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Mooring scientific instruments on the seabed—Design, deployment protocol and performance of a recoverable frame for acoustic receivers

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Abstract

1. Acoustic telemetry is increasingly used to observe and monitor animal movements in aquatic environments. Practical deployment mechanisms are needed to sustain consistent data flows in challenging environments.
2. A tripod frame was developed to facilitate the deployment of acoustic receivers on the seabed, allowing for the recovery of all equipment with an acoustic release system.
3. The procedures of deployment and recovery proved to be practical and efficient during a field trial in the North Sea. Compared to a common cabled design, the tripod frame realized a significantly higher detection probability and performed consistently better at greater distance and louder ambient noise.
4. In the context of ocean observation in challenging environments, the tripod frame is a useful tool for temporary and continuous monitoring of tagged fish presence, potentially fitted with additional instruments.

KEYWORDS
acoustic telemetry, mooring design, movement ecology, oceanographic instrument, tripod frame

1 | INTRODUCTION

Acoustic telemetry enables the observation of animal movements in aquatic environments. Individual animals are provided with a transmitter, relaying a signal that can be picked up by acoustic receivers (Hussey et al., 2015). Receivers are physically set-up in temporary deployments or permanent networks in a range of habitats (Reubens et al., 2019). A lot of practical issues remain with the deployment of receivers, especially in challenging environments and weather conditions.

For deployment on the seabed, receivers are commonly fixed to a line that is attached to a float and anchored to a weight (Cowley, Bennett, Childs, & Murray, 2017; Ellis et al., 2019; Gazit, Apostle, & Branton, 2013; Hoenner et al., 2018). Two concerns

regarding this design are the retrieval of equipment and the variability in receiver orientation. Recovery by diving is limited by depth and weather conditions, as well as budget and person hours. Acoustic releases allow for receiver retrieval without the need to access the instrument at depth. To facilitate this recovery, alternative designs (e.g. products of RS Aqua Ltd and Kintama Research Services) incorporate these acoustic releases with mechanisms for the retrieval of mooring anchor and release pins (Crook, Adair, & Hetherington, 2018; Titzler, McMichael, & Carter, 2010). However, the use of anchor lines in these systems entails a fluctuation of the receiver's orientation and therefore, its performance (Clements, Jepsen, Karnowski, & Schreck, 2005). In this study, we developed and tested a new design for the

installation of acoustic receivers in the field, aiming to facilitate a convenient, cost-effective deployment, with minimal disposal or loss of equipment and an assurance of a high data quality.

2 | DESIGN

The frame consists of a galvanized-steel tripod (c. 80 kg), mounted with a custom-made collar (Deepwater Buoyancy Inc.) with a floating capacity of 11.5 kg (Figure 1). A tether line, correctly coiled in the rope canister in the central beam, connects the tripod to an eye bolt on the bottom of the collar. The rope (8 mm diameter with Dyneema core, 1,000 kg traction) is 1.5–2 times larger than the bottom to surface distance. A Vemco VR2AR receiver with built-in acoustic release is fixed into the collar with stainless-steel screws using the float attachment bracket on the receiver. The collar is then placed on the platform on top of the tripod, with the eye bolt and tether line inside the rope canister. The receiver's release pin, which protrudes through the hole in the top platform of the frame, is connected to the tripod's eye nut with turnbuckles.

