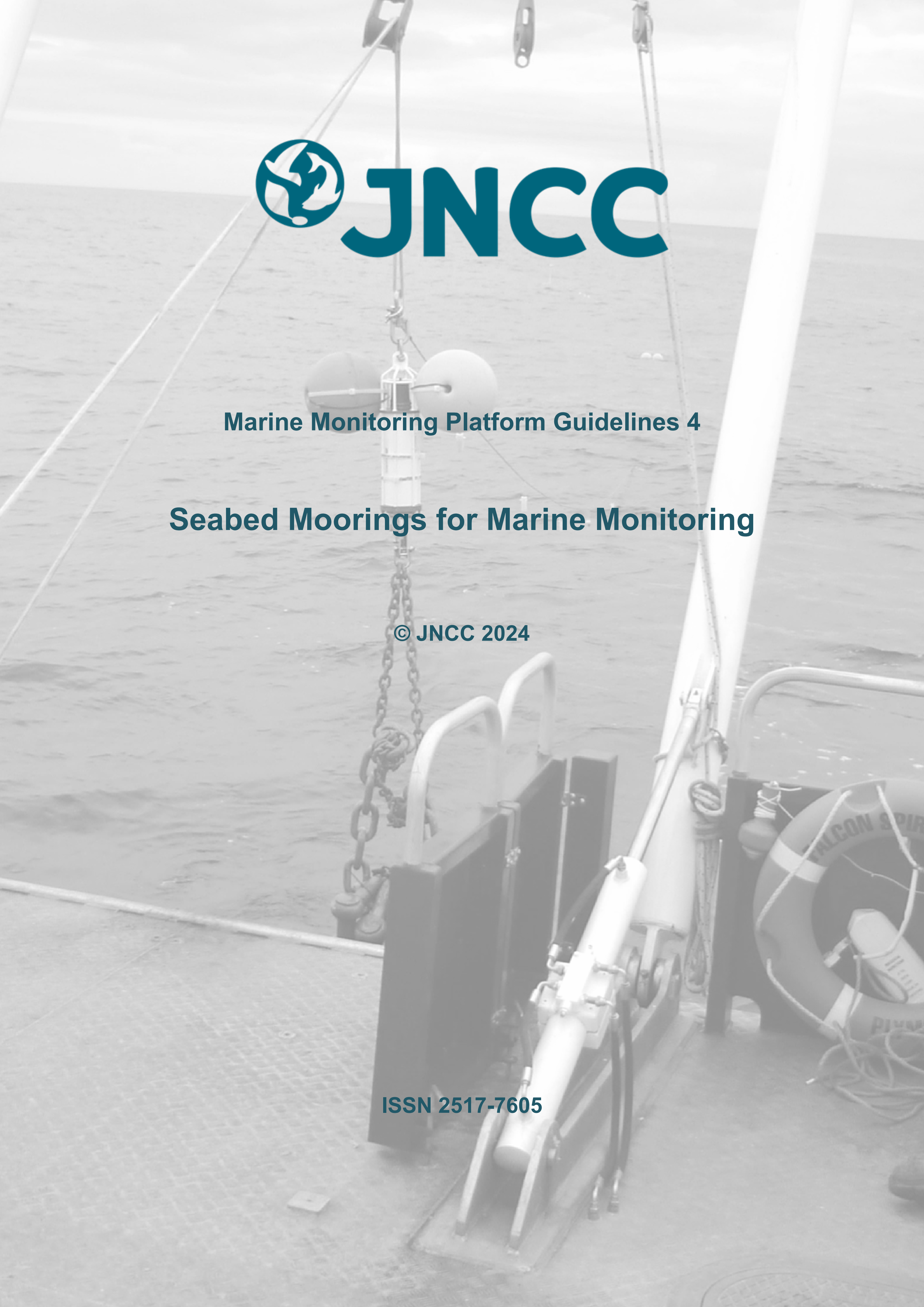

Marine Monitoring Platform Guidelines 4

Seabed Moorings for Marine Monitoring

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Authors: Rhodes, K.A.[a], Rendle, E.J.[a], Hunt, E.[a], Rush, S.[b] & Albrecht, J.[b]

[a] Resilient Coasts Ltd, North Quay House, Sutton Harbour, Plymouth, Devon, PL4 0RA, UK.
[b] Joint Nature Conservation Committee, Quay House, 2 East Station Road, Fletton Quays, Peterborough, PE2 8YY

Contacts: Rhodes, K. (kirsty.rhodes@resilientcoasts.com) and Rush, S. or Albrecht, J. (marinemonitoring@jncc.gov.uk)

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Contents

1. Overview

The purpose of this procedural guideline is to provide general guidance on the platforms available to conduct long-term, in situ monitoring of environmental parameters at or near subtidal benthic habitats. The high-level information provided includes information on equipment, survey planning, operational considerations, and estimated costs (see Table 1 for overview). This procedural guideline is primarily intended for use by marine scientists and survey planners who are considering which monitoring platform will be most suited to meet their survey objectives. Detailed information about specific seabed platforms/moorings and/or guidance on environmental sensors and instruments, such as acoustic Doppler current profiler (ADCP) or CTD (conductivity, temperature, and depth), are outside the scope of this document. A useful resource is the handbook of best practices for open ocean fixed observatories by Coppola *et al.* (2016) for methodologies and protocols relating to seabed platforms.

A marine monitoring platform is defined as any structure or object that will host a sensor or suite of sensors used to measure some aspect of the marine environment (Omerdic *et al.* 2009). Monitoring platforms at the seabed have the capability to provide time-series data on environmental parameters at a fixed location (Bean *et al.* 2017). Their use has contributed baseline data to multiple research areas including marine renewables (Witt *et al.* 2012), benthic biogeochemistry (Thompson *et al.* 2017), ecology (Evans & Abdo 2010 and Santana *et al.* 2020), and climate change (Gallo *et al.* 2020). In situ platforms can be used in a variety of benthic habitats and substratum-types. They are particularly useful in monitoring at depths beyond the range of SCUBA divers and in conditions that may be unsuitable for Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs). Given the extended timeframe that a seabed platform can be deployed, there are considerable financial benefits through reduced time at sea, reduced resource requirements and operating technical equipment.

The platforms described and guidance provided by this document are intended for users planning to conduct environmental surveys in UK waters. Consideration has been given to seabed platforms suitable for a long-term monitoring regime ranging from weeks to years and typically below lowest astronomical tide. The platforms described herein are broadly categorised by their applicability to a range of depths given by depth below mean sea level (MSL):

- Shallow: defined as 20 to 100 m MSL
- Shelf and deeper water: defined as 100 to 2,000 m MSL
- Deep trenches: defined as 2,000 to 3,000 m MSL

Two broad classes of platforms are described in this guideline: those that sit directly on the seabed (bottom mounts) and those that consist of an anchor weight and line (moorings). These platforms are suitable for attaching a range of environmental sensors and data loggers that collect data on or near the seabed.

Table 1: Overview of two broad categories of in situ seabed monitoring platforms (images are examples of platform types supplied by Emma Rendle taken during deployment at The Wave Hub, Cornwall in 2012).

	Bottom Mount	Mooring
Sampling platform	Bottom frame or benthic lander.  Photo taken by Emma Rendle during deployment at The Wave Hub in 2012.	A fixed seabed mooring.  Photo taken by Emma Rendle during deployment at The Wave Hub in 2012.
Scale of operation	Fine (less than 25 m²).	
Habitat-type	Subtidal benthic habitats, near-seabed and water column.	
Substratum-type	All substratum types, including immobile rock (bedrock, large boulder), mobile rock (cobble, pebble), sediments (gravel, sand, mud) and biogenic reefs. Some platform types may be more suitable to particular substrates than others (see Appendix 1).	
Target community	Predominantly used to survey epifauna and associated environmental variables in the water column.	
Samples produced	Physical samples including water and sediment samples. Still images and video footage of macro- and megafauna. Bottom mounts can be used to collect physical samples of organisms through traps and larval invertebrates with settling plates.	
Data products	Video and still images of species and habitats. Environmental data including temperature, depth, salinity, current energy, dissolved oxygen, turbidity, using attached environmental sensors, such as CTD, ADCP.	
Platform costs (see Note 1)	£2,800 to £50,000 (see Appendix 3)	£200 to £100,000 (see Appendix 3)
Deployment/ recovery cost per day (see Note 2)	£1,200 to £37,000 (see Appendix 3)	£1,200 to £37,000 (see Appendix 3)

	Bottom Mount	Mooring
Advantages	• Capacity to mount a suite of sensors to measure multiple environmental parameters in situ for extended durations. • Highly stable, providing fixed measurement with low error risk. • A single modular unit, providing simplicity and efficiency in design and deployment. • Wide range of depths, from intertidal to sea trench surveys (depending on the recovery plan). • Allow free flow of water, reducing load on the platform sides and reducing scour of seabed whilst lowering burial risk. • Ability to produce bespoke mounts designed by the project planners to best suit a particular survey or habitat. • Can be designed to separate into sections, fold or stack for transport and space saving on the vessel. • Bottom mounts can be deployed without surface buoys avoiding shipping hazards to some extent. • Flexibility in design to adapt for the environment, including adjusting or adding weight and acoustic releases.	• Can carry a suite of sensors to measure multiple environmental parameters in situ for the duration of the survey. • A mooring left at a fixed site creates a robust sampling regime and high degree of repeatability. • Basic mooring platforms for deployment in shallow waters require low technical skill. However, inappropriate assembly can cause loss of equipment and data. • Moorings can follow simple designs utilising cheap, easy to source and readily available component parts. • Relative ease of deployment in shallow waters (less than 100 m), nearshore and in favourable conditions. • Moorings can often be deployed without the use of specialised onboard equipment, depending on size and total weight. • Moorings can be deployed on an uneven seabed, where typically only one or two fixed points or anchors are required. • Adaptability for environmental conditions or sensitive habitats, including consideration for fixed anchors.

