



D3.2 Extended Functions and Services

To facilitate gear recovery and potentially support marine mammal friendly “ropeless” fishing operations, UNEW, SF and INESC TEC will investigate designs for an optional low-cost release mechanism that can be activated by tag on reception of a secure acoustic command from the surface. This would, for example, be capable of releasing a small buoy and line to float to the surface. Previous work by UNEW in collaboration with marine biologists proven that the acoustic transceiver circuits, via additional software algorithms, can implement echolocation click detection and classification to sense the proximity of many cetacean species (e.g. dolphins). We will investigate how this can be exploited to reduce harmful bycatch in nets by using this to activate a short term, targeted acoustic and/or optical emission by the device in order to alert nearby animals to the hazard of a net, mooring line or other fishing gear.

Document Information

Grant Agreement no. 101112812

Call ID	HORIZON-MISS-2022-OCEAN-01
Project Name	Preventing, Avoiding and Mitigating Environmental Impacts of Fishing Gears and Associated Marine Litter
Project Acronym	NETTAG+
Project Website	https://nettagplus.eu/
Deliverable ID	D3.2
Work Package Reference	WP3
Due Date of Deliverable	30/04/2025
Submission Date	30/04/2025
Dissemination Level	PUB
Lead Partner	UNEW
Participating Partners	UNEW, SF, INESC TEC

Quality information and Revision History

Version	Authors	Date
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Summary NETTAG+ Project

NETTAG+ aims to provide a portfolio of three innovative smart and sustainable solutions to address the negative impacts of abandoned, lost or otherwise discarded fishing gear (ALDFG) on marine life and habitats. NETTAG+ will be based on synergistic activities between the fisheries industry, scientists and NGOs to develop three solutions to PREVENT, AVOID and MITIGATE the harmful impacts of ALDFG.

NETTAG+ will PREVENT marine litter derived from fisheries activities, AVOID loss of fishing gears, and MITIGATE harmful impact by removing existing ALDFG. These three solutions will jointly contribute to reduce ALDFG and marine pollution, namely by: reducing the introduction of hazardous chemicals and microplastics originating from ALDFG; reducing ghost fishing, bycatch and entanglements of sensitive or endangered species on ALDFG; and improving mapping, tracking and recovery technologies to retrieve ALDFG.

NETTAG+ aims to upgrade and upscale the integrative preventive approach that started in the previous NetTag project, and aims to replicate it in Mediterranean regions, providing the fisheries industry with three smart and environmentally-friendly solutions to reduce ALDFG and prevent the environmental impacts of fishing gears. The three solutions will be developed to maturity (TRL 7-8) by the end of the project, and will be tested, validated and demonstrated in real conditions in Atlantic and Mediterranean countries, namely Portugal (PT), United Kingdom (UK), Spain (SP), Italy (IT), Croatia (HR) and Malta (MT). NETTAG+'s ambition is to change the paradigm of the fisheries industry, aspiring to transform the societal perspectives about the role of fishers as Guardians and Cleaners of the Ocean. NETTAG+ will empower the sector to take effective actions to address marine pollution, promoting their role as key actors to tackle marine pollution.

Contents

Contents	3
Executive Summary	5
1 Acoustically activated release mechanism for ropeless fishing	6
1.1 Ropeless fishing system concept	6
1.2 Release system design	7
1.3 Field testing and demonstration	8
1.4 Conclusions and future work	8
2 Cetacean detection by passive acoustic monitoring (PAM)	10
2.1 Introduction	10
2.2 Target signal characteristics	11
2.3 Click detection algorithm	12
2.4 Whistle detection algorithm	14
2.5 Real-time hardware implementation and testing	16
2.6 Conclusions and future directions	19
3 Acknowledgements	20
References	21

Tables

Table 1. Detection performance of low energy click detection algorithm	13
Table 2. Performance of whistle detector compared to commonly used PAMGUARD software	15

Figures

Figure 1. Acoustic release concept for ropeless fishing.	6
Figure 2. Components and subsystems of prototype NETTAG+ release system	7
Figure 3. (top left) Deployment of system on lobster trap (note: protruding pole added to hold camera for underwater footage and not part of system), (top right) underwater view of release unit on seabed, (middle left) release unit activated, (middle right) arrival on surface, (bottom left) retrieval of thin release line, (bottom right) recovery of trap via equipment line.	9
Figure 4. Spectrogram (time-frequency) view of bottlenose dolphin click trains and whistles	11