2.1 | Protocol

For deployment, the eye on the frame is used to place a quick release clamp, connected to the cable of a winch and to a rope. The tripod is then hauled into the water and lowered to 2 m above the seabed. A forceful tug of the rope disconnects the release clamp, and therefore the cable, from the frame. For the recovery of the tripod, a VR100 transceiver aboard a smaller manoeuvrable boat is used to activate the acoustic release (see Videos S1 and S2). This mechanism separates the release pin (fixed to the frame) from the receiver (attached to the buoyant collar).
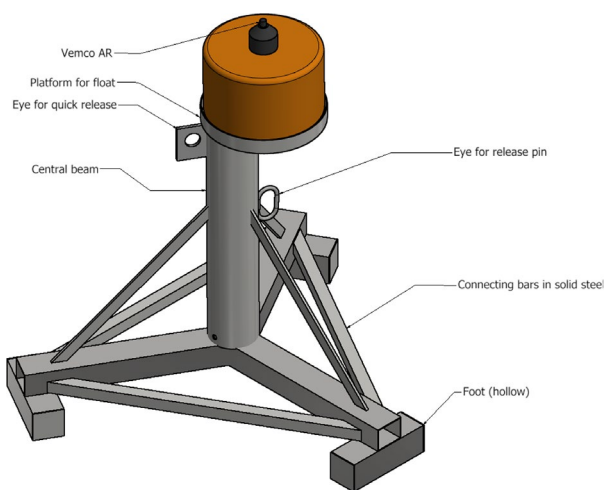
After release activation, the collar and receiver will surface, and can be retrieved using the smaller boat. The tether line, of which the length exceeds the bottom to surface distance, is then disconnected from the collar and passed onto the ship. After fixing the tether line on the ship's winch, the tripod frame is hauled on board. The execution of this protocol requires access to a vessel, equipped with an A-frame (minimal lifting capacity of 1,000 kg). Recovery procedure should be performed during slack tide, to reduce the tension on the tether line.

2.2 | Protocol field trial

The practical operability of the tripod in North Sea conditions was assessed in a field trial. In the framework of the PCAD4Cod project (Slabbekoorn, 2019), 40 tripods were placed in the offshore wind farms Belwind I and Gemini from June to October 2018 (106–119 days; Figure 2). The depth of deployment ranged between 19 and 36 m. Out of 40 deployments, recovery failed twice. In one instance, the release mechanism could not be activated due to a technological error in the receiver firmware that could have occurred in any design, where the depletion of the battery lead to the corruption of the internal circuitry and to the inability to initiate the release. The other frame was not recovered due to strong currents during retrieval. Tension on the tether line caused the rope to be cut as a result of friction with the edge of the frame. This resulted in adapting the recovery procedure to include tides and weather conditions for deployment and recovery. Ideally, recovery should be performed during slack tide and significant wave height below 1 m.

The tripod was developed for deployment in sandy habitat in the southern North Sea, but could be adapted to meet the specific

FIGURE 1 Technical drawing of the tripod frame design. The Vemco VR2AR acoustic receiver is mounted on a floatable collar, with the receiver's acoustic release pin attached to the galvanized-steel tripod at the designated eye. A tether line inside the rope canister connects the float with the frame, allowing for retrieval of the tripod after release of receiver and float
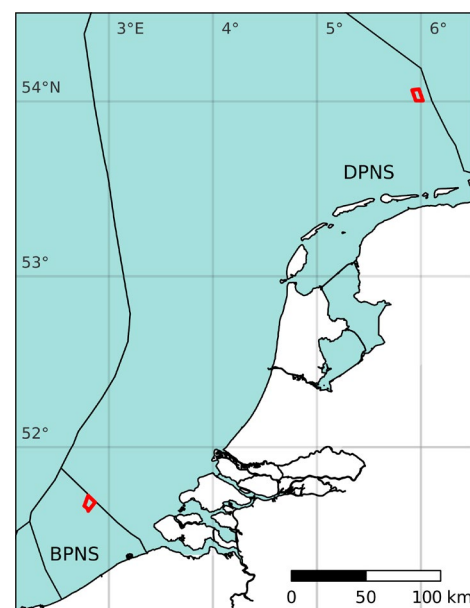

FIGURE 2 Map of study area with offshore wind farms (red) Belwind I and Gemini in the Belgian (BPNS) and Dutch part of the North Sea (DPNS) respectively. Shape files originate from MarineRegions.org

needs of other areas. The depth limit for the current design was 40 m. Increasing the diameter of the central beam, thus fitting more rope in the canister, would facilitate deployment at greater depth. Likewise, a larger collar with greater floatation would ensure the recovery of equipment in areas with more or harder biofouling growth. Finally, sediment type and displacement should be carefully taken into account. For example, frame recovery in silty habitat has proven complicated, as the suction force endured by the equipment might exceed the rope's traction in some cases. For hard substrates on the other hand, deployment would be restricted to areas with sufficiently low rugosity and slope. Considering the challenging conditions in the North Sea, the tripod frame significantly eased the deployment and recovery of the acoustic receivers on the seabed.