	Bottom Mount	Mooring
Limitations	• Deep sea surveys from benthic seabed lander platforms are relatively costly and require a skilled crew and scientific team. • Potential for human error in constructing bottom mount. • Deployment often requires a technical or research vessel which are limited in availability. • Depending on size and weight, a lifting aid, crane or hydraulic lift for deployment and recovery may be required. • May be compromised by tidal current, causing loss of position or movement. • Low profile frames are at risk of burial in sediment. • The seabed topography must be considered as a bottom mount should be situated in an area that is flat and clear of obstructions. • Landers often reach the seabed at high velocity when not controlled. The impact may damage the platform and sensors, if not mitigated over hard substrate. • Surface buoys on lines for platform recovery may interfere with measurements and drag out of position. Acoustic release is advised. • Buoys mark equipment position to others, loss can occur due to deliberate removal or accidental propeller entanglement. • Bottom mounts risk disturbance from fishing trawlers. Consideration for position avoiding known activity and construction can help mitigate risk. • Bottom mounts may cause disturbance to the habitat and associated communities.	• Complex mooring configurations can have many component parts and potential points of weakness. • Potential for human error in constructing complex mooring systems, consider the use of appropriate materials to reduce the risk of corrosion and loss. • Surface buoys deployed for ease of recovery may interfere with sensor readings and cause the platform to be dragged from position by shipping traffic and/or lost due to deliberate removal. • Sensor error may occur due to movement of mooring line and buoys due to waves, current and wind. During data analysis, correction can be applied to account for sensor movements. • Moorings deployed by manual drop pose a safety risk of entanglement to personnel. Adequate risk assessments are required to mitigate risk. • Mooring weights may cause damage to sensitive habitats, such as seagrass meadows, especially chains that have an oscillating movement on the seabed with ebb and flood tide. Impact can be mitigated by choosing a more appropriate mooring configuration or buoy line material.

Table 1 Notes:
Note 1: Estimated cost range based on purchase of platform.
Note 2: Estimated cost range based on suitable vessel hire and day rate for two members of scientific survey team.

2. Logistics

2.1 Equipment

The aims and objectives of the individual monitoring project will determine the type of platform most suited to the survey. Survey planners should consider the survey depth, temporal scale of study, site conditions and budget constraints when selecting or designing a platform. The primary aim driving platform design will be to avoid the platform moving from the survey site to obtain accurate measurements. The chosen platform must be capable of carrying the sensors and associated batteries required to complete the survey. See Appendix 1 for additional considerations when designing an in situ platform for benthic monitoring.

This section describes bottom mount platforms, which can be further categorised into bottom frames and benthic landers (see Table 2), and moored platforms.

2.1.1 Bottom frames

A bottom frame is a common platform used for monitoring environmental conditions in shallow waters. The frame is required to be compact and heavy, especially where it will be exposed to strong currents and tides. Often frames have a tripod leg configuration for stability. Frames can be sourced from manufacturers or custom-made. It is important to consider the material the platform is constructed from and follow guidance from the sensor manufacturer; for example, ADCPs including magnetometers must be mounted to a frame free of any magnetic material. Bottom frames may require ancillary equipment such as a pop-up buoy for recovery and gimbal for correct orientation of sensors. If deployed in a fishing area, a trawl-resistant design may be necessary.

2.1.1.1 Case Study: Design of a recoverable bottom frame for acoustic receivers

Goossens *et al.* (2020) designed a tripod frame equipped with an acoustic telemetry receiver to track animal movements whilst continuously recording depth and temperature (see Figure 1). The design overcame many practical issues associated with traditional mooring platforms for receivers, including recoverability and sensor orientation.

The galvanized-steel tripod frame is equipped with a buoyant custom-made collar that houses the receiver. A built-in acoustic release allows the receiver to be released from the frame and to ascend to the surface, uncoiling a tether line also attached to the frame. Once the receiver is retrieved from the surface, the vessel’s winch is used to haul the tripod frame onboard by the tether line. A field trial in the North Sea deployed 40 tripods for a minimum of 106 days to depths ranging between 19 and 36 m. The platform design significantly improved sensor stability, positioning and performance compared to alternative mooring platforms. Since trials, the tripod design has been modified to hold alternative acoustic monitoring systems and environmental sensors for applications in a range of research areas.

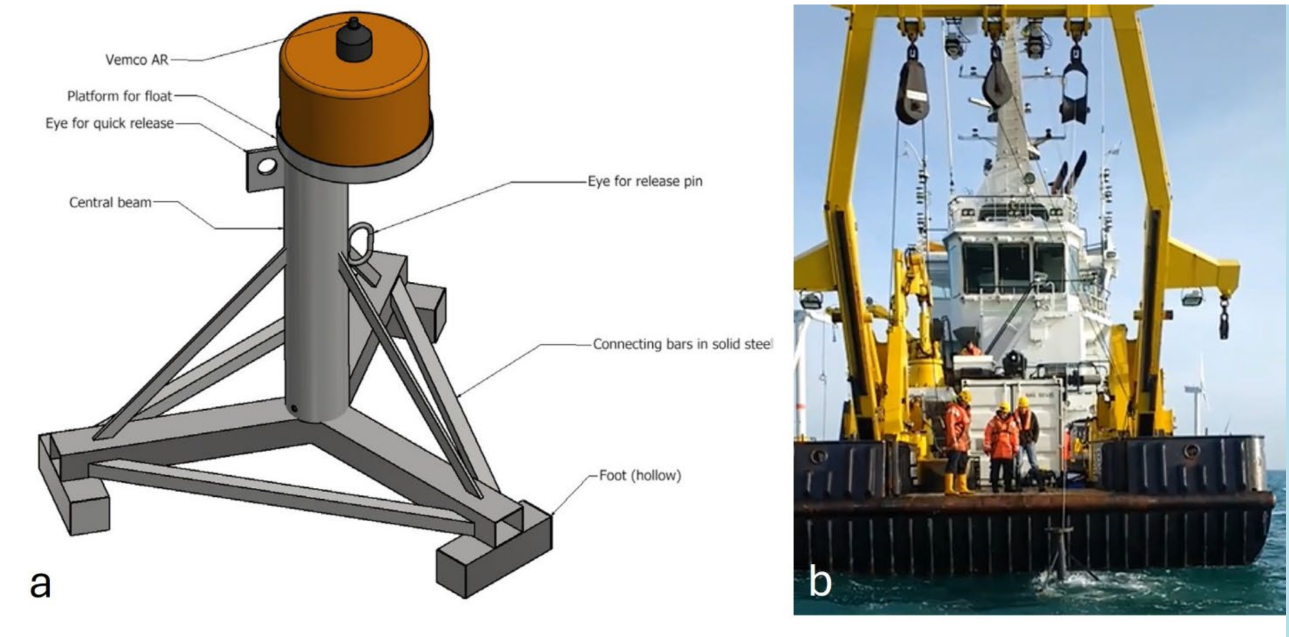

Figure 1: (a) Technical drawing of the tripod frame design; and (b) recovery operation using vessel A-frame From Goossens *et al*. 2020 (Image copyright: © 2020 Goossens *et al*., Methods in Ecology and Evolution published by John Wiley & Sons Ltd on behalf of British Ecological Society).

2.1.2 Benthic landers

Benthic landers are autonomous, unmanned research platforms that sit on the seabed and are equipped with instruments to record biological, physical and/or chemical properties in the benthic zone (Tengberg *et al.* 1995 and Eleftheriou & McIntyre 2005). Weights mounted on the lander legs allow deployment by freefall to the seabed. Once deployed, landers can be left to work autonomously for long periods of time, without the requirement for a vessel and associated personnel at the surface. Landers used for long-term experiments are therefore a cost-effective monitoring method and an efficient use of vessel time compared to wire-deployed systems (Bagley *et al.* 2004). At the end of the survey, ballast weights are released and the buoyant lander, along with the attached sensors, are retrieved at the surface by a recovery vessel.

Table 2: A comparison of bottom mount platforms and description with example images of platform types.

Platform equipment	Bottom frames	Benthic landers
Overview	A frame deployed to the seabed. Includes a simple tripod design that sensors are mounted to that house sensors protected within casing.	An autonomous platform typically comprising of a chassis, buoyancy module, recovery module and ballast with release mechanism that multiple sensors can be attached to.
Examples	Innova tripod, PODS Seabed Platform, CEFAS Minipod, AL-200 DeepWater Buoyancy Trawl Resistant Bottom Mount.  Image: Trawl Resistant Bottom Mount (copyright DeepWater Buoyancy, Inc. 2023).	RAPID Lander & MYRTLE-X lander.  Image: RAPID Lander (copyright National Oceanography Centre (NOC). 2023).
Applications	Long-term measurements of near-bottom conditions.	Long-term measurements of near-bottom conditions.
Typical depth rating	Shallow (20 m to 100 m) Shelf and deeper water (100 m to 2,000 m).	Shelf and deeper water (100 m to 2,000 m) Deep trenches (2,000 m to 3,000 m).
Deployment type	Diver-deployed or lowered from vessel manually or by lifting aid (winch, crane or A-frame).	Freefall from research vessel. Can be lowered by rope using crane for depths up to 200 m, in areas of low current (Kononets *et al.* 2021).
Recovery type	Diver recovered or lifting line by winch, crane, or A-frame. Acoustic or pre-programmed timed release. Bottom frame equipped with radio beacons, strobe lights, etc., for locating at surface.	Acoustic or pre-programmed timed release. Landers equipped with radio beacons, strobe lights, etc., for locating at surface.

Platform equipment	Bottom frames	Benthic landers
Vessel requirements	Platform weight and survey site location will dictate requirements for vessel capabilities. Shallow (20 m to 100 m) deployment or recovery requires small vessel or crane barge. Deployment or recovery for shelf and deeper water monitoring (100 m to 2,000 m) will require a larger vessel with lifting capabilities. Adequate deck space is required for platform stowage and dive team if required.	Offshore research vessel with adequate deck space for platform stowage. Crane or winch for recovery of platform from surface. Dynamic positioning capabilities and hydraulic lift may be required.

2.1.3 Moorings

A fixed mooring is an alternative to a bottom mount for in situ monitoring of environmental parameters. The required sensors can be positioned just above the seabed either attached directly to the mooring line, mounted in frames, or housed within subsurface buoys (Figure 2c).