Figure 5. Spectrogram view of click trains showing variation in signal bandwidth with distance and orientation of the animal.	12
Figure 6. Signal processing steps for dolphin click detection algorithm.	12
Figure 7. Example spectrogram of detected click train.	13
Figure 8. Signal processing steps in low energy whistle detector.	14
Figure 9. Spectrogram views of 9 separate detected whistles (shaded region indicates where first detection occurred).	16
Figure 10. Target hardware platform for real time click detector.	17
Figure 11. NanoPAM Live demonstration unit: (left) circuit and battery, (right) waterproof housing containing circuit and battery with receiving hydrophone and connector to radio antenna.	17
Figure 12. Deployment of prototype click detector system from surface buoy with radio transmitter. .	18
Figure 13. Plot of first week of received click detector data (each dot indicates the time and ICI of a detected dolphin click train).	18

Executive Summary

Technology demonstrators have been designed and constructed to add the following additional functionality to NETTAG+ transponder systems:

- An acoustically activated release mechanism to enable ropeless fishing operations (deployment and recovery of unattended fishing gear without the need for moorings/surface buoys that are a hazard to marine life).
- Passive acoustic detection to provide warning to fishers of the presence of cetaceans e.g. dolphins. This has the potential to reduce bycatch risk if evasive action or targeted deterrent measures are taken.

These technologies have been developed with the same low cost and low power philosophy as the NETTAG+ transponders and successfully tested in relevant environments to achieve TRL 6.

1 Acoustically activated release mechanism for ropeless fishing

1.1 Ropeless fishing system concept

To increase the potential for the NETTAG+ acoustic transponder technology to reduce impact on marine life, this task aimed to create a robust, low-cost release mechanism that could enable ropeless fishing operations. This release mechanism is activated by a command sent using the acoustic transceiver in the surface locator unit (SLU) of the standard location system. The key properties of this design are:

- The same acoustic protocol and tag circuitry are used to receive the release command.
- Upon receiving this command, a mechanism is activated to release the electronics unit (containing all NETTAG+ transponder/release circuits and battery). This ensures that even if the gear cannot be retrieved, the valuable electronics is retrieved and does not itself become marine litter.
- The above unit includes enough buoyancy to float it to the surface along with a line for recovery of the attached fishing gear (e.g. lobster traps).

Figure 1 illustrates the concept and retrieval process using an SLU on the recovering vessel to trigger the release system.

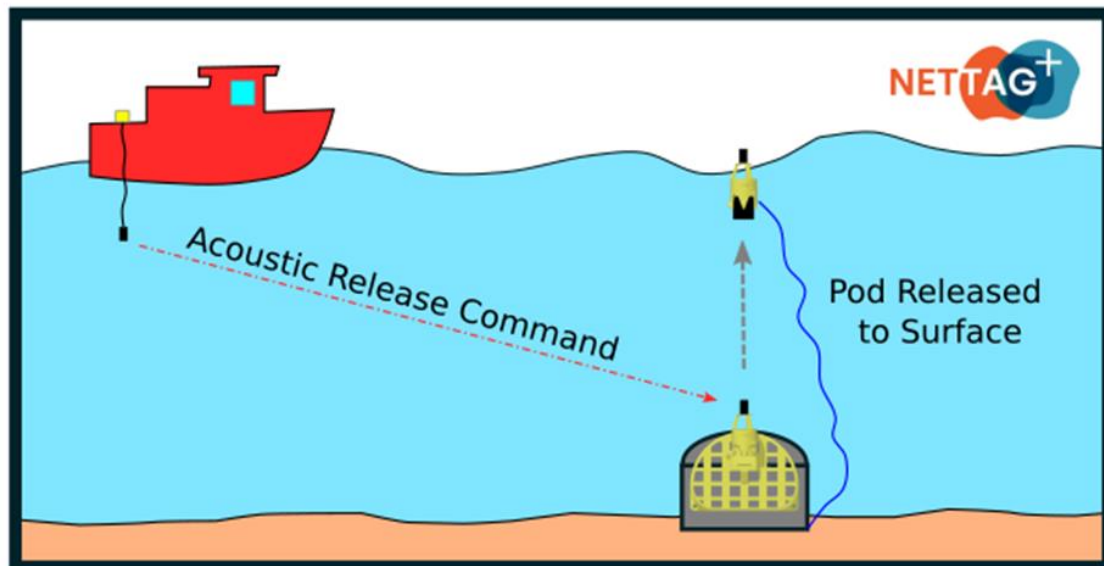


Figure 1. Acoustic release concept for ropeless fishing.

As stated in the proposal, this system was to be developed to TRL 6 (Technology demonstrated in relevant environment) within Task 3.2.

