Clean Catch

Passive Acoustic Reflectors (PARs) Progress Report

March 2025

Clean Catch
Joint Action on Sensitive Species Bycatch

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Introduction

This report covers three key areas related to the development of the Passive Acoustic Reflector (PAR) for bycatch mitigation in gillnet fisheries. First, it presents the results of a robustness trial, where PARs were tested in real fishing conditions to assess its durability and practicality at sea. Second, it outlines a proposed methodology for a fishery-independent behavioural trial to evaluate cetacean responses to the PARs, which was ultimately rejected due to identified limitations. Finally, it explores alternative next steps, including further design refinements, controlled acoustic testing, and evaluation in fishery-independent and fishery-dependent trials.

1. Passive Acoustic Reflector: Robustness Trial Report

Executive Summary

The bycatch of cetacean species in commercial fisheries is a threat to species conservation. Those within the fishing industry suffer from socio-economic effects brought about from the bycatch of cetaceans, as well as issues impacting mental wellbeing when dealing with stressful and disturbing events in their fishing occupation.

As part of the Clean Catch programme funded by Defra to design bycatch mitigation devices for use within fisheries, a passive acoustic reflector (PAR) was designed and prototypes manufactured. This PAR was comparatively designed against a commonly used fishing float, with the addition of reflective properties designed to make it more acoustically visible to echolocating cetaceans. The first batch of these PAR was manufactured in 2024, and before any testing could occur on potential behavioural effects to cetaceans, the design had to go through robustness testing to assess its suitability to be used at sea. This report summarises the results of the robustness testing, which occurred between August 2024 and January 2025. A volunteer vessel, fishing using gillnets was rigged with 19 PARs over a 100m length of net, and after 32 deployments assessment was made on how the PAR had performed at sea within an active fishery.

After recovering and assessing the PAR from the fisher at the end of the trial, we observed: 1) the materials used successfully withstood the mechanical forces that are experienced at sea; 2) that failed PAR were quickly identified, and weak points in manufacture could be addressed in future; and 3) the fishermen could use the PAR without having to alter their practices, PAR did not interfere with the net to the extent that required their removal, and any issues found in deployment could be remedied with proper rigging.

Research Goal and Objective

The passive acoustic reflector (PAR) being designed and tested as part of the Clean Catch Programme (CC) had reached the point where the first batch of prototypes had been fabricated. The initial development of the PAR had seen changes to the shape and configuration of the prototype, with previous tank trials being completed to inform the most suitable design to reflect sound effectively. The PAR comprises of a solid polycarbonate wall with 90-degree angles, within is a pressure proof (100m) nitrogen-infused high density polyethylene foam that introduces acoustic scatter to bounce back sound against the walls, and return it to an echolocating cetacean.

The PAR is fabricated from four parts, an outer polycarbonate shell (2 halves) and internal foam (2 halves). These parts must be fitted together and the outer shell joined by spin welding (thermoplastic melts under high rotational speeds).

Up until this point, the fabricated PARs had not undergone testing at sea, and before any further development or trials are considered a performance and suitability test needed to be undertaken. This trial was started with the goal to observe how the current PAR design performed when integrated into the gear on an active fishing vessel. Assessments would be made on the ability of the materials to withstand the forces associated with being used as a piece of gear, as well as the ease in which a fisher could incorporate them without issue.

Methodology

Testing occurred between August 2024 and January 2025, the PARs were rigged on a volunteer vessel operating from Newlyn Harbour, Cornwall, the vessel was piloted by two skippers over the trial period. The net used is typically used to target red mullet (*Mullus surmuletus),* 100m in length, 2m tall, and with a 67mm mesh. PARs were attached to the headline rope at 5m intervals, with 19 PARs attached in total along the length of the net. The PARs were attached onto a pre-rigged net, so instead of the headline rope being threaded through the middle of the PAR, as with a typical float, 8mm polypropylene rope was threaded through and tied onto the headline rope instead.

To reduce the risk of net entanglement during deployment, nets are 'flaked' into their bins prior to shooting. This process involves separating the headline and leadline onto either side of the bin and is often done using a mechanical flaker; in this trial the process was done by hand, and so the PAR did not pass through this machine during this robustness trial. On this vessel, nets were deployed over the stern from the net bin, passing over a stainless-steel shoot. Deployment occurred at a speed of approximately 3 knots.