Figure 2 (a and b) show the two general mooring methods referred to as a U-mooring and an I-mooring. A U-mooring is suitable for monitoring in shallow, sheltered areas. Placement of the sensor below a subsurface buoy on an additional line is advantageous as the sensor is not subject to the wind and wave conditions that the surface buoy and main line is exposed to, minimising movement of the sensor. In Figure 2a, subsurface buoys are used to reduce abrasion of the seabed at low tide and to provide a back-up recovery system should the surface buoy be lost. The I-mooring is a suitable deployment set-up at any depth. In addition to the set-ups shown in Figure 2, an I-mooring without a surface marker buoy can also be deployed with an acoustic release and subsurface buoy.

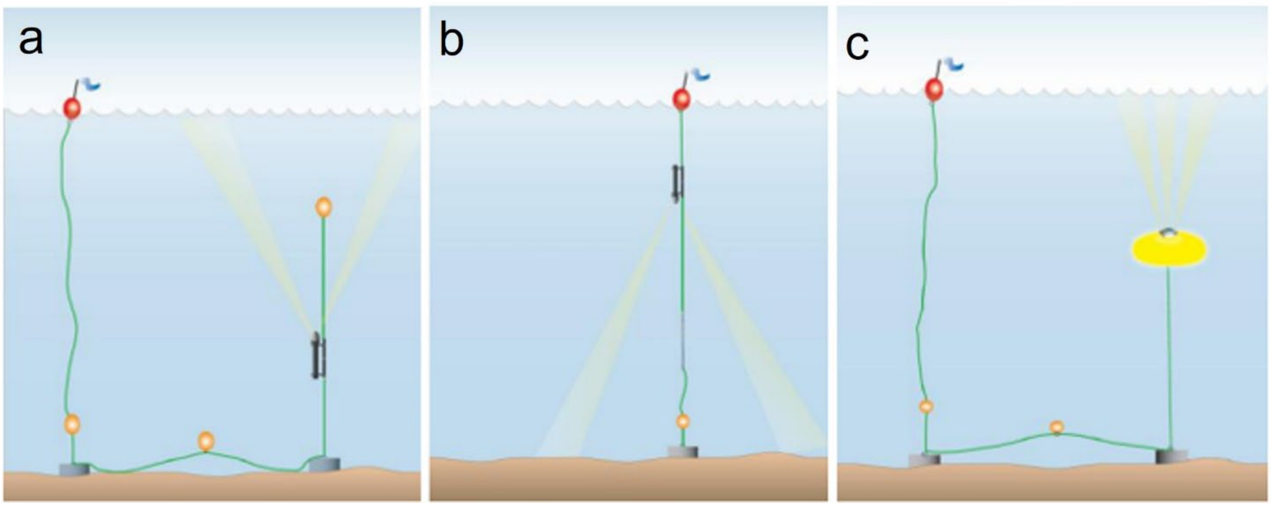

Figure 2: Deployment set up of: (a) U-mooring; and (b) I-mooring with attached ADCP. Sensors housed within a subsurface buoy shown in (c) (Image copyright: © 2024 Nortek Group).

2.1.3.1 Case study: Monitoring of environmental parameters in UK kelp forests from mooring data

Moorings deployed across the UK carried sensors to link ecological structure and standing stock of carbon within kelp forests with environmental variables. Smale *et al.* (2016) deployed the mooring platforms in subtidal rocky reefs across 12 study sites. The locations were selected to survey kelp forest habitat at a range of mean annual sea surface temperatures spanning 10.9°C in northern Scotland to 13.4°C in south-west England. Candidate study sites were selected based on specific criteria including depth, limited anthropogenic activities and exposure. An array of sensors was attached to a small subsurface buoy tethered by rope to a clump weight (see Figure 3). This mooring platform allowed for in situ measurements of temperature, ambient light and water motion caused by tidal flow and waves over a 6-week deployment period. As the survey length collected a fine scale 'snapshot' of environmental variables, analysis was supported with remotely sensed data from NASA and MODIS Aqua satellite data sets. This investigation furthered understanding of the environmental drivers of ecological patterns at a large spatial scale; knowledge that is critical for effective management and conservation of marine habitats.

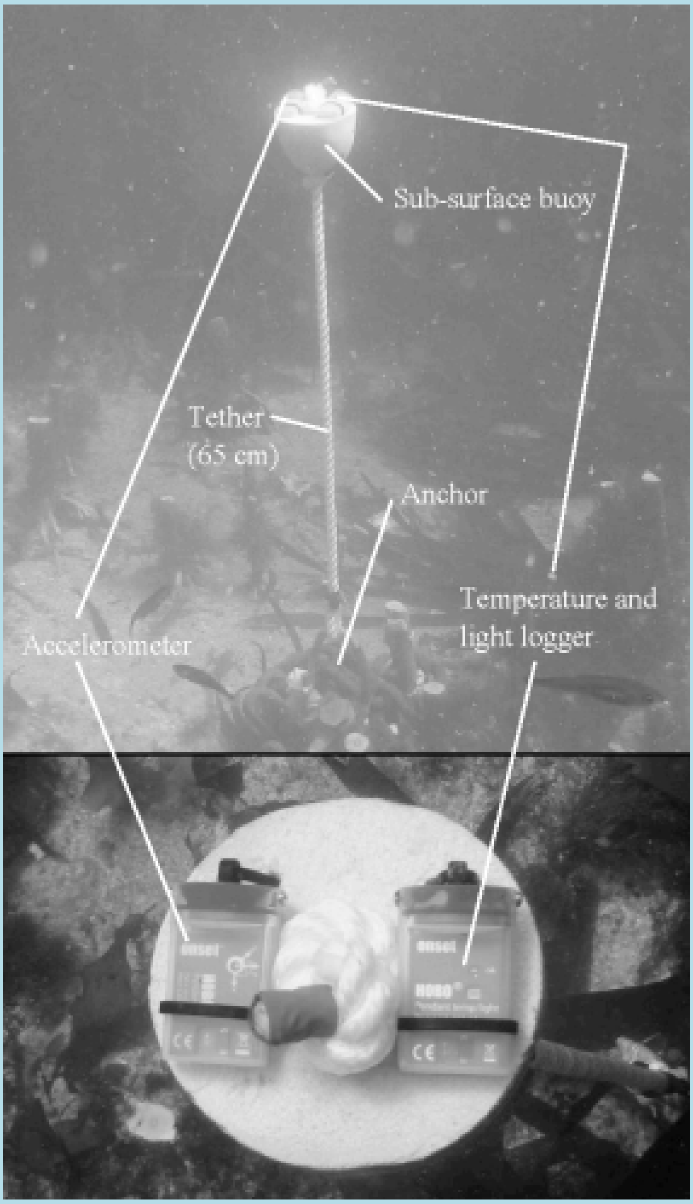

Figure 3: Deployment of sensors attached to a subsurface pellet buoy, tethered by rope to a chain anchor on the seabed. From Smale *et al.* 2016 (Image copyright: © 2016 Inter-Research).

2.1.4 Environmental Sensors

A range of environmental sensor equipment can be mounted to bottom mounts and moorings (Table 3). This is not an exhaustive list of all environmental variables that can be measured at the seabed, or a list of every sensor type available, but aims to provide an overview.

Table 3: Examples of environmental sensors that can be mounted to in situ benthic platforms to survey environmental variables.

Environmental variable	Environmental sensor
Temperature	CTD, temperature data logger, multiparametric probe, digital thermometer.
Chlorophyll / fluorescence	Fluorometer, multiparametric probe.
Salinity / conductivity	CTD, conductivity meter, multiparametric probe.
Light / PAR	Light level sensor, PAR sensor, light meter data logger, multiparametric probe.
Dissolved oxygen	Optode sensor, oxygen microelectrode, oxygen data logger, multiparametric probe, oximeter.
Turbidity	Turbidimeter, acoustic backscatter sensor, ADCP, multiparametric probe.
Wave energy / current energy	ADCP, pressure sensors, accelerometer, velocimeter.
Depth	CTD, temperature data logger, multiparametric probe, depth logger, digital depth sounder, pressure sensor, multibeam echosounder, singlebeam echosounder.

In addition to the above sensors, bottom mounts and moorings can be equipped with apparatus, such as sediment corers and niskin bottles, to collect physical samples (Black *et al.* 2001; Frogner-Kockum *et al.* 2020). Camera equipment can also be mounted to in situ platforms to collect still images and video footage (Hanz *et al.* 2021). There are various positioning options to capture images and footage of habitats and species. For example, Roberts *et al.* (2005) mounted cameras on pivoting plates on a benthic lander to capture vertical and oblique angle seabed images on the Sula Ridge, Norway.

2.2 Survey planning considerations

Survey planning, including deployment, recovery, and maintenance of the benthic platform(s), is the responsibility of the survey manager and will require regular contact with stakeholders. A clear specification of requirements should be provided to the vessel operators and any contractors, such as divers or crane operators, required in deployment and recovery. All scientific staff and relevant vessel crew should receive clear briefings on the survey objectives and operational aspects.

The survey design should specify survey length, replication, and location of survey site(s). These survey elements will be driven by the research objectives and will dictate the platform design. For example, benthic landers and mooring platforms can be recovered after several years if maintenance requirements associated with long-term deployment are considered (see Appendix 1). In a shallow setting, mooring platforms will be best suited to monitoring efforts requiring replication of the survey as, once deployed, the platform can be revisited as many times as is necessary for divers to redeploy sensors at the same site.

The level of planning required will depend on the research aims, complexity of the survey and environmental sensors attached to the platform, and operational requirements such as size and weight of the platform and/or duration of survey. Decision making during planning should be made with all aspects of the survey objectives in mind and the appropriate level of reporting, including monitoring and analysis, risk assessment, health and safety, deployment and recovery, and any maintenance required.

Wider considerations for planning, weather implications for survey implementation, survey notifications and key communications are detailed in Appendix 2.

2.3 Vessel considerations for platform operations

Seabed platforms can be deployed and recovered from a range of vessels. It is worth noting here that in discussions regarding a suitable vessel, this is related to the scope of this guidance, that is depths below 20 m MSL and typically offshore. That said, vessel size might range from small rigid inflatable boats to flat bottomed rear access boats or barges for use in nearshore sheltered areas, to large ocean-going vessels designed to withstand more complex sea states. These vessels will have quite different kit onboard depending on their size and capacity, however standard safety equipment should be onboard, and all vessel crew and scientific team instructed how to operate in an emergency.

