# Conceptualization And Execution of a Boat Transponder and Monitoring System for The Conservation of Protected Waters in Dumaran, Palawan with Emergency Alert Support for Fishermen

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***Abstract*—This research presents the conceptualization and execution of a Boat Transponder and Monitoring System for the Conservation of Protected Waters in Dumaran, Palawan with Emergency Alert Support for Fishermen. The primary objective of the study is to design and implement a low-cost boat transponder that supports the protection of Marine Protected Areas (MPAs) by monitoring the location and activity of fishing vessels operated by fishermen as well as ensure their safety and rescue viability by providing them a way to contact authorities thru an emergency mechanism attached in the device. This study also involves the creation and deployment of a real-time monitoring system capable of tracking fishing vessel movement within designated protected waters. In addition, the system is equipped with an emergency alert that enables authorities to detect fishermen distress signals during emergencies, thereby improving response coordination with local authorities.**

***Index Terms*—Boat Transponder, Emergency Alert Support, Fishing Vessels, Marine Protected Areas, Monitoring System.**

## I. INTRODUCTION

Dumaran, a municipality in northern Palawan, is known for its rich marine biodiversity and pristine coastal resources. It lies within the Coral Triangle, a globally recognized marine biodiversity hotspot that hosts unparalleled reef fish and marine life diversity. Dumaran is part of the Northeast Palawan Marine Protected Area (MPA) Network—a large-scale conservation initiative involving several municipalities that aim to protect and restore the region's marine ecosystems.

According to Blue Alliance Marine Protected Areas [1], the coastal and marine ecosystems of Northeast Palawan include coral reefs with 379 species of corals, over 1,000 marine fish species, seagrass meadows with 13 species, and mangrove forests with 31 species. The region also contains around fifty coral reefs identified as resilient to climate change, with the potential to aid in repopulating neighboring reefs over time.

Several areas surrounding Dumaran have been declared protected waters due to their ecological importance, serving as habitats for coral reefs, seagrass beds, and diverse fish species that are vital to both the environment and local livelihoods. However, despite ongoing conservation initiatives, the area continues to face growing challenges such as illegal fishing, coral destruction, and unregulated human activities that threaten marine ecosystems and contribute to declining fish populations.

According to the Bureau of Fisheries and Aquatic Resources (BFAR, 2021) [2], Palawan ranks among the top fishing grounds in the Philippines with a high prevalence of misregistered commercial fishing vessels—boats registered as municipal but operating on a commercial scale. Specifically, the Calamines Group of Islands in northern Palawan was identified as one of the top three areas nationwide with the greatest incidence of misregistered commercial fishing vessels. This highlights the ongoing challenges in regulating fishing activities and enforcing sustainable fishing policies in the province.

Local authorities and coastal communities often rely on manual monitoring and patrolling, which are limited by budget constraints, lack of real-time data, and the vastness of the marine areas to be covered. According to the Bureau of Fisheries and Aquatic Resources (BFAR), illegal fishing incidents in Palawan have increased by approximately 15% between 2020 and 2024, highlighting the urgent need for more effective and technology-assisted monitoring solutions. In addition, climate-related events such as rising sea temperatures and typhoons further complicate conservation efforts, making continuous observation crucial.

Boat Transponder and Monitoring System for the Conservation of Protected Waters in Dumaran, Palawan with Emergency Alert Support for Fishermen, Palawan is designed to address these pressing issues by providing real-time, automated monitoring of human activities within protected zones. This system aims to assist local authorities and the municipal government in detecting unauthorized activities and strengthening conservation enforcement. By integrating technology into marine protection, the project hopes to enhance sustainability, ensure better resource management, and support the long-term preservation of Dumaran's marine ecosystems.

## II. LITERATURE REVIEW

This review focuses on studies that demonstrate the benefits of using boat transponders for both fishermen and local authorities. Bhavani and Samuel (2016) [3] developed a GPS-based boat detection and tracking system that enhances fishermen's safety by providing advance warnings when vessels approach or trespass into marine protected areas. Their study emphasized the role of real-time location monitoring in reducing risks associated with boundary violations.

Similarly, Priyadharshini et al. (2024) [4] addressed the issue of fishermen unintentionally crossing maritime borders and proposed the use of an IoT-based monitoring and alert system. Their findings showed that timely notifications regarding unidentified sea boundaries can significantly help fishermen avoid border-related incidents.