Nets were recovered using a hydraulic hauler (Spencer Carter NH03), comprising of three powered rollers, and a wheel that grips and pulls the net through as it is hauled aboard. Nets are deposited onto the floor of the vessel, with any catch being removed before the net is sorted back into its bin (figure 1).

Figure 1. PAR passing through the hydraulic hauler (a). PAR deposited on the deck of the boat whilst net continued to be hauled in (b).

The ability of the physical structure of the PAR to withstand these repeated processes would be assessed, with the fishermen making note of any issues encountered by integrating the PAR into regular fishing practices.

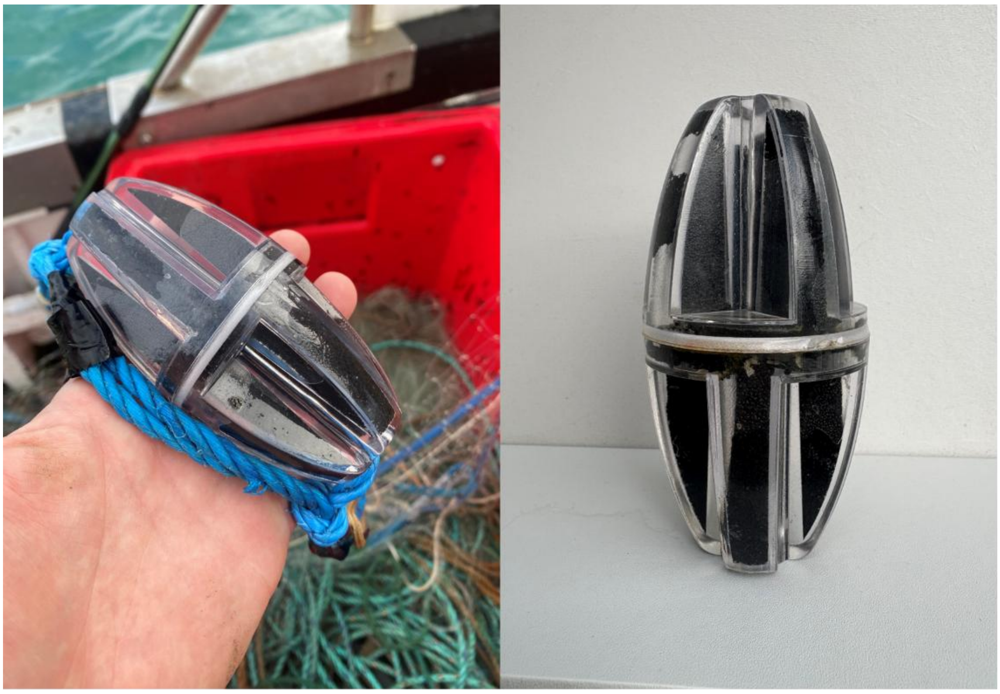
The trial was subject to prior ethical approval. This was obtained from: the ZSL Ethics Committee for Animal Research (ECAR), approved 13/05/2024 (#606 – IOZ120); and the ZSL Ethics Committee for Human Research, approved 08/07/2024. In accordance with the ethical approval participating fishers were required to read and sign a consent form to evidence free, prior informed consent.

Results

Over the course of the trial period the PAR equpped net was deployed 32 times, at a mean depth of 15m and mean soak time of 4 hours across all deployments. Of the 19 initially deployed PARs 17 remained functional at the end of the trial. Two of the deployed PARs physically failed and required removal by the fisherman (figure 2). The two failed PAR both split at the weld location between the two halves, on the first haul of the first deployment, no further damages were observed on any of the remaining PAR over the following deployments and retrievals.

Figure 2. Failed passive acoustic reflector. The PAR has split apart at the weld location between the two halves, indicating a fabrication weakness in this location.

Though the remaining PAR were physically undamaged, the fishermen observed that over repeated deployments condensation and moisture began to build within some of the PARs, and by the end of the trial period all 17 remaining PARs had some level of water ingress within the internal structure (figure 3). Along with water ingress the weld did allow for rust deposition to occur within the PAR, the level of rust was very low however, with most of the surface area remaining clear of any deposit (figure 4).



Firgure 3. Visible water ingress within undamaged passive acoustic reflectors.

