BNAM 2026
Baltic-Nordic Acoustics Meeting
May 04 - 06 2026 Gothenburg, Sweden

INCITESHIP: MEASUREMENT AND INCENTIVE SYSTEM FOR MITIGATION OF SHIP UNDERWATER NOISE

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Shipping generates the largest share of human-induced underwater noise in the global ocean, yet practical methods for linking vessel-specific underwater radiated noise (URN) to environmental impact remain limited. The InciteShip project (2024–2026) develops and validates an integrated system that combines direct noise measurements with an incentive framework. Autonomous buoys powered by solar energy and batteries, and equipped with hydrophones, record noise from passing commercial ships in shallow waters. The system transmits quality-controlled data via 4G to onshore processing units, where algorithms estimate vessel source characteristics. It then converts these measurements into an incentive score based on auditory-weighted source levels for different groups of marine mammals, fish, and invertebrates. Initial deployments along the Gothenburg and Södertälje shipping lanes demonstrate stable operation and high data quality. The InciteShip project establishes a scalable approach for mitigating underwater noise and incorporating it into maritime sustainability frameworks.

1 Introduction

Underwater noise generated by human activities has become a significant environmental pressure in marine ecosystems. Among these sources, commercial shipping contributes the majority of continuous low-frequency sound in the oceans. This persistent background noise overlaps with the hearing ranges of many marine organisms and alters the natural acoustic environment [1]. In contrast to emissions such as greenhouse gases or chemical pollutants, underwater noise remains largely unregulated at the international level, and no binding requirements currently mandate reductions in ship noise.

A substantial body of research has demonstrated that vessel noise affects a wide range of marine species. For instance, harbour porpoises reduce or cease foraging activities when vessels pass within distances of up to one kilometre [2]. Fish species such as cod and haddock experience masking of acoustic signals used during spawning [3], while invertebrates exhibit both behavioural changes and physiological stress responses when exposed to elevated noise levels [4]. These findings highlight the broad ecological relevance of underwater noise across trophic levels.

Despite this evidence, mitigation efforts have progressed slowly. The International Maritime Organization (IMO) updated its guidelines for reducing underwater radiated noise (URN) in 2023, but these recommendations remain voluntary [5]. Regional initiatives, including those under HELCOM in the Baltic Sea, have introduced action plans; however, they lack mandatory enforcement mechanisms [6]. As a result, implementation depends largely on voluntary uptake.

Market-based instruments have demonstrated potential to accelerate environmental improvements in shipping. Schemes such as the Clean Shipping Index, the Environmental Ship Index, and port fee reductions in Vancouver provide financial incentives for vessels that meet certain environmental criteria. However, these systems do not rely on direct measurements of underwater noise.

Several initiatives have advanced large-scale monitoring of ship noise. Programmes such as the ECHO initiative outside Vancouver [7], the MARS project in the St. Lawrence Estuary [8], both in Canada, and the EU LIFE-PIAQUO project [9], have deployed measurement stations capable of capturing vessel noise signatures and is some cases linked them to policy or incentive frameworks. These efforts demonstrate the feasibility of combining measurement with management strategies, but they have primarily focused on deep-water environments.

Many shipping routes and ports in Europe operate in shallow waters, where sound propagation differs significantly due to boundary interactions and environmental variability. Existing international standards for URN measurements [10][11] address deep-water conditions, while ISO 17208-3 extends guidance to shallow-water environments [12]. Building on this emerging framework, the InciteShip project develops a system specifically designed for autonomous, long-term measurements in shallow coastal waters. By coupling these measurements with an incentive model, the project aims to enable effective reduction of ship-generated underwater noise.

2 Methods

2.1 The InciteShip project

The InciteShip project aims to reduce underwater radiated noise (URN) from ships by integrating direct acoustic measurements with an incentive-based framework. The project focuses on developing a system that not only quantifies vessel noise emissions but also translates these measurements into actionable drivers for mitigation.