1.2 Release system design

The prototype release mechanism is contained within a waterproof housing which has a depth rating of 150m, with additional buoyancy added. In a future production system this would be incorporated in a modified NETTAG+ transponder housing. The components of the release mechanism are shown in Figure 2 and are described below:

- An acoustic modem, functionally identical to the NETTAG+ transponder, is used to receive a uniquely addressed command to activate the release mechanism. The same device also supports location by the standard NETTAG+ protocol/method.
- A strong permanent magnetic in the bottom of the housing holds the device in place by attraction to a steel plate in the base (attached to the gear).
- The magnet is linked to a DC motor with a worm drive to achieve linear actuation. Despite the small dimensions and low power of the motor, the gearing provides sufficient force to pull the strong magnet away from the steel plate.
- When the acoustic command is received, the motor drive circuit is activated, pulling the magnet upwards and when the magnetic pull force is lower than the buoyancy the whole device floats upwards. An indicator light, to aid location of the device on the surface in low light conditions, is also activated at this point.
- A thin “release” line uncoils until the device reaches the surface, after which a stronger “equipment” line (rope) can be lifted to the surface to retrieve the gear.

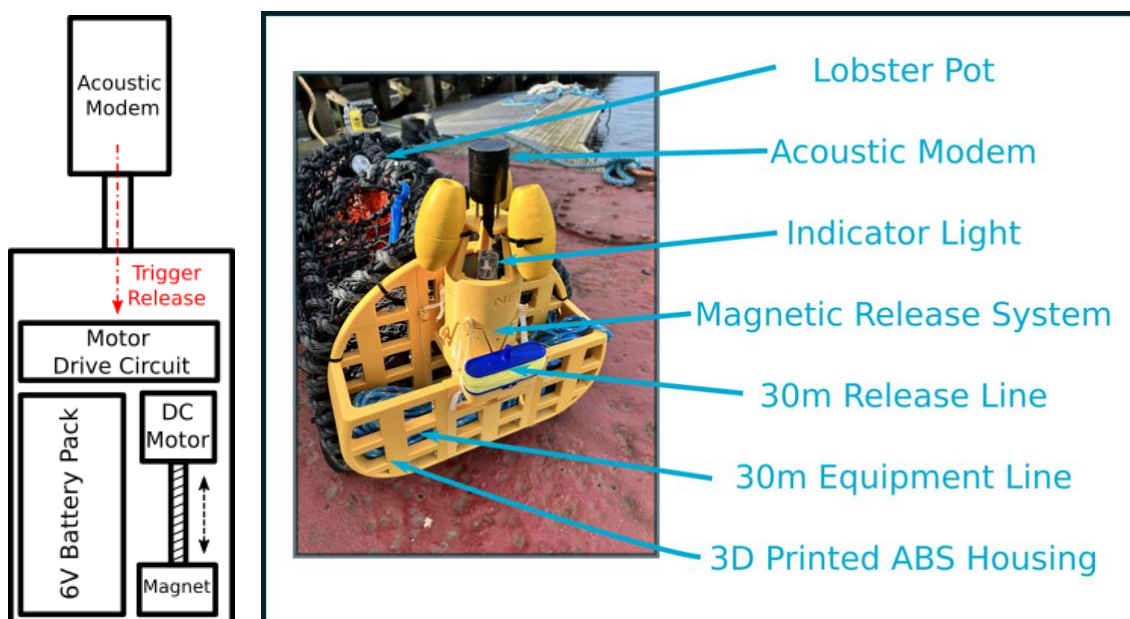


Figure 2. Components and subsystems of prototype NETTAG+ release system.

The magnetic fixing/release mechanism automatically resets itself, ready to be redeployed once the two lines, release and equipment, have been reset. For optional further security during deployment, tying with readily available dissolving string (PVA) was found to be an effective way to temporarily lock the release mechanism for a period of a few minutes.

All components and materials used have been chosen to be low-cost but high-performance. The yellow construction in the image below is a custom design that has been 3D printed in ABS material. The prototype system is designed to easily retrofit to a lobster pot with just a few heavy-duty cable ties as shown in Figure 2. The compact design has also been created to minimise disruption to the end users' valuable vessel deck space.

1.3 Field testing and demonstration

Figure 3 shows the process of deployment and retrieval by hand in estuary of the River Blyth, Northumberland, UK in a depth of approximately 12 m. The system is attached to a standard lobster trap and thrown into the sea for deployment, simulating realistic deployment and the robustness of the system. Underwater footage, from the camera attached, shows the trap settled on the seabed and ready for retrieval. After the acoustic command is issued from the SLU we see the unit detaches and floats to the surface carrying the low diameter release line. This is recovered until we obtain the heavier equipment line which is used to recover the entire gear. The above process has been successfully repeated multiple times including leaving the system in the water for up to 3 days before retrieval. Each time the magnetic fixing/release mechanism reset itself automatically for the next deployment.

1.4 Conclusions and future work

An effective release mechanism has been designed and prototyped using the NETTAG+ acoustic transponder technology for remote activation. This has been successfully applied to a standard lobster trap, demonstrating ropeless deployment and retrieval in a relevant marine environment. Future work will include testing and demonstration in deeper water and design of a fully integrated unit in an extended NETTAG+ housing, in conjunction with SF, with a view to commercialisation.