When selecting a suitable vessel, this checklist should be considered (list adapted from AUV & ROV Procedural Guidelines (JNCC 2018a, 2018b), not an exhaustive list):

- Is the vessel suitable and capable for the area of deployment and likely conditions? For example, a vessel with dynamic positioning capabilities may be required if deploying multiple platforms throughout a day in areas subject to strong tides or currents.
- Is there suitable deck space to store the platform, sensors, and ancillary equipment? Consider if sheltered deck space is required for sensitive equipment. Can the platform be safely transported from area of stowage to deployment area on deck and vice versa for recovery?
- Does the vessel have the equipment required for safe deployment and recovery of a benthic platform (e.g. crane, winch or A-frame)?
- For manual deployment and recovery, is the freeboard of suitable height to allow safe handling? Consider if there are hatches (doors in vessel sides) or if a flat barge with no freeboard is more practical.
- Does the vessel meet workboat codes of practice, such as The Maritime and Coastguard Agency (MCA) Workboat Code. 2014?
- If hired, do the vessel hire costs cover insurance, fuel, and additional costs such as rigging equipment?
- Are the vessel skipper and crew trained and experienced in similar operations? Are specialist operators required such as crane or hydraulic lift operator?

In the case of larger or more complex benthic platform setups for offshore surveys in deep water or trenches, a suitable vessel with the appropriate size and capability to undertake deployment and recovery will be required. Large research vessels are expensive and limited in availability, especially during months of good weather when they will be in high demand. One solution is to join a research cruise where multiple programmes of research activities are undertaken along a carefully planned route. With the efficiency of vessel and resources dedicated, costs can be minimised for individual programs, however survey managers should consider that their team will be onboard the vessel for a longer duration than their activities alone.

An independent report published in 2013 by the Marine Science Co-ordination Committee (MSCC) identified two primary groups of offshore UK research vessels (MSCC. 2013. UK Marine Research Vessels: assessment and proposals for improved co-ordination):

1. UK government agencies' vessels. Primarily used for marine monitoring contributing to research sustaining and promoting ecosystem benefits, ecosystem function and fisheries research.
2. Natural Environment Research Council (NERC) vessels primarily used for ecosystem function and climate change research in UK and polar regions.

In addition to the offshore fleet, UK scientists may source the use of nearshore vessels for seabed research from the Environment Agency (EA), Inshore Fisheries and Conservation Authorities (IFCAs), Marine Directorate of Scottish Government (MDSG), academic and research institutes, or those operated by commercial operators (Bean *et al.* 2017).

2.4 Personnel Requirements

A survey manager is required to ensure all logistical and operational aspects are considered. They should be skilled and experienced in marine monitoring techniques and will be responsible for sourcing and managing the survey team, carrying out the survey safely and communicating with third parties, such as vessel operators. They will need to consider if the platform and attached sensors require the presence of technical experts at each stage of the survey. The type of survey carried out, sensors used, and data collected will determine the team members and expertise required to analyse samples and data.

For deployment and recovery of the platform, it is recommended that the survey manager or fully briefed co-lead scientist is present to fulfil the survey plan and modify operations as necessary. For nearshore deployment of a simple configuration mooring or basic bottom mount, at least two people will be required. These team members should be selected based on experience, skill set, and competence and it may be that a fully briefed member of the vessel crew is able to fill this role. For offshore deployment of a complex mooring system or benthic lander to deep water, the survey manager will need to plan personnel required accordingly. Experienced engineers and/or technical staff may be required so that any sensor or platform issues can be addressed at sea during testing or deployment and recovery.

Whilst no formal qualifications are required to act as survey manager, it is likely that the survey manager will be close to the scientific team and hold a strong appreciation for the sensitivity of the instruments used and data being collected. However, any personnel working at sea should hold the relevant and in date Sea Survival Certificate and ENG1 Medical Certificate (see Annex 3 for costings).

When deploying benthic platforms and environmental sensors in situ for long-term continuous monitoring, there is no requirement for a constant presence by a surface vessel and team, as is the case with ROV or diving surveys, for example. Personnel requirements in the field are therefore limited to deployment and recovery often at the start and end of the survey only. However, data collection, changing batteries, general inspection, and/or maintenance and cleaning may be required and provide reason to revisit the site.

2.5 Risk assessments and health and safety requirements

The survey manager is responsible for ensuring that operations are subject to a robust risk assessment process. All aspects of the survey should be assessed to identify risks and then determine how best to mitigate against and/or manage risks. It is recommended that risk assessments are prepared for each survey location to account for local conditions (Davies *et al.* 2001). The requirement for health and safety briefings should be considered during survey planning. The Health and Safety Executive (HSE) provides guidance and templates for risk assessments. The HSE resources and guidance for working offshore in the energy sector may also be useful to survey managers planning offshore surveys. Further guidance on health and safety aspects in marine monitoring can be found in the Marine Monitoring Handbook (Davies *et al.* 2001).

When developing a risk assessment for in situ monitoring surveys, the following should be considered (not an exhaustive list):

- Risk of injury during manual deployment and recovery of heavy platforms; associated risks of working with onboard winches, cranes, etc.
- Risk of loss of equipment, especially during freefall deployment or potential malfunction of recovery technology (Bagley *et al.* 2004).
- Risk of entanglement and damage of buoys and lines due to shipping traffic; risk of trawling activities causing damage or loss of platform.
- Risk of vandalism and theft of platform if location is marked by surface buoy (Smith *et al.* 2015).
- Risks associated with the use of sensors and battery packs.

The sea state and weather conditions should be taken into account prior to deployment and recovery operations. If poor conditions such as high wind and strong waves are expected, the risk to personnel and platform equipment will be increased. The survey manager must liaise accordingly with the vessel operator to ensure their own safety measures and risk assessments are in place. The survey team should be made aware of the vessel safety procedures. If a dive team is required during the survey, diving operations are subject to the procedures described in the Diving at Work Regulations 1997 and must follow the Scientific and Archaeological Approved Code of Practice.

All members of the survey team should have personal protective equipment (see Appendix 3) and life jackets should be provided by the vessel.

3. Operational guidelines

3.1 Preparation

The survey plan must lay out all steps required in preparation (both shore-based and onboard), prior to deployment operations and sampling. The required personnel, equipment and space (e.g. workshop and laboratory) for platform and sensor preparation should be accounted for. The survey manager must be flexible and adapt the planned preparation steps in response to issues as they arise, such as poor weather.

The steps that should be taken prior to operations include, but are not limited to:

- Carefully consider the preparation steps that are required before going to sea. Working in a contained, stable, and dry environment is considerably easier than onboard a vessel and should be weighed against the potential for risk of transport related damage.
- Preparation, printing and laminating of record keeping and reporting documentation, including the cruise report. These should be circulated to the vessel and crew well in advance of going to sea to align plans. Required record keeping includes sensor position on platform, sensor serial numbers, time of switch on/off of sensors, deployment and recovery time, target deployment position and depth, actual deployment position and depth, etc.
- Collate specific environmental sensor manuals and instructions, to be circulated to scientific teams where appropriate.
- Preparation of appropriate mounting and fixings, including fixing into place housing for sensors, such as tubes or cages.
- Check seals, clean and apply silicon grease to prevent leaks, particularly at pressure.
- Calibration and validation of sensors to the environment.
- Battery capacity, testing and charging, back-up or alternative power, etc.
- Choose whether to mount the sensors prior to transport in the workshops, or onboard the vessel. If using multiple sensors, sensors should be attached to mount in a manner that ensures they do not cause interference with each other (see The Comprehensive Manual for ADCPs).
- Choose exactly where to deploy platform(s), communicate information with the skipper and ensure to include precision in location, with coordinates. In more complex surveys, survey plan reports with location maps to detail bathymetry or seabed substrate is advised.
- Pack into containers and pack well, plan for the worst-case scenario including potential for container leaks or platform being dropped if very heavy equipment is being used.
- When flying or transporting across borders, consider the paperwork requirements for transporting scientific equipment and batteries.

For details of surface preparation steps required onboard the vessel, refer to Annex 2.

3.2 Deployment

Deployment of a bottom frame or mooring from a vessel is achieved by safely lifting the platform to be moved over the side and carefully lowered through the water column to the seabed. A successful deployment mission depends on the ability to: (a) estimate the range of environmental conditions (wind and rain, waves, current, tide) that the deployment site may be exposed, both at the sea surface and at depth; and (b) design a structure that will survive and maintain position under those conditions.

The deployment site should be carefully assessed including bathymetry, substrate type, and human activities in the area (see: The Comprehensive Manual for ADCPs). Often scientific staff will be asked to 'think on their feet' by the skipper and vessel crew to address challenges or concerns in the deployment plan. There may be unexpected weather situations and/or delays, meaning second or third attempts may be required. These should be expected and accounted for in the survey plan and accepted by scientific staff with safety considerations at the centre of all decisions.

Near deployment, the platform should be prepared by laying out the mooring or bottom mount logically, and systematically stepping through all the links and attachments for the sensors.

Light bottom frames or moorings can be deployed manually (if weather conditions and sea state allow and are determined safe in risk assessment). Manual handling legislation defines 25 kg per person as the upper limit to safely lift equipment manually. A manually deployed platform can either free-fall to the seabed or be manually lowered on a suitable line.

An alternative to manual deployment is the utilisation of onboard lifting aids that are either included with the vessel hire or brought on to meet survey requirements. Lifting aids include various types of loader cranes utilising hydraulics, winches, and A-frames. Particularly heavy, sensitive, or high-cost platforms may require increased lift and cable capabilities. The survey plan must specify the line length required and material best suited for lowering the platform (Eleftheriou & McIntyre 2005). When controlled, it is possible to mark a rope to indicate the length of rope released and monitor depth of the lander, and therefore distance from the seabed. If deploying platforms via lifting aids, consideration should be given to the rigging equipment required and ensuring that all components meet with current legislation (for example Lifting Operations and Lifting Equipment Regulations 1998). Depending on platform type and lifting aids used, it may be necessary to plan deployment at, or close to, slack tide to reduce tension on the lifting line.