3 | PERFORMANCE TEST

The performance of the tripod frame was compared to a stone mooring with an anchor line as previously applied by Reubens et al. (2018). In two subsequent years, receivers were deployed in a circular set-up around the offshore wind turbines of Belwind I, with the distance between receivers varying from 120 to 310 m
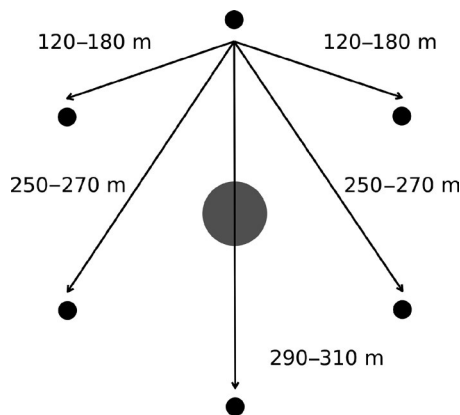

FIGURE 3 Positions of VR2AR acoustic receivers (black dots) around each turbine (grey dot)

(Figure 3). The cabled design was used around turbine F05 in 2017 and the tripod frame around turbines B08, B10 and C09 in 2018. Tilt angle and noise (mV) were measured at a sampling interval of 10 min by the built-in sensors of the VR2AR receivers and built-in sync tags were programmed to transmit at a delay between 540 and 660 s. For every individual broadcasted signal, it was investigated whether it was picked up by the other receivers over different distance ranges. All analyses were performed in R software (R Core Team, 2018), with full details provided in the Supporting Information.

3.1 | Design performance: Tilt

The stability of the fixed receiver position in the tripod frame resulted in lower and more consistent tilt values. For every 10 min, the median tilt value was calculated over all receivers of the two mooring types (Figure 4a). The tripods maintained a more constant and smaller tilt angle, whereas the considerably higher variation in tilt allowed to visually distinguish spring and neap tides for the cabled design. Strikingly, every receiver with the stone mooring reached a maximum tilt angle of 90°, indicating the receivers would hit the seabed (Table 1). Tilt autocorrelation was calculated for 10 min lags up to 25 hr. The resulting peaks at 6.2–6.5 and 12.3–12.5 hr indicated that the inclination of the cabled design was influenced by tides (Figure 4b). No cyclical patterns could be identified for the tripod frame. Running *SD* of tilt was calculated for each receiver to assess variability in orientation, i.e. how much the receiver moved. The window size was set at 3.5 hr, considering the first drop in the autocorrelation at 180–200 min (for the stone mooring). For the stone mooring, running *SD* tilt values varied up to 19.5°, whereas the values for the tripod mooring did not exceed 1.5° (Table 1). No temporal pattern was seen in the latter, whereas apparent spring and neap tides were discernible for the stone mooring (Figure 4c).

The acoustic receivers in the tripod design therefore better maintained a vertical position and remained more stable. As both tilt angle and oscillation of the receiver would negatively influence a receiver's ability to detect transmitted signals (D. Webber, pers. comm.),
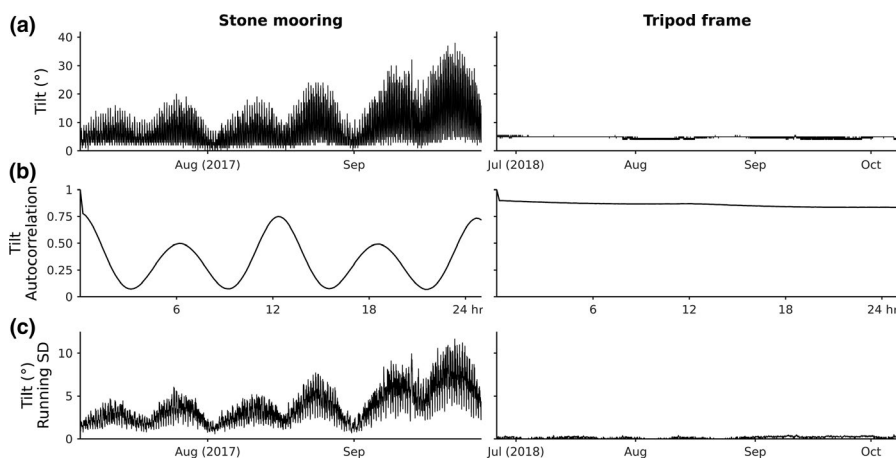