Figure 3. (top left) Deployment of system on lobster trap (note: protruding pole added to hold camera for underwater footage and not part of system), (top right) underwater view of release unit on seabed, (middle left) release unit activated, (middle right) arrival on surface, (bottom left) retrieval of thin release line, (bottom right) recovery of trap via equipment line.

2 Cetacean detection by passive acoustic monitoring (PAM)

2.1 Introduction

In Task 3.2, we have investigated the feasibility of detecting cetaceans (dolphins, porpoises or whales) in real time via their echolocation click trains and/or their vocalisations for communication (e.g. whistles), and integrating this functionality into the low cost, low power acoustic transceiver circuitry of the NETTAG+ devices. The potential use cases for this technology to help reduce bycatch are:

- Incorporation of cetacean detection into the NETTAG+ surface location unit (SLU) to provide live alerts of animals present in the area of fishing operations.
- Incorporation of cetacean detection in the NETTAG+ transponder units (installed on fishing gear) to activate a targeted acoustic and/or optical deterrent.

Within the scope of this limited Work Package it was not possible to consider all cetacean species and so the work has focused on bottlenose dolphins commonly occurring in the North Sea (*Tursiops truncatus*). However, their click and whistle characteristics are representative of many dolphin species around the world and the same technology could operate in other regions with little or no software modification.

Also, within the scope of this limited Work Package and timescale it was not feasible to investigate the effectiveness of specific deterrent methods in reducing bycatch. The difficulties in quantifying bycatch reduction by any method are well documented, and there is also a significant risk of unintentionally increasing bycatch by some deterrent methods. For this reason, the work carried out here focused only on the reliable *detection* of cetaceans as an enabling technology to increase the effectiveness and reduce negative impacts of bycatch reduction methods developed by other researchers in marine biology/ecology.

Nevertheless, substantial progress has been made in developing such detection methods within this Work Package. Computationally efficient algorithms for the detection of dolphin echolocation click trains and whistles by passive acoustic methods have been developed and rigorously tested on hydrophone recordings from the North Sea. These algorithms have been implemented in real time on a low power ARM microprocessor similar to that used in the NETTAG+ devices, using the same acoustic transducer element to receive click and/or whistle signals. A prototype dolphin click detector (named “NanoPAM Live”) has been successfully demonstrated in the North Sea with a live feed of detection data via radio communication.

2.2 Target signal characteristics

Figure 4 shows a spectrogram view of typical acoustic signals recorded in the North Sea, showing both clicks and whistles from several bottlenose dolphins. Most energy in the whistles signals is between 5 – 20 kHz frequency, although harmonics of this can appear at higher frequencies. Click trains appear as vertical lines (short, broadband signals) with most energy above 20 kHz and extending as high as 150 kHz [1]. We see a mixture of low rate click trains, used for navigation and finding targets, and high rate click trains, used when the animal is homing in on a close target/prey.

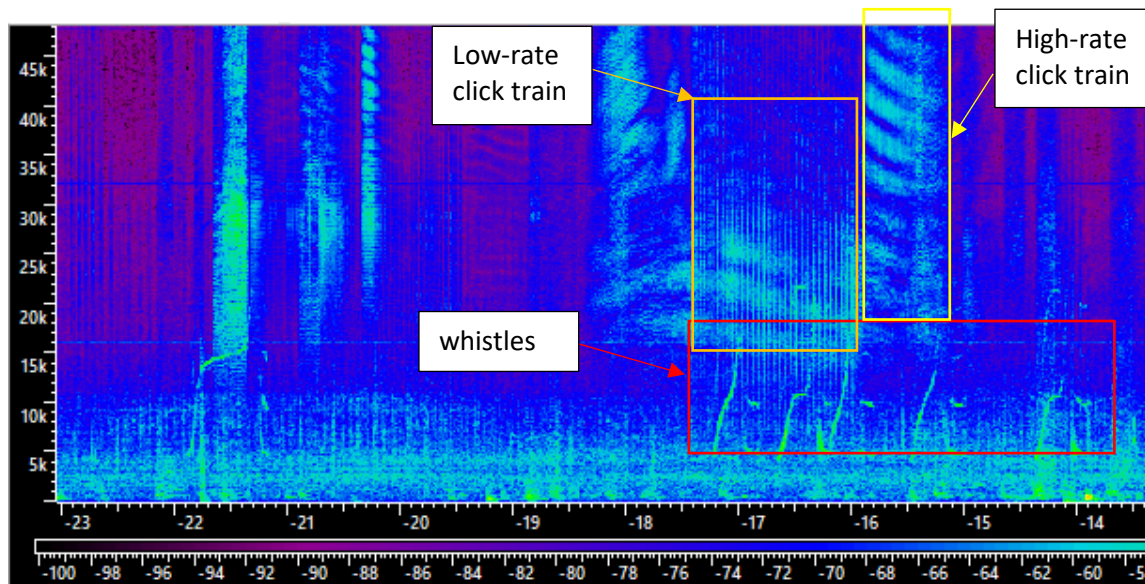


Figure 4. Spectrogram (time-frequency) view of bottlenose dolphin click trains and whistles.