The importance of monitoring systems was further reinforced by McGeady et al. (2023) [5], who highlighted that effective Marine Protected Area (MPA) management relies on continuous and reliable monitoring to collect data for assessing whether conservation objectives are being met. Their study underscored monitoring as a critical component of sustainable marine resource management.

Additionally, Gita and Febrianty (2024) [6] demonstrated how technology can be used to prevent illegal fishing activities. Their research showed that the implementation of Vessel Monitoring Systems (VMS), Automatic Identification Systems (AIS), and remote sensing technologies significantly improved the monitoring of fishing operations in the Natuna Sea.

Overall, the reviewed studies consistently demonstrate that the integration of boat transponders and related monitoring technologies provides significant advantages in terms of fishermen safety, boundary awareness, and regulatory enforcement. GPS-based tracking, IoT-enabled alert systems, and advanced monitoring tools such as VMS, AIS, and remote sensing have been shown to reduce accidental border crossings, support Marine Protected Area management, and strengthen efforts against illegal fishing. While these studies highlight the effectiveness of existing systems, they also suggest the need for localized, cost-efficient, and user-friendly solutions that can be readily adopted by small-scale fishermen and local authorities. These gaps indicate an opportunity for further research and system development tailored to specific coastal and operational contexts.

## III. METHODOLOGY

The researchers used the prototyping model particularly the High-Fidelity Prototyping in the creation of the boat transponder and monitoring system.

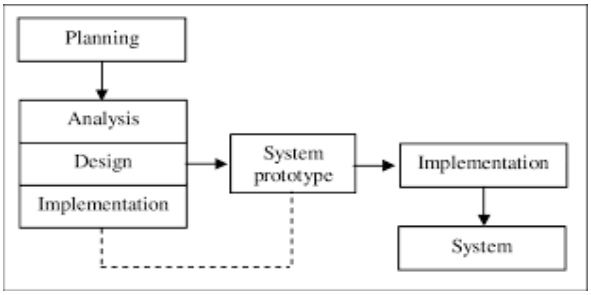


*FIGURE 1. PROTOTYPING MODEL BY HELMY, MOHD, ET AL.*

PLANNING PHASE

The planning phase focused on defining the objectives, scope, and feasibility of developing a boat transponder and monitoring system with an emergency alert feature. The primary goal of the system is to prevent unauthorized entry into restricted maritime zones, enhance fisherman safety and provide local authorities with real-time vessel monitoring capabilities. During this phase, requirements were gathered through an interview with the beneficiaries, consultations with domain experts, and analysis of existing maritime monitoring technologies. Resource planning was also conducted to determine the necessary hardware components, software tools, budget constraints, and development timeline.

ANALYSIS PHASE

In the analysis phase, the functional and non-functional requirements of the system were identified. Functionally, the system must be able to track boat locations in real time, transmit data to a monitoring station, issue alerts when vessels approach restricted zones, and allow fishermen to send emergency distress signals. Non-functional requirements include system reliability, low power consumption, ease of use, and scalability. Potential risks such as signal loss, power limitations, and environmental conditions at sea were also analyzed. This phase ensured that the system requirements were aligned with the actual needs of fishermen and the operational requirements of monitoring authorities.

DESIGN PHASE

The design phase translated the system requirements into a detailed technical architecture. The boat transponder design consists of RP2040, GPS Module, nRF24, LiFePO battery, MPPT module and solar panel. On the monitoring side, a centralized server and mobile application were designed to receive, store, and visualize vessel data. The system design also includes geofencing mechanisms to detect entry into restricted areas and automatically trigger alerts. Emphasis was placed on designing a compact, weather-resistant, and energy-efficient transponder suitable for small fishing vessels.

IMPLEMENTATION PHASE

The implementation phase involved the actual development and integration of the system components. Hardware components were assembled and programmed to collect GPS coordinates and transmit location data at regular intervals. Software development included coding the microcontroller firmware, configuring the communication protocol, and developing the monitoring application. The emergency alert feature was implemented to allow fishermen to manually trigger distress signals, which are immediately transmitted to the monitoring center. Data encryption and authentication mechanisms were incorporated to ensure secure communication between the boat transponder and the monitoring system.