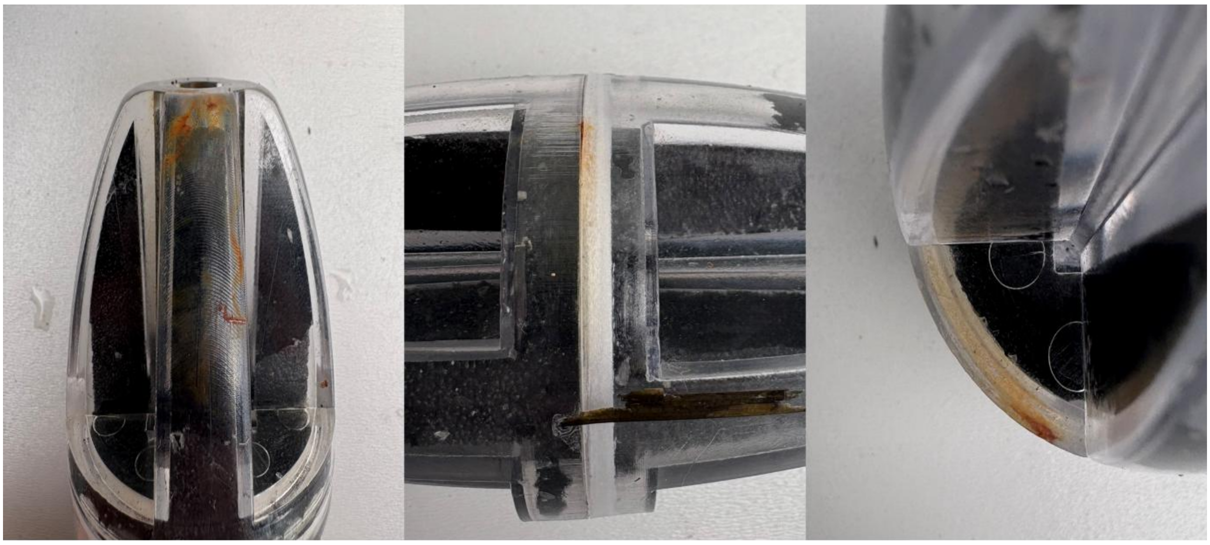


Figure 4: Rust present on the surface of the PAR, and within the area of the spin weld.

On five deployments the skippers made note of the PARs causing “hitching” or “catching” of the net filament, requiring operation to cease and the net to be unwound before being shot. During the trial no cetacean bycatch occurred in any of the PAR rigged nets, nor the non-treatment nets deployed alongside.

Discussion

Though the trial occurred over a relatively short period of time, with a limited number of deployments it was demonstrated successfully that the PARs could be used within an inshore gillnet fishery and performed adequately.

The polycarbonate shell of the PAR was able to withstand being shot and hauled, with no physical damage being observed on any of the PAR; the two failed PAR were examined and found to have a flawed weld where the two halves met. Though they had become separated, there was no indication of chips or cracks at the break site, with it being likely that a fault in the construction occurred leading to a weak join. The spin weld join between the two halves of the PAR was found to be the main area of weakness, allowing the ingress of water into the internal foam chambers. Improvements to the weld will come with changes to the rotational speeds applied during fabrication, reducing the risk of water ingress and fracture in this area. Though the materials had withstood the forces found on this particular vessel, other fishing vessels may deploy their nets differently, either at greater speeds or with the use of mechanical flakers. It is possible that on boats shooting whilst travelling at a greater speed of knots, the deployed PAR would be subject to greater physical forces as they left the net bin and interacted with the vessel structure at greater velocity. The hauling mechanism of this vessel had no issue retrieving the PAR treated nets from the water, with PAR passing safely through the rollers and gripping wheel satisfactorily. On inspection of the PAR rust deposits were found, many skippers use steel chain as end weight for their nets, the PAR would have contacted these within the net bin where the rust will have transferred from. The level of rust that occurred was not abnormal but was higher than that found on regular fishing floats. The weakness of the join allowed internal rust ingress, and strengthening this area would lower the potential for matter to encroach into the PAR. The fouling that did occur was easily removed without damage to the shell, and with 32 deployments over the course of five months the level of fouling is deemed to be low within this trial. It is noted that the soak times during this trial were limited, averaging 4 hours, other gill-net vessels may have much longer soak times and a quicker reset, meaning PAR remain in the water for longer, increasing the potential for biofouling.