To achieve this goal, the project pursues several key objectives. It develops and validates autonomous buoy systems capable of measuring ship noise in shallow-water environments. It also establishes an ecological assessment approach that links measured URN signatures to impacts on marine mammals, fish, and invertebrates. Based on this assessment, the project designs an incentive model that, with further developments, can be incorporated into the Clean Shipping Index, enabling financial mechanisms to reward quieter vessels. All system designs, software tools, and methodologies are made openly available to facilitate replication and encourage broader international adoption.

The project runs from 2024 to 2026 and brings together partners from research institutes and industry. These include IVL Swedish Environmental Research Institute, FOI Swedish Defence Research Agency, SMHI Swedish Meteorological and Hydrological Institute, and the Clean Shipping Index organisation. The shipping companies Terntank and Stena Teknik contribute to testing and validation activities. The Swedish Transport Administration (Trafikverket) funds the project.

2.2 Measurement system

The InciteShip system targets autonomous and cost-efficient operation in shallow-water environments. It comprises two main components: a sea-based measurement unit and a land-based processing unit.

The sea unit consists of a surface buoy installed adjacent to a shipping lane and secured to the seabed by an anchoring system. Solar panels supply primary power that is sufficient to power a sea unit at least during the summer period of May to September. Onboard batteries provide energy storage to ensure continuous operation during hours of darkness and extended low sunlight periods. Three seabed-mounted Colmar GP1280 hydrophones connect to the buoy via cables with lengths of up to 500 m, allowing flexible positioning relative to the shipping route (Figure 1). A stainless steel container houses electronics, and a second similar container houses batteries. The system design prioritises low power consumption, using a modular electronics and software design.

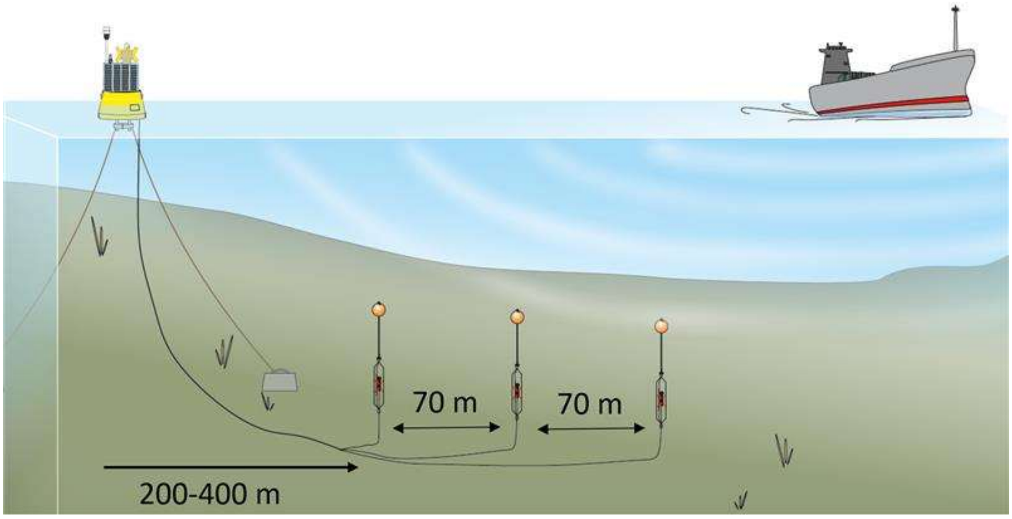

Figure 1. A schematic drawing of the measurement setup of the InciteShip system at a deployment site near a shipping lane.

The land unit receives data transmitted from the buoy through an encrypted 4G communication link. It processes the incoming signals to estimate source level spectra using transmission modelling techniques. The system stores these spectra together with vessel information derived from the Automatic Identification System (AIS), along with additional metadata, in a central database. Although the system can record raw acoustic signals, it typically converts recordings into hybrid centidecade spectrograms—using up to 100 frequency bands per decade—before transmission. This approach reduces both energy consumption and communication bandwidth requirements while retaining essential acoustic information.