SYSTEM PROTOTYPE

A functional prototype of the boat transponder and monitoring system was developed to validate the design and implementation. The prototype includes a working transponder unit installed on a small vessel and a monitoring dashboard accessible to authorized personnel. The dashboard displays real-time boat locations, alert notifications, and historical movement data. The emergency alert feature was tested to ensure that distress signals are accurately detected and promptly displayed on the monitoring interface. The prototype serves as a proof of concept, demonstrating the feasibility and effectiveness of the proposed system.

## IV. TECHNOLOGY USED

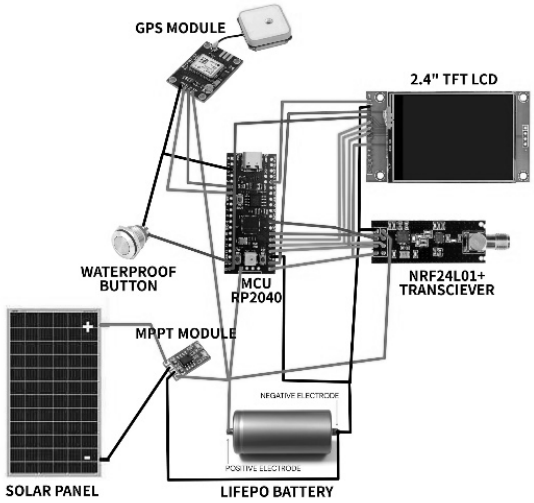


*FIGURE 2. HARDWARE SCHEMATICS*

RP2040 MICROCONTROLLER

The RP2040 microcontroller serves as the main processing unit of the boat transponder system. It is responsible for controlling system operations, processing GPS data, managing wireless communication, and handling emergency alert signals. Its dual-core architecture, low power consumption, and flexible GPIO support make it suitable for embedded applications requiring real-time data processing and energy efficiency.

GPS MODULE

The GPS module is used to determine the real-time geographical location of the fishing vessel. It continuously receives satellite signals to generate accurate latitude and longitude data, which are transmitted to the monitoring system. This component enables vessel tracking, geofencing, and location-based alert functionalities within the system.

NRF24L01 WIRELESS MODULE

The NRF24L01 module is utilized for wireless communication between the boat transponder and the monitoring system. It enables the transmission of GPS data and emergency alerts over short to medium distances with low power consumption. This module is suitable for coastal monitoring applications where efficient and reliable data transmission is required.

LIFEPO$_4$ BATTERY

A Lithium Iron Phosphate (LiFePO$_4$) battery is used as the primary power source of the system. This type of battery was selected due to its high energy density, long life cycle, thermal stability, and safety characteristics. It ensures continuous operation of the transponder even during extended periods without sunlight.

MPPT CHARGE CONTROLLER MODULE

The Maximum Power Point Tracking (MPPT) module regulates the charging process of the LiFePO$_4$ battery using energy harvested from the solar panel. It optimizes power conversion efficiency by ensuring that the solar panel operates at its maximum power point, thereby improving charging performance and prolonging battery life.

SOLAR PANEL

The solar panel provides a renewable energy source for the system by converting sunlight into electrical energy. It supports sustainable and long-term deployment of the boat transponder by reducing dependence on manual battery charging. The solar panel, in combination with the MPPT module, ensures uninterrupted power supply during fishing operations.

## V. CONCLUSIONS

This study successfully designed and developed a boat transponder and monitoring system with an integrated emergency alert feature aimed at improving maritime safety and enhancing monitoring capabilities for local authorities. Through the systematic application of planning, analysis, design, and implementation phases, the system demonstrated its ability to provide real-time vessel tracking, boundary awareness, and immediate distress signaling. The development of a functional prototype further confirmed the feasibility of integrating GPS technology, wireless communication, and geofencing mechanisms into a compact and practical solution for small fishing vessels.

The results of the prototype testing indicate that the system can effectively support fishermen by reducing the risk of accidental entry into restricted maritime zones and by enabling rapid response during emergency situations. Additionally, the monitoring platform offers authorities a reliable tool for overseeing fishing activities, managing marine protected areas, and addressing illegal fishing concerns. Overall, the system contributes to the advancement of technology-assisted maritime monitoring and presents a cost-effective approach to strengthening safety, compliance, and sustainable resource management in coastal communities.

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