Net hitching does occur in regular fishing operations without PAR, where net filaments catch on both standard fishing floats and other filament within the net bins, and its occurrence is not unusual. In discussion with the skippers taking part in this trial however it was believed to happen more frequently on the PAR treated nets. This was contributed to the post-hoc way the PAR were attached to the headline rope, with both skippers believing that there would be a reduction in net hitching if the PAR were threated onto the headline rope as intended. The possibility of detrimental PAR and net interactions may increase with an increase in mesh size; however, on this vessel the 67mm mesh was smaller than the length of the PAR meaning the possibility for the PAR to slip through the mesh was reduced. This so called “button-holing” could occur in nets of larger mesh sizes commonly used on inshore and offshore boats, increasing the potential for interference in fishing operations.

Conclusion

The passive acoustic reflector has been found able to function viably as a piece of gear alongside typical gillnetting methods in this instance, independent of any effect produced by its acoustically reflective nature. The materials and design used were able to withstand repeated deployments and hauls, along with hours spent soaking at depth. In the instances where PAR did fail the break occurred immediately in an observed weakness area (the welded joint between two halves of the polycarbonate shell). Minor modifications to the fabrication approach will address this fault. Though this is one specific vessel fishing with limited gear types, the comparative float used for the initial PAR design (Castro T0-80) is ubiquitous within fisheries. Finding the PAR viable even on a net of one mesh size provides optimism that with further testing and refined design the PAR could be used in fisheries where the float it was designed against is found.

Based on the results of this trial it is recommended that the PAR development be moved forward to begin testing to determine behavioural effects on cetaceans and potential to mitigate bycatch.

2. Passive Acoustic Reflector: Fishery-Independent Trial Feasibility Report

Executive Summary

The report provides an overview of scoping work carried out to consider the feasibility of a PARs fishery-independent trial. The proposed methodology for a fishery independent trial sought to determine **whether odontocetes (toothed whales, e.g harbour porpoises) exhibit a behavioural response to passive acoustic reflectors (PARs)**. This methodology along with a number of limitations identified were presented to the Clean Catch National Advisory Board. Following advice from the NAB and advice from subject matter experts, a decision was made to investigate other potential options to assess PARs potential to mitigate bycatch. Options for next steps are outlined in the subsequent section.

Context

Gillnets consist of a wall of monofilament mesh, hanging vertically in the water between a buoyant headline rope and a weighted foot rope. Target species are caught as they attempt to swim through the net becoming entangled at the gills. The mesh size is chosen to target specific species and size classes and is therefore selective. Gillnets may be set at the surface, midwater or on the bottom and fished statically (anchored in place) or drifting.

Odontocetes are known to be particularly at risk of entanglement in gillnets. Of particular concern in UK waters is gillnet bycatch of harbour porpoise and common dolphins. Odontocetes echolocate by emitting high frequency directional clicks and interpreting the resulting echoes, caused by reflection from objects. Echolocation is used during foraging and navigation, providing a high-resolution perception of their environment. Entanglements in gillnets are assumed to occur when odontocetes are not able to adequately perceive and avoid the net. The exact circumstances leading to entanglement are not known, for example whether individuals are more vulnerable during specific behaviours (navigation, surfacing to breath, foraging, predator avoidance), or environmental conditions (e.g. sea state, turbidity). The factors affecting entanglement risk may also vary according to how and where gillnets are deployed. For example, demersal foraging is more likely to result in entanglement with bottom-set nets, whilst surface set nets pose a risk when transiting and surfacing to breathe.

There is existing evidence that odontocetes can detect some components of gillnets, e.g. the buoyant headline rope and headline floats. However, monofilament mesh has very low acoustic reflectivity and is thought to be significantly less detectable through echolocation. Thus, it is suggested that entanglement occurs when the monofilament portion of the net is not detected or perceived as an obstacle.

A potential solution is to increase the acoustic reflectivity of the gillnet (particularly in the monofilament mesh), such that it is more readily detected and perceived as a physical barrier to be avoided. Previous experiments, in tanks and the wild, have provided some evidence that adding passive reflectors changes the acoustic reflectivity of the net (or 'dummy' net), resulting in avoidance by odontocetes treating the acoustically reflective barrier as a physical obstacle. These previous studies are limited in number, scale and have typically employed commercially available fishing floats as the passive reflector.