The system initiates recordings based on AIS data analysis. It continuously monitors vessel movements and predicts when ships will pass within a predefined range suitable for accurate measurements. When these criteria are met, the system automatically starts recording. Operators can configure which vessel types or individual ships to include, and they can modify system settings remotely via the land unit. The system can also initiate background recordings when no ships are near, make recordings according to a predefined schedule, and allow manual recording control.

Measurement geometry varies with site conditions. At the Gothenburg location, where water depths range from 25 to 35 m, hydrophones were positioned approximately 50, 120, and 190 m from the centre of the outbound shipping lane. At the Södertälje site, with depths of 40 to 50 m, hydrophones were placed at distances of about 20, 90, and 160 m from the lane centre.

A graphical dashboard was developed to facilitate data inspection and quality control. It allows simultaneous presentation of centi-decade spectrograms or a recording (Figure 2) and AIS tracks captured during the recording (Figure 3). Recordings are triggered by AIS data from passing vessels and are initiated when a vessel comes within a pre-defined “recording range”, typically 2000-3000m. Vessels also need to pass within a pre-defined smaller “trigger range”, typically 200-250m, to be recorded.

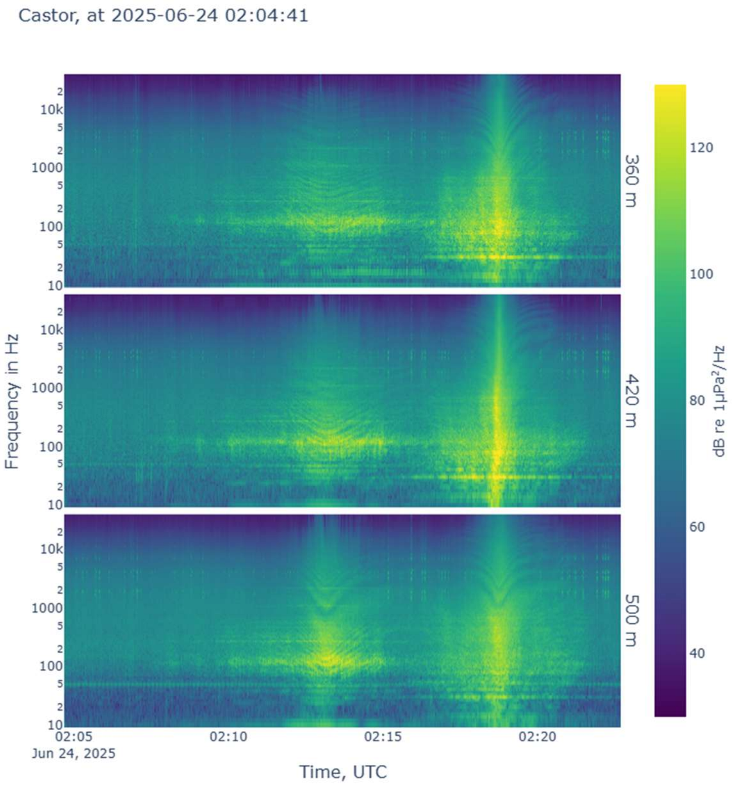

Figure 2. The InciteShip dashboard spectrogram display, showing a spectrogram of the recording from each of the three hydrophones. Here we see ship passages at approximately 02:13 and 02:18 UTC.