FIGURE 4 Median values of tilt (a), tilt autocorrelation (b) and running standard deviation of tilt (c) for the receivers deployed on the stone mooring (left) and on the tripod frame (right)

TABLE 1 Tilt measurements of each VR2AR receiver deployed at different depths around turbines F05 (stone mooring) and B08, B10 and C09 (tripod frame): minimum, median and maximum values of tilt and tilt running standard deviation (*SD*)

Turbine	Receiver	Depth (m)	Tilt (°) Min	Median	Max	Running SD tilt (°) Min	Median	Max
F05	546622	30.3	0	7	90	0.5	3.6	19.3
	546891	24.4	0	10	90	1.0	5.5	19.4
	546892	25.7	0	7	90	0.0	1.0	19.5
	546893	26.8	0	4	90	0.3	2.2	19.1
	546894	28.9	0	7	90	0.7	3.3	19.2
	546895	31.6	0	6	90	0.4	2.5	19.3
B08	545718	23.3	0	3	5	0.0	0.2	0.7
	545720	20.8	5	7	11	0.0	0.0	0.9
	546043	20.7	0	6	8	0.0	0.4	0.9
	546044	22.3	0	3	6	0.0	0.2	0.8
	546045	23.8	4	7	9	0.0	0.0	0.8
	546047	24.0	0	4	5	0.0	0.2	0.5
B10	546052	27.6	3	5	9	0.0	0.3	0.5
	546130	25.7	7	9	10	0.0	0.2	0.5
	546620	24.4	2	3	5	0.0	0.4	0.6
	546621	25.8	0	3	12	0.0	0.0	0.9
	546622	27.4	2	4	5	0.0	0.0	0.7
	546893	28.1	3	5	6	0.0	0.0	0.5
C09	546891	22.0	2	6	9	0.0	0.0	1.3
	546895	21.2	2	6	8	0.0	0.0	1.0
	546897	19.9	2	4	6	0.0	0.3	0.9
	546898	19.9	3	5	7	0.0	0.2	0.8
	546899	20.9	0	5	9	0.0	0.4	1.5
	546900	21.6	2	6	8	0.0	0.0	0.5

FIGURE 5 Mean hourly detection percentage of built-in transmitter signals at each turbine (a), averaged (mean) over receivers placed next to each other (120–180 m), diagonal of each other (250–270 m) and opposite to each other (290–310 m). Median hourly noise measurements by the built-in sensor of the receivers, averaged (median) over each turbine (b)
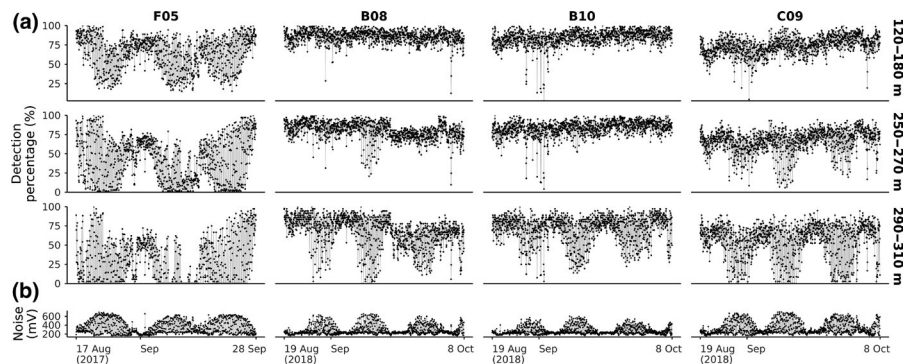
the acoustic receivers in the tripod frame would better capture biologically driven patterns in the presence of tagged animals, rather than variation in receiver performance.

