the project to a clear outcome: a coherent, forward-looking approach to strengthening ocean stewardship. Throughout the work, the focus remained on creating a monitoring solution that supports both environmental protection and community engagement.

The initiative reinforces the value of sustained observation, shared knowledge, and responsible innovation in addressing today's marine challenges. It also opens the door to future expansions that can deepen its impact and broaden its reach, ensuring that the effort begun here continues to grow beyond this report.

Future Vision:

Looking ahead, AQUA SENTINEL envisions evolving from a national initiative into a regional model for sustainable ocean intelligence.
The next phase involves expanding its monitoring network along Tunisia's coasts and integrating it into a Mediterranean-wide data platform, forming a true digital ocean observatory. This AI-powered system will monitor biodiversity, forecast ecological trends, and strengthen cooperation among researchers, NGOs, and coastal authorities.

By promoting education, open data, and citizen science, the project aims to transform communities into active ocean guardians.

By 2030, AQUA SENTINEL aspires to advance global marine sustainability goals and redefine humanity's relationship with the sea, not merely observing it, but understanding, protecting, and coexisting with it.