Although dolphin clicks have a very broad spectrum when observed from short range and when the animal is facing the receiver, a very different spectrum is typically observed when the animal is further away, since higher frequencies are greatly attenuated with range [2]. Also, if the animal is not directly facing the receiver, the bandwidth is reduced as the emitted sonar beam is highly directional and frequency dependent [3]. This is illustrated in Figure 5 where we see substantial reduction in the maximum frequency visible in each click as an animal moves further away or turns away from the receiver.

Due to the above phenomena, our work suggests that the maximum detection range/probability and overall signal to noise ratio on bottlenose dolphin clicks is obtained by measuring in the 20 – 40 kHz frequency band. This lends itself to a low complexity and power efficient detector design as sampling rates can be greatly reduced compared to sampling the full theoretical source spectrum of the animal. Likewise whistle detection was best performed in the 5 – 20 kHz band.

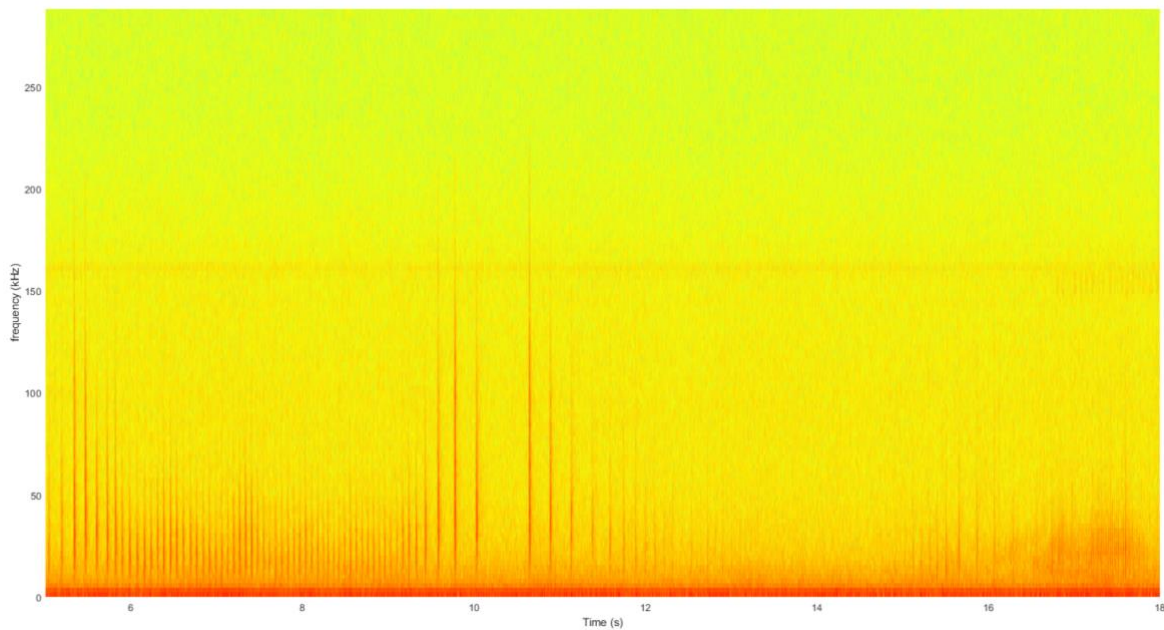


Figure 5. Spectrogram view of click trains showing variation in signal bandwidth with distance and orientation of the animal.

2.3 Click detection algorithm

The signal processing operations for the click detection algorithm are summarised in Figure 6 .

The algorithm works by:

1. Filtering to the optimum bandwidth and detecting the envelope of the signals.
2. An adaptive thresholding process is used to find and timestamp individual clicks.
3. Each click is analysed to measure its time duration (= bandwidth) to enable discrimination of narrower band man-made sonar pings.
4. The inter-click intervals (ICI) are analysed by regression to identify structure (periodicity) in the click patterns.
5. Thresholds are applied on the ICI regression statistics and pulse durations to identify dolphin click trains.



Figure 6. Signal processing steps for dolphin click detection algorithm.

Evaluation of this algorithm was carried out working in conjunction with marine biologists/bioacousticians at UNEW who have previously created large, manually annotated datasets of dolphin click trains and whistles in the North Sea. Signal recordings were passed through an offline version of the detection algorithm (in MATLAB) to assess detection performance in terms of true positive detection rates and false positive (false alarm) rates. Each detected click train is displayed as a spectrogram to enable further corroboration by the user, an example of which is shown in Figure 7.