Acting on the suggestions of gillnet fishermen, Arribada have developed a purpose-built Passive Acoustic Reflector (PAR). The PAR is intended to replicate commercially available T80 headline floats, but with greater acoustic reflectivity in the range odontocetes echolocate. Enhanced acoustic reflectivity is achieved through high density foam inserts. The ongoing development and testing of the PAR is incorporated in the current phase of Clean Catch (2024-2026). A component of this, an initial investigation into the feasibility of a trial to assess whether odontocetes exhibit a behavioural response to these novel PARs, was delivered in conjunction with a PhD student at the University of Exeter and is the subject of this report.

Aims

The overarching long-term aim of the research and development of PARs is to determine whether the PAR can be used to reduce odontocete bycatch in gillnet fisheries. Developing and assessing the efficacy of bycatch mitigation devices in commercial fisheries is inherently challenging. Consequently, we are adopting a stepwise approach, addressing fundamental questions in a focussed and limited way, rather than a full-scale fishery dependent trial. This will allow issues to be identified and rectified (or for the PAR to be rejected as a potential bycatch mitigation device), at an earlier stage, in a more cost-effective manner. This is a practical prerequisite in the spirit of our stepwise approach. The subsequent aims for testing PARs in order of increasing ambition are:

1. Does the PAR elicit any behavioural response from wild harbour porpoises and/or common dolphins? (Initial investigate work considered in this report).
2. If, yes, does that result in avoidance, i.e. do odontocetes perceive gear rigged with PARs as a physical barrier and swim around it? (Potentially to be addressed by a modular addition to this study with support from SMRU/CIBBRiNA using a hydrophone array).
3. If, yes to 1) and 2) can that be achieved by a configuration that is realistic for a commercial fishery? (To be addressed by a future fishery dependent research).

Methodology

The overarching approach investigated for the purposes of this report was adapted from a previous study by Rosshagen et al (2023). In summary, the proposed study would employ 'dummy nets' rigged to approximately replicate commercially used gillnets but without a monofilament mesh (to avoid capture of any animals). Responses to a dummy net equipped with PARs at regular intervals would be compared to an identically rigged control (a dummy net without PARs) (Figs 1-3). Responses would be measured using continuous acoustic monitoring devices (F-PODs) capturing acoustic signals sent by echolocating odontocetes in the vicinity of control and treatment dummy nets.

Study site

The trial would be carried out in a location yet to be decided in Cornwall as our partners Cefas have long-standing relationships with fishermen in this area. Therefore, there is a precedent for similar deployments in this area with cooperation from fishermen. Additionally, this area is known to have a relatively high abundance of common dolphins and harbour porpoises maximising the likelihood of us being able to detect behavioural responses to the 'dummy' nets. The exact location of the trail within Cornwall would be chosen based on small cetacean abundance and distribution and consultation with local focus groups and the NAB.

We would deploy one treatment 'net' equipped with PARs spaced 2 meters apart vertically and horizontally (Fig 3), and one control 'net' without reflectors. Individual vertical rope lines would be connected between the float and the sink line instead of a wall of mesh, to reduce the risk of catching any protected species (Fig 3). These 'nets' would be positioned in similar locations within a trial location to be determined in Cornwall, UK, to ensure environmental consistency. The treatment and control nets would be alternated every two weeks over a period of four months, starting in June/July 2025. This rotation is intended to mitigate location-specific biases and to ensure that both nets experience a variety of environmental conditions.