3.2 | Design performance: Detection efficiency

To compare detection efficiency between designs, periods of time when nearby fish-borne transmitters were transmitting at an extremely low delay of 30–60 s were excluded from the data. In the remaining subset, the hourly number of fish present around each turbine was maximum 5, which was considered low enough not to impact detection probability. Mean hourly detection percentages decreased at greater distance for every turbine, but this decline was markedly stronger for the stone set-up than for the tripod (Figure 5a). On average, receivers mounted on a tripod would still register 65% of signals transmitted at larger distance, whereas detections by the stone set-up were limited to 26%. Hourly median noise values at each turbine allowed to visually distinguish spring and neap tides (Figure 5b), whereby comparable noise peaks seemed to reduce the detections more drastically for the stone mooring than for the tripod, especially at greater distance.
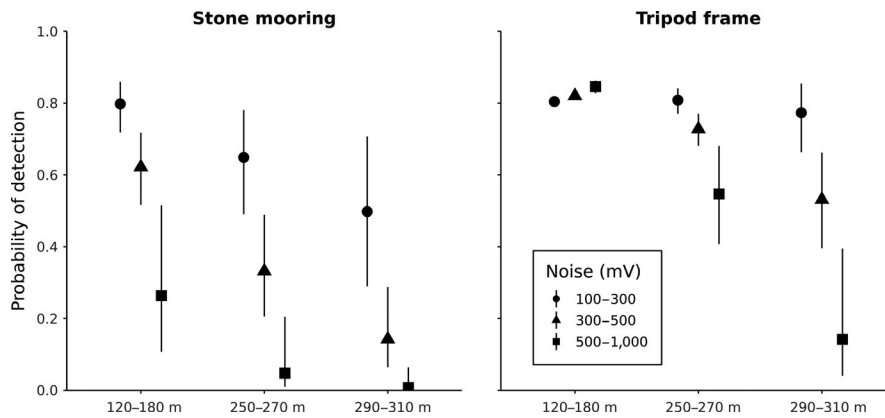
FIGURE 6 Predicted detection probability of the logistic regression model

Detection probability was then compared between designs at various distances and noise levels in a generalized linear model with the Bernoulli distribution (Zuur, Ieno, Walker, Saveliev, & Smith, 2009). Tilt was not considered in the model, as the effect would be strongly dependent on, yet not distinguishable from, the effect of the deployment set-up. Detection probability was estimated as a three-way interaction between deployment set-up, distance and noise. The tripod coped significantly better with distance and ambient noise than the stone mooring (Figure 6). The detection range of the receivers in the tripod frame was only severely reduced at extremely high noise. The stability of the frame therefore produced a better and more consistent receiver performance.

4 | CONCLUSIONS

The tripod frame facilitates the gathering of tracking data in challenging environments. In this study we demonstrated that the design of the tripod allows for efficient deployment and recovery of acoustic receivers. The rigid design of the frame resulted in stability of the receiver, providing more continuity in data quality and detection range than a commonly used cabled design. The majority of deployment set-ups in scientific publications however, consisted of anchored buoy lines, implying considerable variation in detection probability. Apart from retroactively accounting for this performance variability (Brownscombe et al., 2020; Payne, Gillanders, Webber, & Semmens, 2010), the application of the frame could help avoid drawing erroneous conclusions on movement patterns based on (rhythmic) changes in detection probability.

The acoustic release system and principle of the tripod frame can serve other instruments as well, alongside the acoustic receiver. Since the described field trial, the frame has been modulated to hold a C-POD (Chelonia Ltd.), a SoundTrap hydrophone (Ocean Instruments NZ) and an acoustic Doppler current profiler (ADCP; Teledyne Marine). It has also been used in the framework of the autonomous reef monitoring structures (ARMS) program. Such a multidisciplinary scientific equipment entity can be deployed as an ambulatory mooring, answering a diverse range of integrated research questions. The continuous development and modification of operable field systems such as the tripod are vital to provide the

high quality observation data necessary for the understanding and conservation of aquatic ecosystems.

AUTHORS' CONTRIBUTIONS

J.G. analysed the data and wrote the manuscript; M.T. and J.R. developed the design and deployment protocol; K.D. coordinated the work and managed the LifeWatch project; J.R. contributed to the data analysis and the writing. All authors critically revised the paper and approved the final manuscript.

DATA AVAILABILITY STATEMENT

Technical details of the frame can be shared upon request, on the condition that the design is correctly acknowledged. All data are available through https://doi.org/10.14284/404 (Goossens, T'Jampens, Deneudt, & Reubens, Flanders Marine Institute: Belgium, 2020). In addition, detection data are available on the data platform of the European Tracking Network (http://lifewatch.be/etn/). R scripts are made available on GitHub (repository https://github.com/lifewatch/Tripod-frame_Performance-test).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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