LIFE Recreation ReMEDIES Advanced Mooring Systems worldwide

Project Summary Report

January 2024

Natural England Commissioned Report NECR508

www.gov.uk/natural-england

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Catalogue code: NECR508

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Keywords

LIFE Recreation ReMEDIES, anchoring, mooring, seagrass, Advanced Mooring Systems

Acknowledgements

This work would not have been possible without the interaction and contributions of several key individuals and organisations – Rebecca MacDonalds-Lofts (marine conservation and education specialist), Angela Clark (Natural England), Oliver Reddy, James Scott-Anderson (Blue Parameters).

Also input from Lionel Péan (SEAFLOATECH SAS), Todd Harris (Hazelett Marine LLC), Koh Exist, SEAFLEX, and Sealite.

Co-funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

Citation

R. Stainthorp. 2024.LIFE Recreation ReMEDIES Advanced Mooring Systems worldwide: Project Summary Report. NECR508. Natural England.

Foreword

The LIFE Recreation ReMEDIES: 'Reducing and Mitigating Erosion and Disturbance Impacts affecting the Seabed' project (LIFE 18 NAT/UK/000039) runs from July 2019 - Oct 2024 and will improve the condition of seagrass beds in five Special Areas of Conservation (SACs) between Essex and Isles of Scilly. This will be achieved by restoration, demonstration and reducing recreational pressures. Promoting awareness, communications and inspiring better care of sensitive seabed habitats will be key. Natural England (lead partner) is working with Marine Conservation Society, Ocean Conservation Trust, Plymouth City Council/TECF and the Royal Yachting Association. The project is financially supported by LIFE, a financial instrument of the European Commission.

As part of the LIFE Recreation ReMEDIES project we are installing trials of Advanced Mooring Systems (AMS) www.saveourseabed.co.uk both as boat moorings and as markers to reduce the impact to the seabed. Rather than use the term 'eco-mooring' we have been using the term AMS to emphasise that these systems are not just improved designs in terms of seagrass protection but also improved in terms of functionality for boats – they have longer life spans, have just as good if not improved performance compared to traditional moorings.

Historically, Natural England and other partners have commissioned a number of review projects on AMS but these have focussed on UK studies. Examples of reports looking at use of AMS worldwide are out of date.

The aim of this project was to try and help answer regular queries we receive from stakeholders such as- How many of these different systems are used around the world? Where and in what environmental conditions? What has been the performance of these systems?

This review will help inform the work of the LIFE Recreation ReMEDIES project and future AMS workshops, help inform management options for sensitive seabed habitats including MPAs, answer queries from harbour authorities, stakeholders and boaters and used to inform development of long term web resources.

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Executive summary

This work, commissioned by Natural England through the Life Recreation ReMEDIES (Reducing and Mitigating Erosion and Disturbance Impacts affEcting the Seabed) project, has collated information on the various Advanced Mooring System (AMS) types manufactured worldwide and constructed a global database of boat mooring AMS installations. In comparison with traditional chain moorings, AMS technology can provide ecological benefits by reducing the interaction between the mooring and sensitive seafloor ecosystems, as well as increasing user performance through reduced maintenance costs and increased longevity.

The approach taken by this project involved a combination of online literature review, public questionnaire, social media engagement and one-on-one interviews. Nineteen different AMS technologies were identified that are currently available on the market; varying in terms of design, materials and technical product performance specifications. Data gathered on AMS installations and trials demonstrate global distributions, with hotspots located in Europe, North America, and Australia.

Evidence on the performance and success of AMS technology both from an ecological and user perspective is reported for a number of case studies. However, in many cases the installations were either too recently installed, or regular maintenance check ups had not been performed, and performance data was lacking. The limitations of the methodological approach also contributed to data gaps, as successful conversions from viewing the post to taking an action such as clicking the link to the survey were only 2.9%.

This report will be of interest to marine managers including harbour authorities as well as individual mooring users and owners.

Contents

1. Introduction

1.1 Project background

The LIFE Recreation ReMEDIES: ‘Reducing and Mitigating Erosion and Disturbance Impacts affecting the Seabed ’project is focused on improving the condition of seagrass beds in five Special Areas of Conservation (SACs) between Essex and Isles of Scilly, UK. Natural England (lead partner) is working with Marine Conservation Society, Ocean Conservation Trust, Plymouth City Council/TECF and the Royal Yachting Association. The project is financially supported by LIFE, a financial instrument of the European Commission.