Rigging of treatment and control net

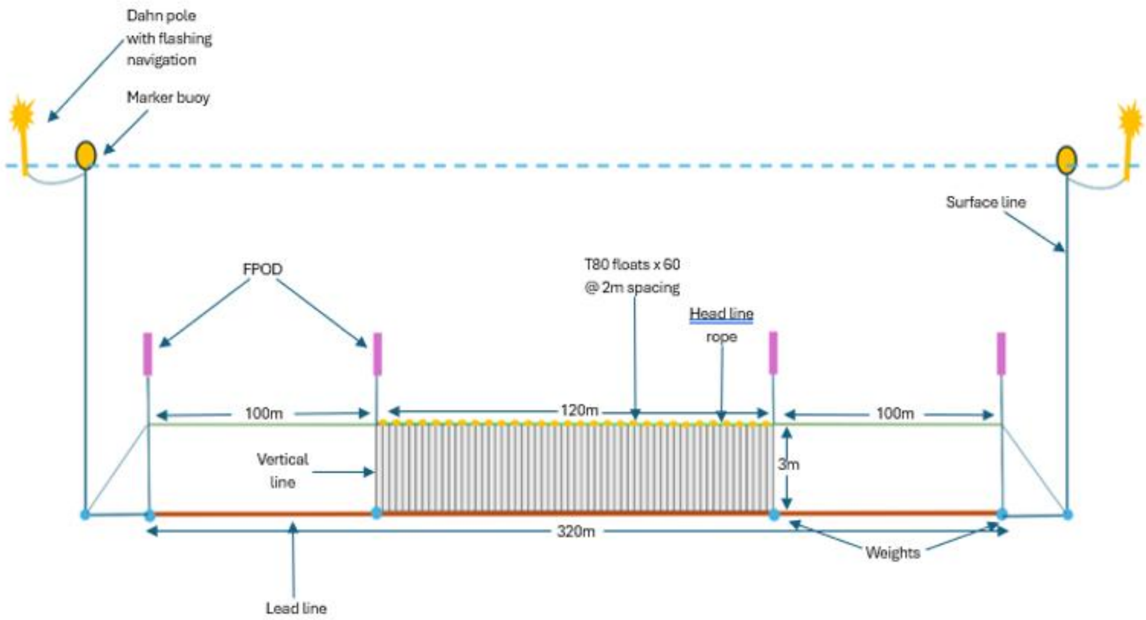


Figure 1: Schematic of the experimental set-up of the 'dummy' net. The treatment and control net would be positioned in similar locations within the study site.

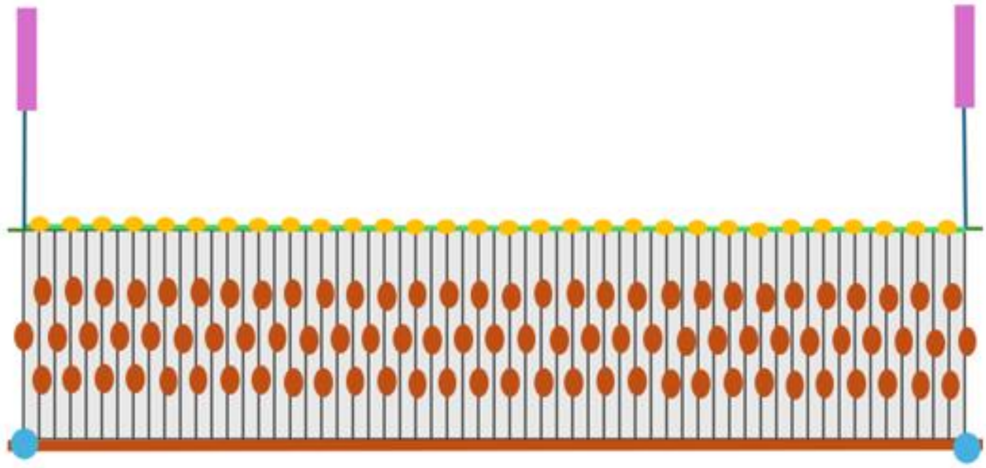


Figure 2: Schematic of how the passive acoustic reflectors (PARS) would be rigged on the 'dummy' treatment net. The yellow headline floats are T80s, the orange floats are the PARs and the purple cylinders represent the F-PODs.