In shallow water, it may be practical to contract a dive team to deploy the platform. This may be necessary to ensure the platform is placed at an exact site or to ensure correct orientation of sensors once in place on seabed if not using gimbals. Deployment from a vessel can also be followed by divers to confirm the exact platform location and placement (Gonzalez Colmenares *et al.* 2023).

Benthic landers are typically deployed from research vessels using lifting aids to raise the platform which is then subsequently released to freefall to the seabed (Tengberg *et al.* 1995). The lander is usually ballasted to be negatively buoyant so that it descends to the sea floor at a rate of 0.5 to 1.0 mJ s^{-1} (Bagley *et al.* 2004). Landers are required to be shock-resistant if freefalling to hard substrate and subsidence resistant if expected to land on soft sediments (Yu *et al.* 2022). Deploying a lander frame by line to the seabed may be conducted but is typically not suitable in depths over 200 m (Kononets *et al.* 2021). Benthic landers may also be designed to be ROV-deployable, such as the "Little MonSta" lander array which have been successfully deployed on the Western Irish shelf (Wheeler *et al.* 2021).

3.2.1 Case study: ROV-deployable benthic lander array

Most benthic landers freefall to the seabed and operators have no capability to guarantee specific location or adjust platform positioning post-deployment. As such, significant developments in benthic lander design have been made as part of the MMMonKey_Pro program (mapping, modelling, and monitoring key processes and controls in cold-water coral habitats in submarine canyons).

The “Little MonStas” benthic lander array was developed to offer an alternative platform design for monitoring physical and chemical oceanographic properties in cold-water coral habitats (Wheeler *et al.* 2021) (see Figure 4). The compact, lightweight landers are deployable and recoverable by work-class ROV, allowing precision location in extreme submarine canyon terrains to a depth of 3,000 m. This novel innovation has been successfully used to survey long-term environmental trends in the Porcupine Bank Canyon (PBC) on the Irish-Atlantic margin. It is worth noting that the platform design must be small to allow for ROV-deployment and therefore, a limited sensor array can be fitted. However, the design allows for precision deployment, and associated reliable data collection, which has the potential to be a powerful tool in understanding benthic environmental dynamics.

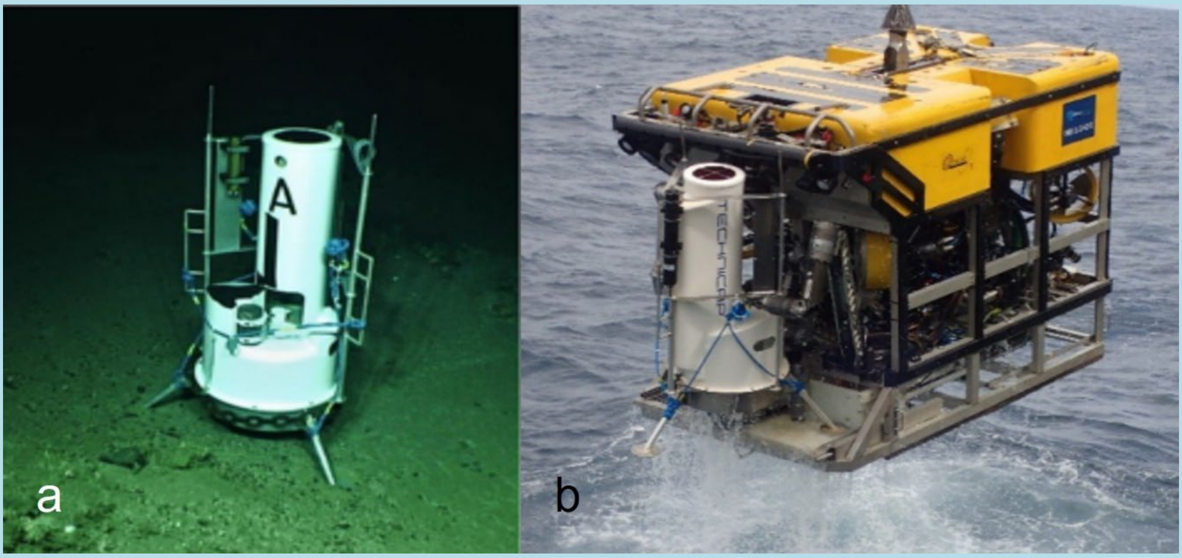

Figure 4. (a) Little MonSta lander deployed at 685 m in the PBC; and (b) the Holland I ROV recovering a Little MonSta by manipulator arms. As a back-up, the lander is also hooked to the ROV. From Wheeler *et al* 2021 (copyright: © 2021, by Wheeler *et al*., Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/)).

3.3 Sampling operation

Once deployed, an in situ seabed platform for long-term monitoring typically remains on the seabed without interference until it is recovered at the end of the survey. Unless there is a requirement to download data (freeing memory) or exchange batteries (power) or other general maintenance concerns (such as biofouling), the most cost-effective approach is to allow the sensors to collect data uninterrupted.

Data retrieval and success of the survey is typically unknown until recovery, allowing for inspection of the sensors and data download. This opens the survey to risk if sensors are not properly turned on or calibrated, or fail due to damage, corrosion, loss of memory or power. For these reasons shore-based testing prior to deployment, consultation of manuals, and discussion with product suppliers are essential to building the survey plan and sampling regime. The sensors can be calibrated appropriately, and frequency settings chosen to ensure that the device memory and power supply is sufficient for the duration of the survey. Often there is a practical interplay between choosing settings which meet the research requirements with high enough frequency for appropriate analysis and interpretation of the data, whilst considering the limitations of a device or sensor.

Some platforms have a means of communication during sampling. For example, more technical landers have communication systems that relay back to the vessel the successful performance of stages of the lander survey (Tengberg *et al.* 1995). However, an acoustic link with the surface, which also allows for some reprogramming during deployment, requires vessel presence and incurs far greater expense.

3.4 Recovery

Similar to deployment, a successful recovery operation requires a good weather window and preferably, a lack of boat traffic in the immediate vicinity (Kononets *et al.* 2021). The tidal conditions may need to be factored into the recovery plan when using lifting aids as recovery operations performed during slack tide reduces the tension on the lifting line (Goossens *et al.* 2020).

Platforms deployed with a surface marker buoy can be retrieved from a vessel either manually or with the use of lifting aids, such as a winch. The platform should be carefully guided over the sides of the vessel by skilled crew members to avoid damage to the sensors.

Platforms deployed without the constant presence of a surface marker can be located and recovered by a range of methods. For example, some vessels are equipped with USBL (ultra-short baseline) underwater positioning systems which make it possible to locate a platform carrying the related transponder on the seabed (Kononets *et al.* 2021). A well-equipped research vessel may have the benefit of multibeam echo sounder to scan the seabed to identify the platform position. Once located underwater, it may be appropriate (dependent on depth or sea state) to deploy divers for platform recovery. The divers can either attach a lifting line to the platform for retrieval from the vessel or use lifting bags to cause the platform to ascend (Cook 2016). Alternatively, a pop-up buoyancy aid and associated line can be deployed with the platform. If using pop-up recovery aids, a signal can be sent acoustically to the platform to trigger release of the buoyancy aid and attached line (see Figure 5) to then recover the platform.

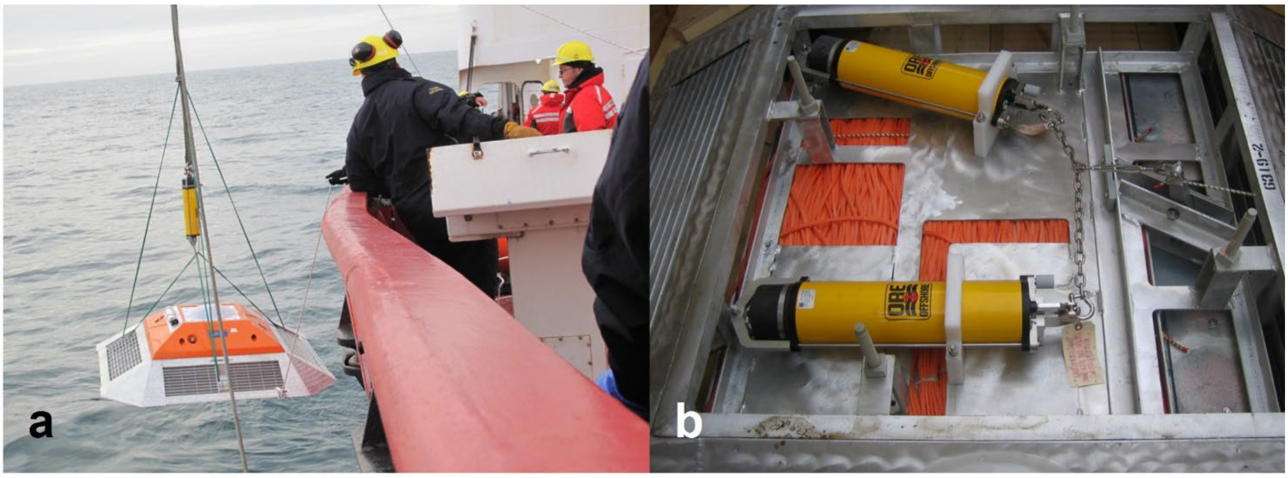

Figure 5: Images of: (a) a trawl resistant bottom mount deployment; and (b) folded orange recovery line in platform base (Image copyright: © DeepWater Buoyancy, Inc. 2023).

The recovery of benthic landers, and some mooring systems, is initiated by a timed release or acoustic command to release the ballast weights and allow the buoyant platform to ascend to the surface. It is important to locate the platform as quickly as possible at the surface to ensure it does not drift out of the search zone (Tengberg *et al.* 1995). Landers should be equipped with detection tools, such as satellite or radio beacons, strobe lights and visual markers to make them easier to locate (Bagley *et al.* 2004). Back-up acoustic release systems should be in place to ensure recovery is possible if the initial system fails or buoy lines are tangled.