As part of the LIFE Recreation ReMEDIES project, Advanced Mooring System (AMS) trials have been installed in various locations around the UK for boat moorings and as marker buoys. These types of moorings are also sometimes referred to as ‘eco moorings’, ‘environmentally friendly moorings’ or ‘conservation moorings’, and are designed to minimise the amount of contact the mooring has with the seabed, thus reducing damage to sensitive habitats like seagrass meadows. In addition, this technology can also offer superior operational performance to more traditional types of mooring systems, which use a heavy chain to attach the surface buoy to the anchor. The term ‘Advanced Mooring System’ was developed by partners in the ReMEDIES project following an RYA led workshop in 2018 to reflect the dual advantages of this technology, both for the environment and for users. During consultation with stakeholders and boat users, a review of the way AMS technologies were installed, used and performed in other countries was identified as an important step to help deliver the best possible management options for sensitive seabed habitats, improve stakeholder confidence and engagement and to inform future projects. In the past Natural England and other partners have commissioned a number of review projects on AMS but these have focused on UK studies. Examples of reports looking at use of AMS worldwide are currently out of date.

1.2 Project description

This report identifies and outlines current available AMS technology types for boat moorings and describes relevant aspects of each of the identified technologies. In addition, a global database summarising the location and details of reported AMS installations has been created. This report presents a condensed summary of this data in Section 3.4 with the full database available in Appendix 3. Where information was available, further evidence was also gathered relating to users’ attitudes towards AMS technology, performance indicators and/or evidence of environmental remediation following installation. This report identifies key trends according to these metrics and presents a number of case studies where there has been evidence of environmental recovery.

Overall, a synthesis of the current picture for AMS technology in use worldwide was made in order to provide Natural England with a review to explore options that can:

- Inform the work of the LIFE Recreation ReMEDIES project and future AMS workshops
- Inform management options for sensitive seabed habitats including MPAs
- Answer queries from harbour authorities, stakeholders and boaters
- Used in communications, publications and social media
- Inform development of long term online resources on AMS

2. Methodology

This project builds upon initial scoping work carried out by the Ocean Conservation Trust as part of the LIFE Recreation ReMEDIES project in Autumn 2022.

In order to identify and outline available AMS technology types for boat moorings, a review of the literature was undertaken. This was achieved by conducting topical literature search exercises utilising primary, secondary and commercially-derived literature sources, in addition to anecdotal/opinion-based sources (e.g. both in written form and personal communications). Gathered information was utilised to prepare descriptions and accounts of identified AMS technology, including environmental conditions and performance metrics at each location where data was available.

2.1 Literature sources

Literature searches were conducted across multiple search engines (Google, Bing, Yahoo, Ecosia and others) and across multiple country code domains for each (.co.uk, .com, .org, and others). This approach aimed to account for different results or different rankings of websites by the search engine algorithms and allow us to compile a more comprehensive database. Search terms used BOOLEAN operators and key words to refine queries to the most relevant results and sources.

The online literature search had three objectives:

(1) to identify AMS technologies and obtain product specifications,

(2) to record the location of AMS trials and installations along with environmental conditions and performance data at each site, and,

(3) to find point-of-contact information for organisations involved in manufacturing, installing and/or trialing AMS technology in order to conduct interviews and obtain expert opinion where data was lacking for (1) or (2).

Specifically data was collected on:

- Details of the mooring location, which AMS technology is installed, year of installation, environmental conditions at the site, the type and size of vessels using the moorings;
- What are the primary incentives or drivers for AMS installation i.e. legislative requirement, environmental protection, reduced maintenance costs, etc.;
- How do boaters attitudes and use of AMS respond following installation;

- What evidence is available on the performance and success of AMS installations both from an ecological and user perspective;

- What evidence is available on remediation of mooring scars where AMS have replaced traditional moorings.

A summary of the literature sources found to contribute towards objectives (1) and (2) are as follows: peer reviewed journal articles (n=14), commissioned reports (n=6), MSc thesis (n=1), Local Authority or regional management plan (n=3), website (management organisation or conservation project) (n=4), website (AMS manufacturer / supplier) (n=4), online newsletter (n=3).

2.2 Public survey/questionnaire

A questionnaire was designed to capture user accounts of AMS boat moorings (see Appendix 1 for the list of questions asked). The survey was shared online via social media platforms (Twitter, Facebook, LinkedIN, and Instagram) and responses submitted electronically. Posts were made on different days of the week and at different times of day in order to try to capture different audiences and increase reach. Across all channels posts received a total of 4,483 impressions over 4 weeks (see Table 1 for a summary of post engagement across each platform).

Table 1. The total number of people reached, unique engagement and actions taken for each post made on Instagram, Twitter, Facebook and LinkedIn over 4 weeks. Engagement includes reactions i.e. likes, comments, sharing and reposts. Some cells are left intentionally blank. R=Reach; E=Engage; A=Action

	Instagram			Twitter			Facebook			LinkedIN		
	R	E	A	R	E	A	R	E	A	R	E	A
Post 1	654	38	3	2254	47	5	33	3	0	294	15	0
Post 2	395	30	2	366	11	0	35	2	2	425	4	0
Post 3										12	0	0
Post 4										15	3	0

In terms of reaching the widest audience, Twitter proved to be the most effective platform with an average reach of 1,310 per post, followed by Instagram (525), LinkedIN (187) and Facebook (34). Facebook and Instagram resulted in higher engagement rates however, with 6-9% of people who saw the posts reacting through likes, comments or reposting (Twitter and LinkedIN = 2-3%).