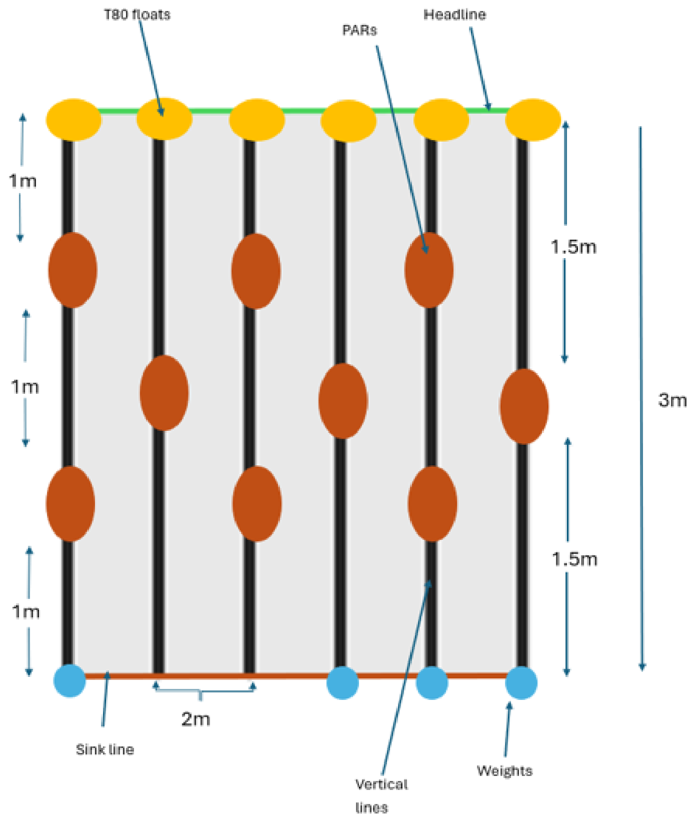


Figure 3: Schematic illustrating the spacing of the passive acoustic reflectors (PARs) on the 'dummy' treatment net.

Measuring responses

Our primary objective would be to measure the difference in acoustic behaviour of small cetaceans between the treatment and control 'nets'. Acoustic data would be collected continuously using acoustic monitoring devices (F-PODs) attached to both 'nets'. Small cetacean presence would be examined by studying clicks in terms of detection positive minutes (DPM) per hour and click behaviour would be determined by extracting the specific buzz-click pattern in relation to the total number of clicks (buzz ratio). This is considered to be an appropriate proxy for click behaviour. These metrics would allow us to determine if there is any difference in small cetacean presence and click behaviour between the treatment and control 'nets'. Additionally, we would deploy F-PODs 100m away from the 'nets' (Fig 1) so that we can detect changes in direction or orientation of small cetaceans.

Acknowledgement of limitations

The proposed aim (see 'Aims') were deliberately modest but intended to be achievable within the practical/resource constraints. We have outlined the limitations identified through consultation below and discussed them.

The study is of limited novelty, previous literature has demonstrated a behavioural response to passive acoustic reflectors. – In general, there is relatively little research in this area, there have only been a handfuls of studies to date. To our knowledge, this is the first test of a purpose-built PAR, engineered to maximise its acoustic reflectivity.

The dummy net is comprised of materials that are acoustically reflective (e.g. floating headline rope and T80 floats). There is evidence in the literature that these can be detected by odontocetes and in some instances invoke a behavioural response in the form of movement or echolocation activity. So, the results would be compounded by the fact that odontocetes may perceive and respond to the control. – We assume this is likely to be happening in real fisheries. Odontocetes are sometimes able to perceive and avoid nets but not always that is why bycatch occurs. By comparing identically rigged control and treatment (+PARs) we are testing whether the PARs result in a behavioural response that is different. Our experimental setup would allow us to determine whether PARs perform better (e.g., effect size is larger) than the T80 floats.

The spacing of PARs might not be practical in a real fishery. – We acknowledge that ensuring PARs can be deployed in a real fishery is key to their success and have suggested that this might be a useful next step before proceeding to a fishery-independent trial (Table 1) we have also provided further clarity below.

We accept that in order to make nets acoustically visible and be perceived as a physical barrier (a wall) then it is likely that PARs would need to be incorporated at regular intervals within the mesh portion of a gillnet (i.e., not just serving as a like for like replacement for T80 floats on the headline). This is obviously dissimilar from existing commercial practice. However, it is worth noting that whilst floats (T80s) are usually only used on the headline, they are incorporated in the foot rope in wreck set gillnets, where the aim is to avoid entanglement in a seabed obstruction. Therefore, there is precedent in real fisheries for incorporating floats elsewhere in gillnets. It is also possible that incorporating PARs into the mesh section of a net may have beneficial impacts on catches. We note that Fish Aggregating Devices (FADs) are widely used in commercial fisheries elsewhere and essentially work by adding structure to the water column which attracts fish.

There is evidence that the presence of FPODs may affect echolocating behaviour. – This is unavoidable but crucially the number and configuration of FPODs on the control and treatment would be the same. We would therefore still be testing whether the addition of PARs to the treatment results in some difference in response.