A contingency plan should be in place if the platform cannot be recovered from the seabed. For example, divers can be deployed in shallow water to conduct a search pattern to locate a lost platform. Recovery of a lost seabed platform in deep water will be more challenging. The use of grappling trawlers over sandy uniform beds may provide success in mid-depths. However, undertaking a cost vs benefit assessment that includes alternative scenario comparison is an advisable first step. Specialist marine salvage teams or ROV operators are safe alternatives, particularly in deep water or over complex and sensitive habitats yet come at considerable additional cost.

3.4.1 Case study: Recovery systems and protocols of the Gothenburg benthic lander fleet

Between 2006 and 2020, 51 research expeditions have been conducted to deploy the University of Gothenburg’s suite of benthic landers 308 times. This repeatability has led to ongoing design developments with a focus on flexibility, ease of operation, fast turn-around time between deployments, low power consumption and high-quality control abilities (Kononets *et al.* 2021).

The largest of the Gothenburg landers is designed with three independent systems for recovery. The first two are iXblue acoustic release devices initiated by acoustic signal sent from the surface. To date, the dual acoustic releases have operated as intended on each recovery mission. As a back-up, the third recovery system is custom-made magnesium bolts inserted into the ballast weights that eventually corrode, break, and release the buoyant lander. The time taken for complete corrosion is dependent on surrounding conditions such as temperature and salinity. For visual recovery at the surface, location systems are activated by pressure switches at 10 m below surface. This includes blinking flashlights, a VHF radio transmitter, and a satellite beacon (Figure 6).

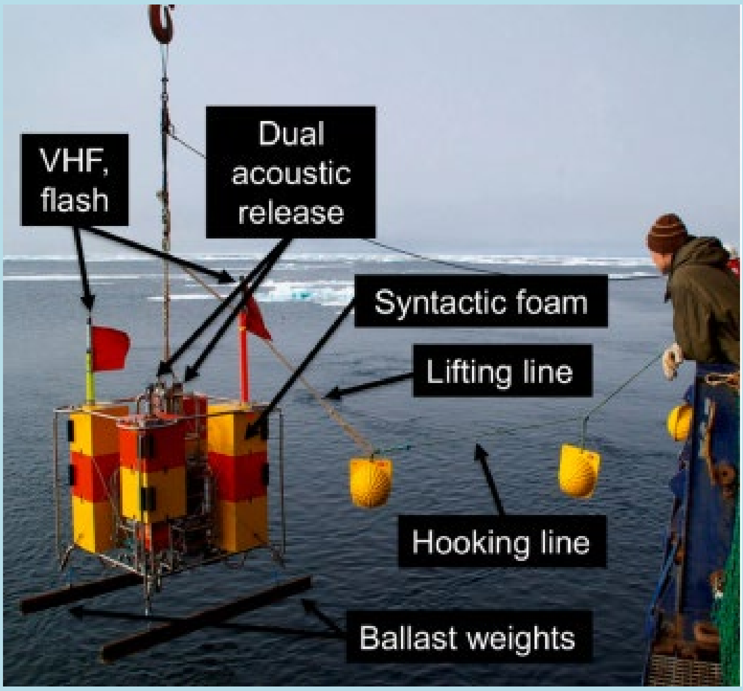

Figure 6. Deployment of the “big” Gothenburg lander in the Arctic Ocean showing recovery and location systems. From Kononets *et al.* 2021 (copyright: © 2021, Kononets *et al.* Published by Elsevier B.V.)

3.5 Stowage

Onboard stowage plans must be in place regarding storage of the platform(s) and associated sensors both prior to deployment and post-recovery. The dimensions and weight of the platform will dictate stowage options available to the survey manager. Mitigation of risk to the platform should be at the centre of all stowage decisions.

Stowage plans should be made with the vessel operator or skipper and other survey managers on the research cruise. The crew and scientific team will need to be briefed on their involvement required to safely action stowage plans.

There must be appropriate space onboard to stow the platform, either strapped on deck or stowed below deck, as appropriate. Platforms should be appropriately secured with bungies, ropes, and/or ratchets and strops. Containers may also be required ranging from small heavy duty plastic boxes to large metal shipping containers. Further packaging can be used for safe transport and stowage. Ease of access will be required if the platform is to be redeployed imminently at an additional site. The method of loading and unloading platform(s) on the vessel and transporting to the stowage area may either be manual (e.g. using trolleys or human chain approaches) or using lifting aids.

4. Interpretation guidelines

The measurement data extracted from environmental sensors depends on the sensor utilised and settings, which align with the project aim and objectives. Sensors have their own associated software to view, process, analyse and extract data in the appropriate format. Extraction and processing of data may be automated, particularly in instances where large volumes of data are concerned. It is beyond the scope of this guideline to address the specific interpretation guidelines for each individual sensor given the wide variety of environmental sensors available (as shown in Table 3). Further information is provided by the Marine Monitoring Method Finder (JNCC 2020), which brings together methodological guidelines, recommendations, and standards, some of which relate to monitoring oceanographic and environmental conditions.

5. Quality assurance measures

No specific quality assurance measures apply to in situ seabed platforms and their associated environmental sensors. However, selecting the platform best suited to meet survey aims and site conditions, and ensuring the competency of personnel involved in designing and constructing the platform, as well as survey planning and operations, will increase the likelihood of acquiring high quality survey data.

Various environmental sensor guidelines can improve the likelihood of achieving high quality data and reduce the risk of errors. Initially, selecting an appropriate sensor to operate within the desired environmental conditions is essential (e.g. temperature or depth ranges). Bushnell *et al.* (2019) provide a useful overview of best practices for quality assurance with regards to oceanographic sensors. This includes highlighting the importance of pre- and post-deployment calibration, and the deployment of an alternative sensor (preferably from a different manufacturer) within proximity to the principal sensor for validation and estimation of errors.

Comparisons with historical data can often assist with data validation. Additionally, it is recommended to exchange or service sensors regularly, and monitor the sensor's performance temporally. Manufacturer specifications often provide further advice on quality assurance practices with regards to the individual sensors. The UK Geo-spatial Metadata Interoperability Initiative (GEMINI) offers guidance to ensure geospatial metadata conforms to UK Government guidelines and ISO standards, adopted by data archive hubs such as MEDIN.

6. Data products

Environmental sensors mounted to in situ seabed platforms can collect a range of quantitative data during deployment. Different types of data products, related to environmental variables, that may be collected from these sensors are outlined in Table 3. Sensors can store data internally, powered by internal or external batteries, whereby data must be retrieved from the sensor. Alternatively, sensors can transmit data to shore via online cable or acoustic modem (transmits data to ocean surface, which can subsequently transmit to shore (e.g. via GSM), such that measurements are continuously available (see The Comprehensive Manual for ADCPs).

6.1. Data management

Processed data and associated metadata should be archived within the appropriate database. The Marine Environmental Data and Information Network (MEDIN) leads marine data management within the UK, providing a long-term central hub to store and access marine data, including biological, oceanographic, and meteorological data. Accredited Data Archive Centres (DACs) coordinated through MEDIN (e.g. Water Column Oceanography (BODC) and Meteorology (UK Met Office)) among others, follow common standards and quality control procedures (Figure 7). Guideline documents, free workshops and a helpdesk offer advice and guidance to assist data managers where required. The MEDIN metadata portal provides access to data from available metadata records, subsequently uploading data to other databases (e.g. the European Marine Observation and Data Network (EMODnet), United Kingdom Directory of the Marine Observing Systems (UKDMOS) or data.gov.uk).

UKDMOS provides a searchable database of metadata regarding marine monitoring programmes conducted within the UK, managed, and updated by MEDIN. New monitoring programmes or series can be added to the database through a provided template, ensuring consistency across the database. EMODnet is a central hub for European marine data archives, consisting of over 120 contributing organisations. The available data is standardised, with data quality indicators for the user's benefit. Applications can be made to become an associate partner, in order to contribute to the expanding database.