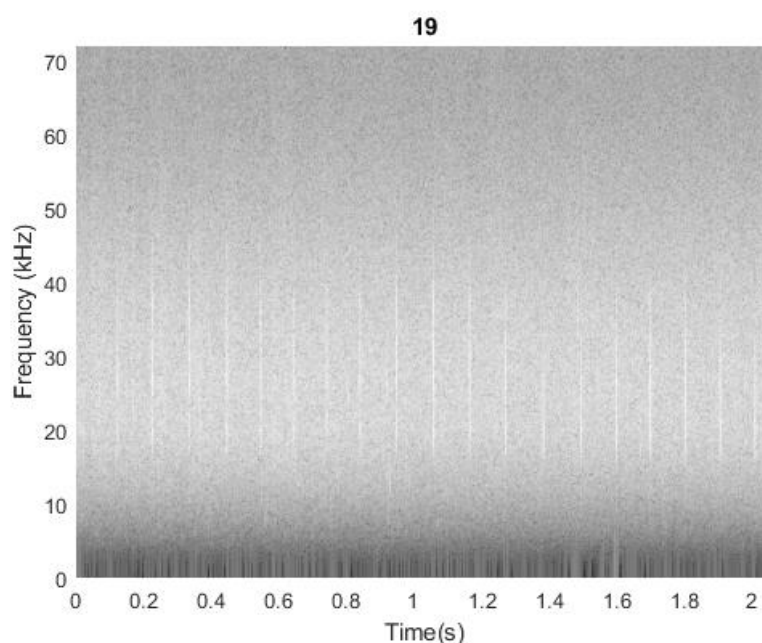


Figure 7. Example spectrogram of detected click train.

Table 1. Detection performance of low energy click detection algorithm.

	Detection positive minutes
True Positive	140 (92.1 %)
False Positive	0 (0%)
True Negative	568
False Negative	12

Table 1 summarises the performance of the detection algorithms on an example dataset consisting of 12 hours of rigorously annotated recordings from the North Sea. Data is analysed in terms of detection positive minutes (i.e. have animal(s) been detected or not in each minute of the recording period). The click detector achieved 92.1% true positive rate (140 out of 152 positive minutes) and 0 % false positive rate. Whilst higher detection (true positive) rates are

achievable with different filter settings and/or lower thresholds, it is critical to maintain practically zero false positive rate to provide confidence in any reporting of cetacean occurrence. This has been further verified with many more hours of recordings including vessel traffic, sonars and varying weather conditions.

This click detection algorithm has been implemented in real-time on a low cost/low power hardware platform very similar to the NETTAG+ devices and this is described in section Real-time hardware implementation and testing2.5.

2.4 Whistle detection algorithm

The signal processing steps in the whistle detection algorithm are described in Figure 8. This algorithm operates as follows:

1. The signal input to the click detector is low-pass filtered and decimated to a sampling frequency of 48 kHz to reduce the computational load.
2. A Short Sime Fast Fourier Transform (STFFT) is applied to produce spectrogram data, selecting on the frequency bins representing 5 - 20 kHz.
3. A “background subtraction” process, effectively a high-pass filter on each frequency bin, is applied to remove any persistent spectral lines or other background features.
4. The STFFT data, after background subtraction, is analysed to extract the frequency with most energy (peak frequency) for each time period as well as a peak-to-average ratio (indicative of Signal to Noise Ratio).
5. Regression analysis is then applied, over a moving window of ~ 100 ms, to detect clear spectral lines that sweep up or down in frequency.
6. Thresholds are applied to the regression statistics (fit error, gradient) and peak-average ratio to decide if a whistle is present.

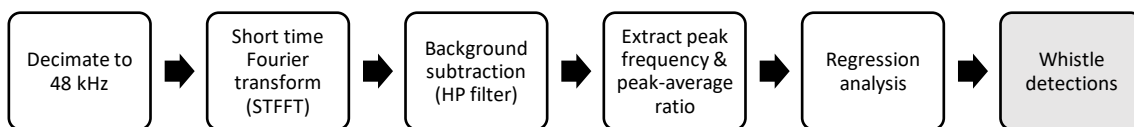


Figure 8. Signal processing steps in low energy whistle detector.

As with the click detector, the whistle detector was evaluated against manually annotated datasets provided by bioacousticians, comparing against ground truth and an industry standard passive acoustic monitoring software tool known as PAMGUARD [4]. The algorithm performed

very well in this test, detecting 11 out of 13 possible whistles with zero false detections. Table 2 summarises this performance. This also slightly outperformed the PAMGUARD tool in this test (also note that unlike the algorithm developed in this work, the PAMGUARD tool is not suited to direct porting onto very low power microprocessor platforms). Figure 9 shows example spectrogram views of detected whistles (from a different data set).

Table 2. Performance of whistle detector compared to commonly used PAMGUARD software.