The buoyancy of the treatment and control would be different because the PARs are buoyant. Similarly having the PARs on the net would increase drag in the face of currents. The nets may therefore behave differently. – Additional weight would be added along the footrope to offset the buoyancy of the PARs. To keep the rigging identical these additional weights would also be present on the control. This is a partial mitigation. We acknowledge that the nets may react differently to currents, e.g., when the tide is running it may have a greater impact on the net with PARs. To help compensate for this, we would take advice on setting from fishers, for example setting nets in line with rather than across current. Inclusion of tidal state as a variable in models may also partly mitigate this.

The study would only determine if the click rate of odontocetes changes in response to PARs. It would not determine whether they avoid or swim around the dummy net equipped with PARs, which is the desired outcome to reduce bycatch. – True. This could be addressed by the modular addition of a hydrophone array to this study which would provide detailed insight into how odontocetes move in relation to the treatment and control net. Some limited inference might be possible by employing additional FPODs away from the dummy and treatment nets (N. Tregenza, pers. comm). We have presented this as a possible option (Table 1).

3. Project Re-evaluation and Next Steps

Following consultation with NAB members and subject matter experts, the decision was taken not to proceed with the fishery-independent trial to explore possible alternative approaches. These alternative approaches were developed in light of the limitations recognised above. By taking these steps, we can ensure that the project is well-conceived and resource-efficient, ultimately saving time and money while maintaining academic and reputational integrity.

We have developed four possible options to explore, outlined below and summarised in Table 1. We are in the process of forming an Expert Working Group (EWG) to facilitate more in-depth discussion and advice on the next steps. There is the potential to proceed with one or more of these options simultaneously or in a step-wise manner. Depending on the advice provided by the EWG, the group may transition into a trial design group. This process will encapsulate the Clean Catch co-design and partnership ethos.

Behavioral trial

A fishery independent behavioral trial comparing the response of wild odontocetes to a dummy net equipped with PARs and a control net (with no PARs). In this instance the behavioral response of odontocetes would be measured using a hydrophone array (rather than FPODs as above). Use of a hydrophone array would allow the 3D movement of individual odoncetes to be tracked in response to the dummy and control net. This approach would require expert input and collaboration with SMRU,

Peru fishery dependent trial

The Peruvian gillnet fishery is known to exhibit extremely high levels of cetacean bycatch. It has been subject to prior research to quantify bycatch rates and test the efficacy of mitigation approaches. It therefore offers an opportunity to trial the PARs in a fishery with a higher (and known) bycatch rate, which is more likely to yield statistically meaningful results in a shorter space of time, than equivalent trials in UK fisheries.

Acoustic tank experiments

The initial R&D process for the PAR included acoustic tank experiments to identify the best materials and shape to maximise acoustic visibility. Thes experiments compared individual prototypes and existing products. Now a working prototype that has passed at-sea trials is available there is an opportunity to conduct further tank-based trials. Specifically, these would explore the optimal configuration/spacing to maximize the acoustic reflectivity and increase the chances that a PAR equipped gillnet is perceived as a wall/barrier. This would include exploring the effects of incorporating PARs into the wall of the mesh (as well as spaced along the headline).

Fishery practical testing and workshopping ideas with fishers

Recognising that the least acoustically visible component of a gill net is the mesh (as opposed to the headline) we propose presenting this challenge to the fishing community. A workshop (or similar) would provide an opportunity to share the progress to date and explore fisher led ideas for rigging PARs into gillnets including the potential to incorporate them into the mesh. Working with fishers, ideas could be trialed at sea, initially to test practically (similar to the robustness trial described above). This would give the Clean Catch team a better idea of what works practically from a fishery perspective informing other tests or development.

Table 1: Four possible options for future PARs evaluation

Option	Primary question addressed	Pros	Cons
1. Behavioural trial	Behavioural response	• Significant advantages over FPOD approach explored to date	• Reliant on availability of hydrophone array • Depends on SMRU appetite and resources
2. Peru fishery trial	Efficacy	• Addresses the fundamental question • Best proof of concept	• Requires new collaboration(s) • Staff time (e.g., new employee) to run trial in-country • Fishing operation and bycatch species may not be representative of UK
3. Acoustic tank experiments	Configuration	• Uses existing collaboration • Low risk • Relatively inexpensive	• Inferential leap between interpretation / visualisation of acoustic data and what odonotocetes perceive and how they respond • Size; may not be able to replicate a gillnet in a tank
4. Fishery practical testing	Configuration	• Spirit of co-design, consulting with fishers and net riggers on how PARs	• May result in optimising for fishers but not optimal or effective for mitigating bycatch

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