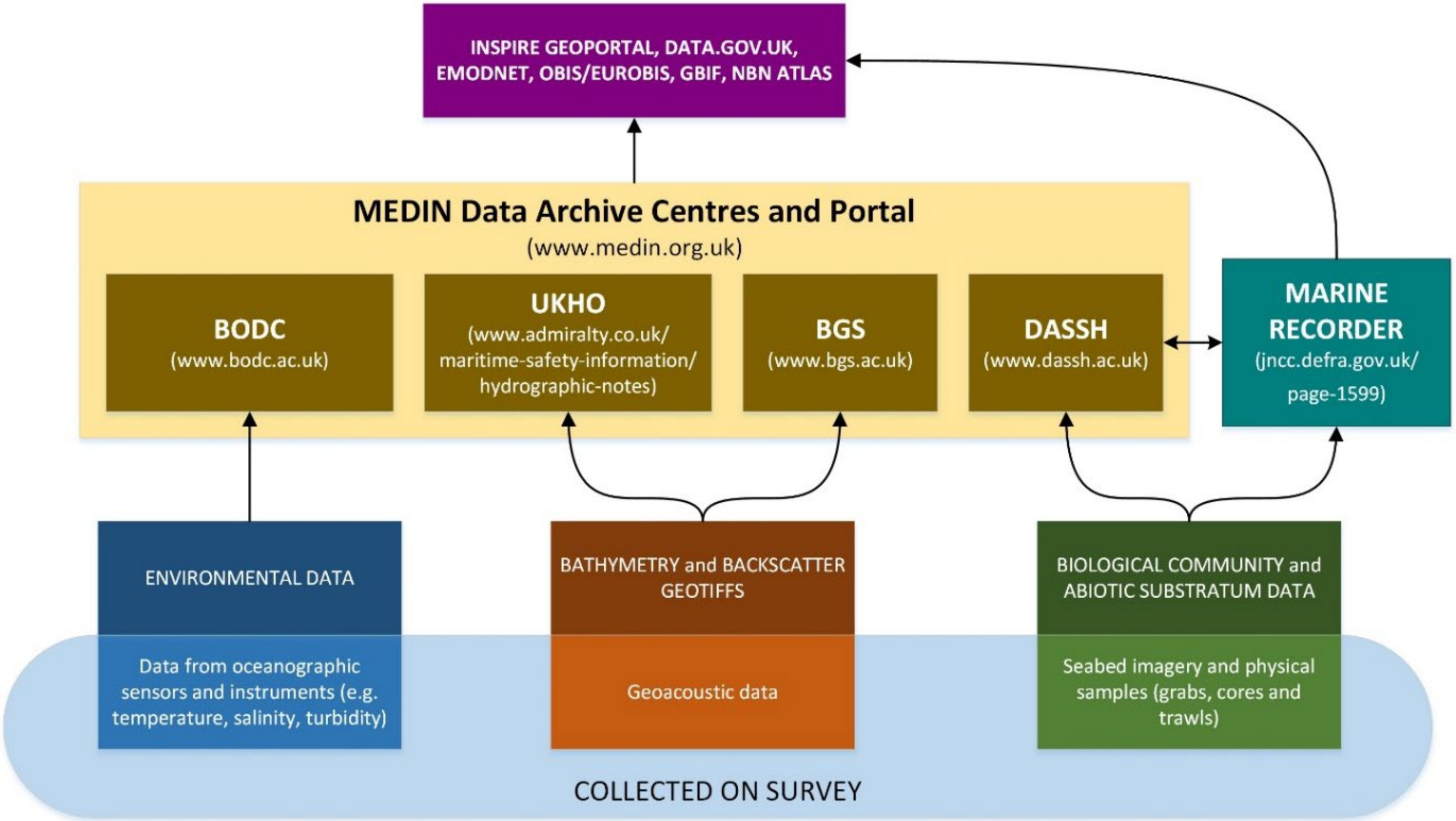

Figure 7: Diagram showing a simplified flow for marine data in the UK, from collection on survey to storage in MEDIN data archive centres, Marine Recorder and other databases as indicated. MEDIN = Marine Environmental Data and Information Network; BODC = British Oceanographic Data Centre; UKHO = United Kingdom Hydrographic Office; BGS = British Geological Survey; DASSH = Data Archive for Species and Seabed Habitats; EMODNET = European Marine Observation and Data Network; OBIS = Ocean Biogeographic Information System; EUROBIS = European Node of the international Ocean Biogeographic Information System; GBIF = Global Biodiversity Information Facility; NBN Atlas = National Biodiversity Network Atlas. Image produced by JNCC, 2018.

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Glossary

ADCP	Acoustic Doppler Current Profiler
AUV	Autonomous Underwater Vehicle
CTD	Conductivity, Temperature, and Depth
DAC	Data Archive Centre
DAERA	Department of Agriculture, Environment and Rural Affairs
EMODnet	European Marine Observation and Data Network
GEMINI	Geo-spatial Metadata Interoperability Initiative
GSM	Global System for Mobile communication
HSE	Health and Safety Executive
IFCA	Inshore Fisheries and Conservation Authorities
MCA	Maritime and Coastguard Agency
MEDIN	Marine Environmental Data and Information Network
MSCC	Marine Science Co-ordination Committee
MSL	Mean Sea Level
NRW	Natural Resource Wales
ROV	Remote Operated Vehicle
UKDMOS	United Kingdom Directory of the Marine Observing Systems
VHF	Very High Frequency

Appendix 1. Additional equipment considerations

When designing a bottom frame or mooring platform, the following considerations should be prioritised in addition to those described in the Equipment section of this guideline:

- Stability.
- Buoyancy for platform or sensor placement and retrieval.
- Mobility elimination of the platform and sensors.
- Ease of deployment vs weight required for above.
- Number of sensors required, their orientation and placement on platform.
- Maintenance and cleaning requirements of sensor(s) and platform.
- Ease of transport and stowage.
- Substrate type of survey site (consider risk of burial).
- Potential for damage to seabed habitats and communities.
- Risk of vandalism and damage by shipping or fishing activity.
- Retrieval and location method.

As a mooring is composed of multiple component parts, in comparison to a bottom frame which is often a modular unit, the following components should be considered in system design:

- Surface buoy: to indicate position of sensor and act as retrieval tool. Sufficient buoyancy is required to keep the mooring line and sensor as vertical as possible whilst remaining a manageable size. Survey planners should consider the surface conditions the surface buoy will be exposed and subsequent buoy watch circle (the freedom of movement of a surface buoy, defined by the mooring line length). Foam or air-filled hard plastic buoys are recommended for long-term surveys as soft plastic air-filled buoys can puncture and be lost.
- Subsurface buoy: buoys placed along the mooring line throughout the water column help to maintain a vertical position and keep the sensor as stationary as possible. Subsurface buoys act as a back-up recovery if the surface marker buoy is lost. Some mooring designs utilise subsurface buoys to reduce damage caused by chains to the seabed habitats (Luff *et al.* 2019; Parry-Wilson *et al.* 2019). Subsurface buoys can also be used to attach or house the sensor. The depth rating of subsurface buoys must be checked prior to deployment.
- Mooring line: Amount required is dependent on the water depth. Line material should consider ease of handling, duration of deployment, environmental conditions and drag. To avoid excessive drag, a mooring line with the smallest possible diameter should be used. For deep-water surveys, elastic synthetic rope will reduce the effect of sensor movement and absorb movement of the surface buoy in adverse weather conditions (see: the Nortek Comprehensive Manual for ADCPs).
- Anchor: The anchor must be of sufficient weight to sink and remain static on the seabed and is offset against ease of deployment.
- Connecting hardware: shackles, swivels and links are used to connect the mooring components. Hardware must be corrosion resistant, and use of different metals or alloys should be avoided.
- Ancillary equipment: an acoustic release may be deployed close to the anchor for recovery of the sensor and mooring system. Location systems may be required for surface recovery. Ancillary equipment relating to the sensors should be accounted for, such as gimbals and batteries.

Platforms and sensors left in situ for long-term monitoring may require regular maintenance. One maintenance concern is the need to clean sensors of substrate deposits and biofouling. Biofouling and other deposits will increase the weight of the platform, potentially causing issues with recovery operations. Biofouling of sensors is of particular concern in long-term deployment as a limiting factor in data acquisition (Coppola *et al.* 2016). Equipment should either be regularly cleaned manually, or automatic wiper units fitted to sensors (Pearson *et al.* 2021).

Appendix 2. Additional survey planning considerations

Survey planning

Prior to the survey, details of equipment, personnel, transportation, itinerary, health & safety measures, insurance and any special platform handling, preparation, stowage, or operational considerations should be planned and accounted in reports to share with contractors. Any problems should be identified and then resolved prior to the survey by the survey manager. Potential risk in upcoming survey operations should be identified, assessed, and mitigated. Risk assessment and management plans are key reporting requirements. In more complex settings, mobilisation and demobilisation plans should be in place to commence and end the survey. This plan should correlate well with the vessel operators own mobilisation and demobilisation plans. Plans should additionally be made for survey elements relating to the environmental sensors using specific and relevant monitoring protocols. This includes sensor mounting and security, equipment calibration, considerations for settings (frequency, duration, etc.), sufficient power, data download and / or sample collection, organisation, storage, review, and analysis bearing in mind that long-term surveys will produce large amounts of data to be managed.

Prior to commencing survey operations, planning meeting(s) should take place with the survey manager, co-lead scientist, technical leads, vessel skipper and contractors (such as dive team) to agree how operations will be conducted. All parties will need to reach an agreement on the following key points:

- Survey objectives and expected outputs.
- Itinerary including co-ordinates of survey site(s), number of operational days required and contingency plan for poor weather or operational problems.
- Tasks and responsibilities of survey team and crew.
- Vessel capabilities and requirements for specialised equipment, such as lifting aids.
- Mobilisation and demobilisation plan.
- Risk assessments and health and safety measures including any safety briefings required onboard.
- Vessel coding and onboard protocols.

The survey manager should prepare an onboard checklist to initiate deployment and recovery operations. Factors to consider include, but are not limited to:

- Check all required personnel are onboard.
- Check correct vessel coding is in place.
- Check all equipment, spares and back-ups are onboard.
- Unpack from transportation and repack for safe stowage.
- Visual and physical inspection of platform by technical staff.
- Check the most up to date weather and sea state forecasts.
- Schedule of briefings for scientific staff and crew.
- Ensure all documentation is in place including Health & Safety and risk assessments.
- Fill in required record keeping documents, such as a cruise report including a log of major problems and faults identified to assist planning of future surveys (see McPhail *et al.* 2011, for example cruise report deploying lander).
- A test run of platform deployment and sensors may be necessary, especially if the survey is considered high-risk (e.g. when launching a new platform design).

Survey window recommendations

Consideration should be given to the expected weather conditions at the survey site. A full briefing of the survey aims, and platform design should be given to the skipper to determine environmental limiting factors, such as season, weather, currents, etc.

Strong wind, tide, current and wave exposure will impact deployment as adverse conditions may cause the platform to drift in the water column and miss the intended landing position (Tengberg *et al.* 1995). If it is crucial to deploy the platform to an exact position on the seabed, deployment should be planned during calm weather windows and delayed if necessary. Similarly, equipment recovered by means of automatic or acoustic release will drift significantly during ascent and potentially be difficult to locate at surface. It is important to build contingency days into the survey plan and vessel hire if conducting a survey during seasons associated with poor weather.

Survey notification

Seeking early engagement with key regulators or statutory bodies is an important step for any project. While there are policy, governance and legal aspects which are common to all UK and Ireland administrations, there are also key differences. It is the responsibility of the survey manager to ensure advice is requested and procedures followed. Whether working offshore or on privately owned seabed, survey managers should engage with the key regulators as licenses for depositing temporarily or permanently to the seabed are often required, and permission is always required.

The level of input to obtain a license or permission depends on the overall survey plan, assumed, or measured environmental impact or interference with wider activities, and total timeframe. Often there will be deliberate or accidental loss at sea during the survey. Where complete retrieval is planned, often a lighter permissions process is required compared to when a survey plan includes leaving anchors or weight deposited on the seabed. A license to deposit at sea will be required (see Marine Licencing Definitions from the MMO).

For small scale, scientific research where surveys are time-limited and low impact, often there is a fast-track process to obtain permission or licence. That said, organisations and agencies can take time to deliberate and discuss project details, therefore these consultations should be factored in well in advance of any planned sea going activities. Survey managers should be prepared for the permission and licensing requirements to change if the project activities are scaled-up or extended. Organisations have developed online proformas within their websites typically to manage enquires, which can be submitted with activity details and location.