	UNEW Whistle detector	PAMguard
True Positive	11	9
	84.62%	69.23%
False Positive	0	0
	0.00%	0.00%
True Negative	707	707
	100.00%	100.00%
False Negative	2	4
	15.38%	30.77%

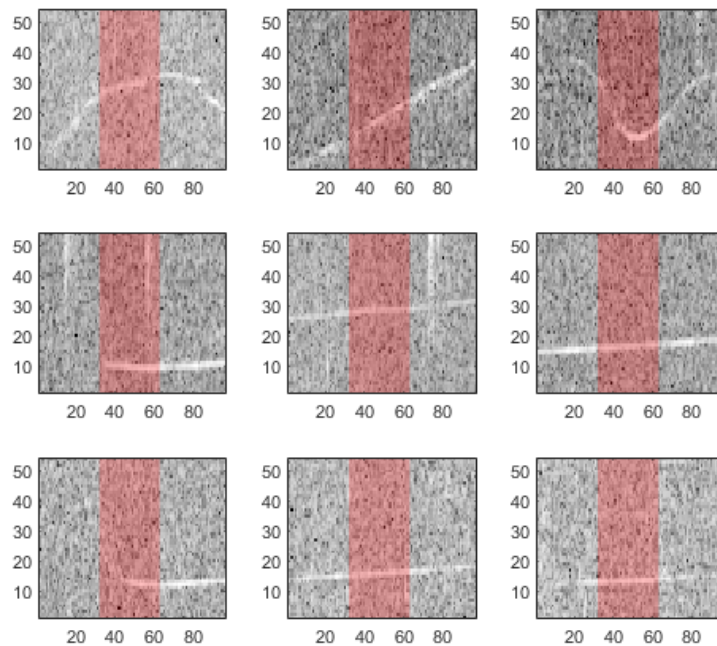


Figure 9. Spectrogram views of 9 separate detected whistles (shaded region indicates where first detection occurred).

2.5 Real-time hardware implementation and testing

An existing acoustic processing board (described in Figure 10), using the same family of ARM microprocessors used in the NETTAG+ location devices, has been adapted to provide a platform for real time implementation and testing of the dolphin click detector algorithm of section 2.3. This is connected to the same low cost PZT ceramic transducer and similar front end circuitry to the NETTAG+ devices, paving the way for shared functionality in a future NETTAG+ SLU. To enable long term testing (as dolphins cannot be expected to be present during a short experiment on a vessel), this demonstrator unit also incorporates a LoRa radio module to enable detection data to be transmitted back to UNEW's shore station. The packaged unit is pictured in Figure 11 with receiving hydrophone and a waterproof connector to connect the radio

antenna. Power consumption of the click detector unit is measured at 13 mW which is almost identical the NETTAG+ transponder in its listening state.

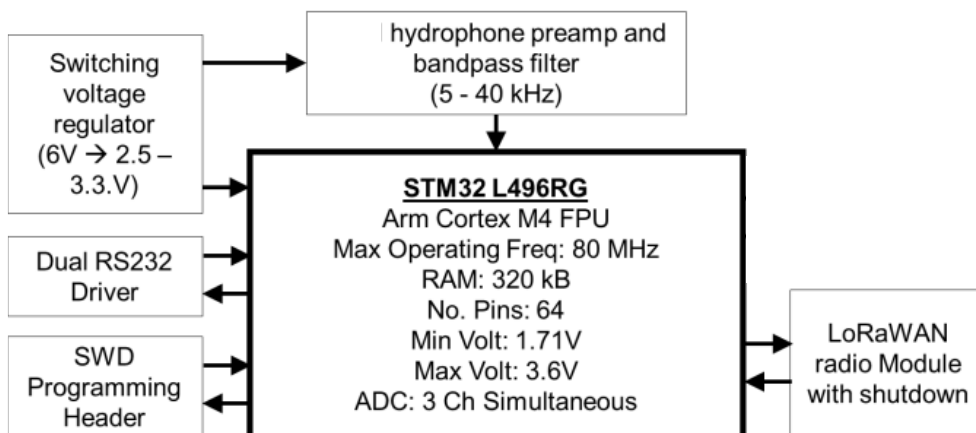


Figure 10. Target hardware platform for real time click detector.



Figure 11. NanoPAM Live demonstration unit: (left) circuit and battery, (right) waterproof housing containing circuit and battery with receiving hydrophone and connector to radio antenna.

On 1st April 2025 the prototype detector unit was deployed in the North Sea approximately 3km out from the Port of Blyth, Northumberland, UK. This area has almost daily bottlenose dolphin sightings throughout most of the year and was hence an ideal test site. The unit was suspended approximately 5m below a tethered surface buoy, with a cable running up to the LoRA radio transmitter on the surface (as shown in Figure 12). A “Soundtrap” recorder was also attached to

the line to record raw acoustic signals and enable later offline analysis to manually corroborate dolphin detections.