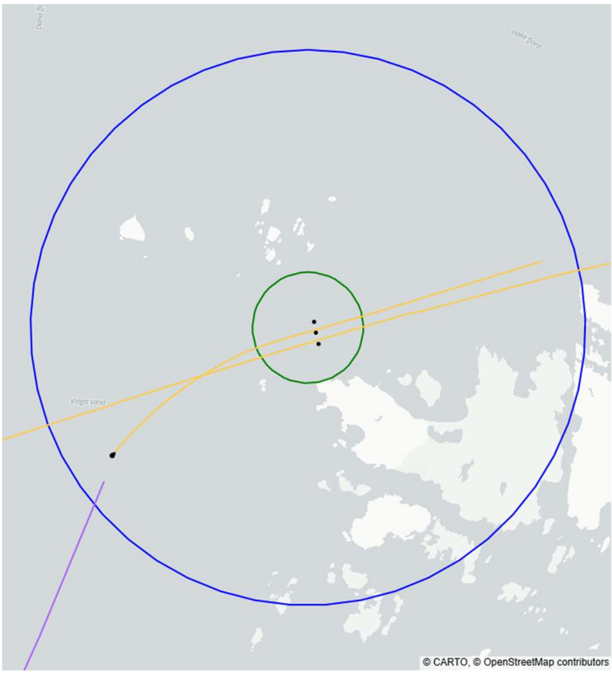

Figure 3. The InciteShip dashboard ship track display shows the ship movements in the vicinity of the sea unit. Here we see two ships (yellow) passing the hydrophones (three black dots). The graph also indicates the trigger range (green) and the recording range (blue).

2.3 Incentive system

The Inciteship project assigns ecological scores by auditory weighting and normalisation within vessel categories. A vessel source level signature, expressed as radiated noise level (RNL), is weighted for auditory sensitivity across different animal groups [13][14] (Figure 4).

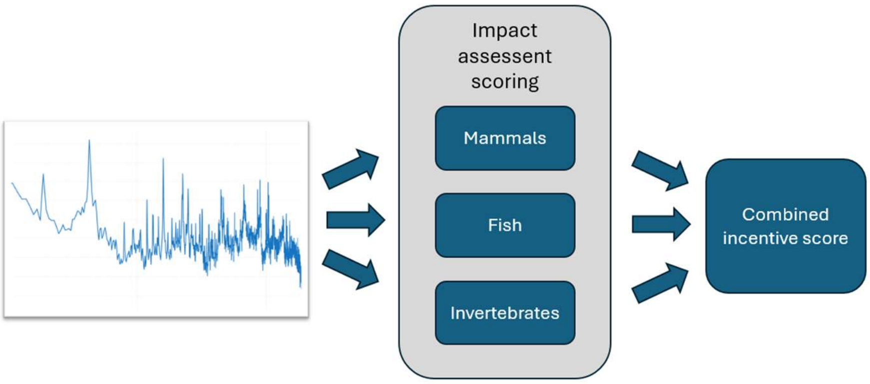

Figure 4. Auditory weighting of a vessel's source level spectrum for different taxa generates an incentive score.

3 Results

The initial deployment phase was carried out during the summer of 2025, when two measurement systems were installed along the Swedish coastline. One buoy was positioned near the main shipping channel leading to the Port of Gothenburg (57°39.071′N, 11°43.703′E; Figure 5), while the second buoy was deployed south of Södertälje harbour (58°46.144′N, 17°47.323′E). The Södertälje system was installed on 19 May 2025, followed by the Gothenburg deployment on 12 June 2025. Both systems remained in operation until September 2025, when they were recovered. Installation required a crane with a lifting capacity of at least 500 kg and typically took between two and three hours to complete on site.

Throughout the deployment period, the systems recorded more than 2700 vessel passages in Gothenburg and approximately 1100 in Södertälje. Both installations operated continuously until the beginning of September 2025, demonstrating stable performance under field conditions. There were some minor operational issues, but the only major problem involved a malfunctioning tether at one of the sites. The project will assess the repeatability and accuracy of the derived source signatures during the extended measurement campaign planned for summer 2026.

During the 2025 campaign, the 4G communication links remained permanently active to facilitate system monitoring, fault detection, and software updates. Although this operating mode exceeded the original power budget assumptions, both systems sustained continuous operation using only solar energy. This outcome indicates that the system design includes sufficient energy margins to support reliable long-term deployment.

Figure 5. The InciteShip sea unit, deployed at the Gothenburg measurement site during the summer of 2025.

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