Authorities for licensing, management, and conservation in England, inshore and offshore, include:

- The Marine Management Organisation (MMO) delivers planning, licensing activities and enforcement functions from mean high water springs.
- Permission from The Crown Estate will be required if within 12 nautical miles (nm).
- Inshore Fisheries and Conservation Authorities (IFCA) manage inshore fisheries out to 6 nm, MMO manage fisheries from 6 to 200 nm (both under the Marine and Coastal Access Act 2009).
- Natural England (from 0 to 12 nm, territorial waters) and The Joint Nature Conservation Committee (from 12 to 200 nm, offshore waters) advise on designated habitats and management of marine protected areas.
- The Marine and Coastguard agency and Trinity House provides authorisation on navigational and shipping related matters.
- Notify coastguard/ harbourmaster when working inshore, and fisheries organisations and/or local landing sites (ports) as suggested by consulting the above organisations.

In Scotland, Wales and Northern Ireland, national parliaments have devolved responsibility and compliance typically over marine conservation, planning, licencing, and fisheries inshore. Wales also holds devolved competence offshore. It is worth checking with The Crown Estate and/or the MMO regarding the status offshore, alongside the national governments. There is a useful summary in Preston *et al.* (2020). Competent authorities and advisory agencies for areas requiring licensing and permissions in Wales are Natural Resource Wales (NRW) and Welsh Assembly Government. The Department of Agriculture, Environment and Rural Affairs (DAERA) oversees Northern Ireland, whereas in Scotland, Marine Scotland and NatureScot will advise.

Communications

During the survey, there must be regular communication between all personnel contributing to operations. Safety briefings should be held regularly and attended by all personnel. Offshore research cruises operate 24 hours in multiple shifts. For efficient operations, it is vital that full handovers take place between shift managers covering progress made during shift, next steps, issues encountered and any potential hazards. A pre-shift briefing should be held with the survey team and relevant crew to discuss shift objectives, weather conditions and any safety and personnel matters.

Appendix 3. Survey costs and time

The following section is intended to advise survey managers of an indicative cost to conduct a survey, expanding on the costs estimated in overview Table 1. All costs are an estimate (at time of writing) and serve as a guide only. Survey managers should contact platform manufacturers, vessel operators and consultants for the most up to date rates.

Post-survey cost estimates including sample and data processing, and reporting are outside the scope of this procedural guideline. However, these costs should be accounted for in the survey planning stage and budgeted for accordingly.

Equipment costs

Detailed below in Table 4 are the estimated equipment costs for a variety of platform types with depth ratings. The costs presented are current rates to purchase 'off-the-shelf' equipment available to UK-based survey planners. Appropriate lead times should be factored into the survey plan as many of these platforms are most often built to order based on the sensors to be fitted, intended operational depth and likely survey site conditions. Estimate costs exclude ancillary equipment (e.g. gimbal axis, lifting weight, acoustic release, etc.). Mooring cost estimates include weight, chain, line, sub-surface buoy, surface buoy, swivels, and shackles.

Survey managers should also contact appropriate research institutes for rates to hire their equipment. A comparison can be made between purchase vs hire rates considering survey frequency and longevity to determine which will be the most cost-effective strategy. If a survey manager cannot source a suitable platform for their survey requirements, they should consider contacting suppliers to modify existing models or to design their own platform to be custom-built.

Table 4: Summary table of estimated equipment costs (in 2023).

Equipment	Cost to purchase (rated to depths, m)
Tripod bottom frame	£2,800 to £4,000 (200 m)
Trawl resistant bottom mount	£16,000 (200 m) to £40,000 (500 m)
Benthic lander	£40,000 to £50,000 (6,000 m)
Mooring components	£200 to £500 (100 m)
Mooring components	£15,000 (200 m) to £100,000 (3,000 m)

There is a wide range of sensors available to measure environmental parameters (see Table 3 for overview). Estimated costs for sensors is not included in this guideline and survey managers must budget accordingly for the sensors themselves, as well as the platforms.

Vessel costs

Outline cost estimates for hire of a range of vessel types are shown in Table 5. The hire costs presented are inclusive of skipper, crew, fuel and insurance. When liaising with vessel operators, the survey manager must ensure these costs are including in quotes.

Table 5: Summary table of estimated vessel hire costs per day (in 2023).

Equipment	Cost to hire/day
Small nearshore vessel	£700 to £3,000
Nearshore crane barge	£1,200 to £1,700
Large nearshore vessel with winch	£3,000 to £12,000
Large offshore vessel with hydraulic lift capabilities and dynamic positioning	£20,000 to £35,000

Personnel costs

Typical day rates are presented in Table 6 for a range of survey contractors including oceanographers, ecologists, and technicians. The exact personnel day rate is dependent on level of experience, qualifications, competence, and seniority. It is assumed that all personnel carry the relevant training and certification for their profession. However, we have included costs for the survey manager or co-lead scientist to complete a sea survival certificate and ENG medical certificate course for work at sea. The survey manager should liaise with the vessel operator to ensure all contractors meet their requirements for health and safety certification. These costs represent the course cost only and do not include salary costs or travel and subsistence. Personal protective equipment is required for working onboard a vessel. At a minimum, all personnel should be equipped with a hard hat, foul weather gear, toe capped boots, gloves, and safety glasses.

Travel and subsistence rates provided include cost of food, accommodation, and travel (which may include airfare). These costs are highly variable across the UK.

Table 6: Summary table of estimated personnel costs to carry out survey (in 2023).

Personnel	Day rate per person
Survey manager / co-lead scientist / oceanographers / benthic ecologists / technicians / PhD students	£250 to £1,000
Travel & Subsistence	£150 to £1,000
Sea Survival Certificate	£140 (1 day) to £550 (3 days)
ENG 1 Medical Certificate	£115
Personal Protective Equipment (PPE)	£250 to £750

Cost variability

Key factors that lead to cost variation between surveys include (list adapted from AUV and ROV Procedural Guidelines (JNCC 2018a, JNCC 2018b); not an exhaustive list):

- Purchasing versus hiring equipment.
- Experience, skillset, and seniority of personnel.
- Complexity of operations, number of deployments, distance from shore and water depth as:

  - Planning requirements will be greater due to the increased complexity, scale and risk of all survey stages when surveys are offshore in deeper water;
  - Length of survey increases vessel hire costs; *and*
  - Distance travelled by vessel will affect fuel consumption and length of hire.
- Contingency days required due to:
  - Deployment and/or recovery operations in poor weather window; *and*
  - Use of novel platforms requiring additional time for test runs.
- Sample and data processing costs are highly variable and outside the scope of this guideline.

Appendix 4. Alternative options for surveying / sampling

A decision must be made as to whether a bottom mount or mooring is the platform most suited to meet the survey aims, considering costs and other factors. It may be appropriate to achieve research objectives utilising other monitoring platforms and methods, such as sampling trawl, dredge, ROV survey, etc., alongside in situ benthic platforms.

Before implementing any survey plan to collect environmental data, it is worth checking if the required data can first be derived from other sources. For example, the National Oceanography Centre (NOC) in Southampton coordinated the Fixed-point Open Ocean Observatory (FixO^3) with involvement from 29 European partners from academia, research institutes and small & medium enterprises. FixO^3 combined data from moorings and data buoys throughout the water column ranging from the sea surface to deep seafloor in the Atlantic and Arctic Oceans, and Mediterranean Sea. A key aim of the project was to provide free and open data services and products and to enhance understanding through knowledge exchange and training, such as a handbook of best practices (Coppola *et al.* 2016). The cabled observatories, seabed bottom mounts and moorings that make up part of the FixO^3 network may be of interest to researchers requiring long-term in situ benthic data sets.

For ease of operations, it may be suitable to utilise existing offshore infrastructure. Fujii and Jamieson (2016) monitored fish movements and environmental parameters around a decommissioned offshore oil platform in the North Sea. The infrastructure provided a platform to launch a moored autonomous monitoring system. Figure 8 shows the monitoring system which was tethered to the oil platform at the surface. A survey methodology utilising fixed infrastructure may help to negate issues of deployment and relocating monitoring equipment for recovery.

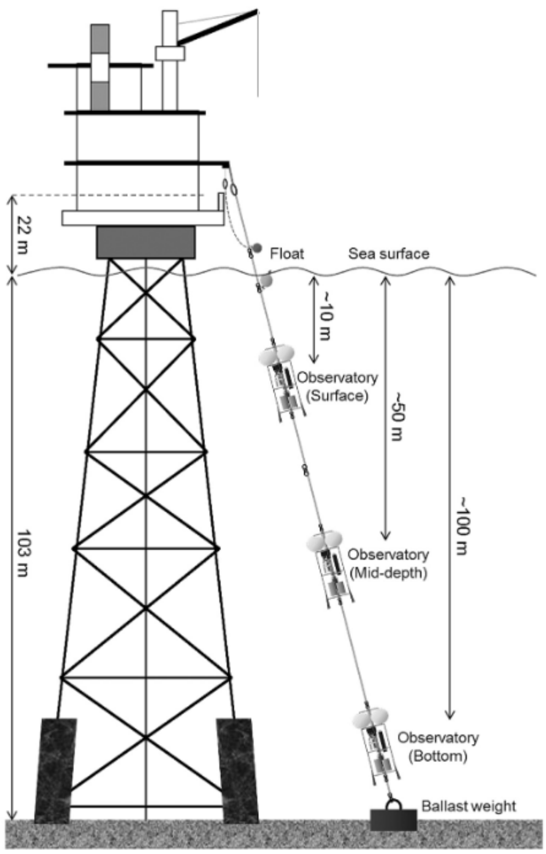

Figure 8: A schematic diagram of the monitoring observatory at 10 m, 50 m and 100 m deployment depth. The mooring line is weighted at the seabed and tethered to the oil platform at the surface (from Fujii & Jamieson 2016, published under a Creative Commons License: https://creativecommons.org/licenses/by-nc-nd/4.0/).

Marine Monitoring Platform Guidelines 4

Seabed Moorings for Marine Monitoring

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