North Sea trial deployment



Figure 12. Deployment of prototype click detector system from surface buoy with radio transmitter.

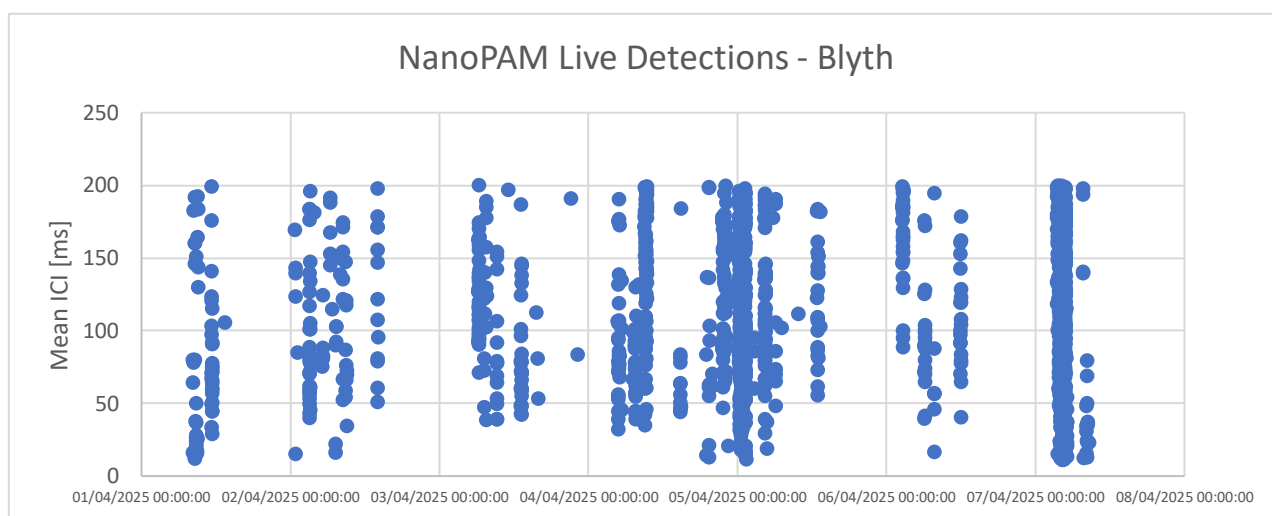


Figure 13. Plot of first week of received click detector data (each dot indicates the time and ICI of a detected dolphin click train).

Received detection data is logged on a server hosted at UNEW and a prototype web interface has been created to make updates on dolphin detections available live. An example of the first week of detection data is shown in Figure 13 and the system has been running continuously for 3 weeks at the time of writing. Clusters of detections have been reported almost every day over

this period and many of these have been in close agreement with dolphin sightings reported on social media platforms.

2.6 Conclusions and future directions

Low complexity, passive acoustic detection algorithms for both echolocation clicks and whistles have been developed and proven extensively using offline recordings of dolphin activity, with independent verification by bioacoustics/cetacean experts. Although these algorithms target bottlenose dolphin clicks and whistles, they are also applicable to other dolphin species with little or no modification. Detection of higher frequency, narrowband clicks emitted by porpoises is also envisaged with the hydrophone and front-end amplifier/filtering appropriately modified (although this could not be achieved on a standard NETTAG+ device). Detection of lower frequency calls emitted by larger whale species is also possible with similar hardware and algorithms, and the lower sampling frequencies required would enable further reduced complexity and hence power consumption. Alternatively, more sophisticated processing involving machine learning based signal classifiers may be possible for a similar energy budget.

These algorithms were designed to enable implementation on the low cost and low power processing platform incorporated in the NETTAG+ acoustic transponder system. Indeed, the click detection algorithm has been successfully implemented with almost identical power consumption to the transponder. This has been proven by a device operating in real time, reporting dolphin detections at sea, for a period of several weeks using a similar battery capacity to the NETTAG+ devices. Hence it is feasible for cetacean detection to be incorporated in either the NETTAG+ SLU or the transponder to provide additional functionality, potentially contributing to reduced bycatch in fisheries using this technology.

Furthermore, an affordable technology for long term cetacean detection and real time reporting (as demonstrated in the NanoPAM Live system) has significant commercial potential with applications in marine science, mitigation and impact assessment for offshore construction and eco-tourism.

3 Acknowledgements



**Funded by
the European Union**

Funded by the European Union under the Horizon Europe Program, Grant No. 101112812 (NETTAG+). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the granting authority. Neither the European Union nor the granting authority can be held responsible for them.



**UK Research
and Innovation**

UK partners University of Newcastle Upon Tyne and Succorfish Ltd. are funded by the UKRI under the agreement on the association of the UK to Horizon Europe (Grant No. 10066822).

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