Conversion rate for each platform was calculated as follows:

$$\text{Conversion rate} = (\text{Unique link clicks to survey} \div \text{Total number of impressions}) \times 100$$

Facebook was the most effective platform across all posts for conversion rate (2.9%), however in real terms this only resulted in 2 clicks to the survey overall. The conversion rate for Instagram and Twitter was 0.5% and 0.2% respectively. LinkedIN did not result in any people clicking on the link to the survey.

Of the 12 people in total who followed the link to the survey, only 2 electronic responses were submitted. One respondent works for a non-profit marine conservation organisation called Koh Exist, which operates on Ko Tao island in Thailand (Koh Exist, 2022). The second response came from Mallets Bay Boat Club, Vermont USA.

2.3 Personal (email/telephone) communications

Correspondences with people/companies reasonably considered to have expert knowledge, opinions and/or experience with regard to the use of AMS technology was sought. Communications with the following were pursued and an indication of the response, if any, is reported:

People

- Marine Management Organisation global marine team were contacted but no responses were received
- Relevant contacts in Defra were sought who may have been able to provide further information but no responses were received.
- Lindy Orwin, Cooloola Coastcare (Australia) - Contact through Rebecca MacDonalds-Loft (marine conservation and education specialist, UK), no response
- Rachel Nazplezes, Healthy Land and Water (Australia) Email and phone call, no response

AMS manufacturers

- James Scott-Anderson, Blue Parameters (UK) - Email and telephone interview
- Lionel Péan, SEAFLOATECH SAS (France) - Email, provided product specifications for SEAFLOATECH technology, willing to engage further with the project but unable to arrange an interview within the project timeline

- Todd Harris, Hazelett Marine LLC (USA) - Email, positive response and willing to engage with the project but unable to arrange an interview within the project timeframe
- Enviro Mooring (Australia) - Email and phone call, no response
- Sea Marine and Diving Services Pty Ltd (Australia) - Email and phone call, no response
- Seaflex AB (Sweden) - Email, provided details about Seaflex products
- Sealite (Dubai) - Email, provided details about Sealite Synthetic Mooring

3. Review of current AMS technology

3.1 Single-point mooring description

This report is focused on the use of AMS technology for single-point moorings, sometimes referred to as swing moorings. This type of mooring is designed to remain fixed in place and provides a means of securing vessels, as an alternative to anchoring and marina berthing.

A single-point mooring typically consists of three components: 1) a fixture on the seabed, including either a type of block (weight or gravity anchor) or a drilled/screwed (embedment) anchoring system, 2) a floating buoy on the water surface to mark the location of the fixture, and 3) a system of chain and rope/s for the purpose of tethering a vessel to the seabed structure.

3.2 Environmental impact of traditional swing moorings

Traditional single-point moorings often use a block anchor and heavy chain to connect to the mooring buoy. As tides, currents and wind conditions move the buoy or moored vessel around the anchor point the chain can be dragged across the seabed, resulting in characteristic circular ‘scars’ where flora and fauna have been scoured away. Sensitive habitats such as sea grass meadows or coral reefs can be heavily impacted by this damage, with low chance of recovery unless the mooring is removed. Walker et al. 1989 reported that scouring had impacted areas up to 300m² in the seagrass meadows around Rottnest Island, Australia, the size of scar around each mooring depending on chain length related to vessel size.

In addition to vessel size, factors such as seagrass species and water depth determine the eventual size of mooring scar. Glasby & West (2017) individually mapped mooring scars in meadows of slow growing *Posidonia australis* (55-706m²) which were generally larger than those in the more opportunistic seagrass *Zostera muelleri subsp. capricorni* (22-342m²). Scar size in both species of seagrass increased significantly with depth and boat length. In the UK, 6ha of the fast growing and rapidly reproducing *Zostera marina* was reported lost due to moorings by Unsworth et al. 2017. However, the scar size of *Z. marina* was less than that recorded for *P. australis* in other studies (Demers et al. 2013), and seagrass rhizomes were mostly present in areas defined as scar site, indicating that the species may have a greater capacity to recolonise areas that have been damaged by moorings.

More recent studies reporting the damage that traditional single-point moorings can cause to seagrass meadows, fragmenting the habitat and reducing resilience to other pressures, include those by: Evans et al. 2018, McCandless 2018, Morrisey et al. 2018, Broad, Rees and Davis 2020, and Ouisse et al. 2020.

3.3 Advanced Mooring Systems for swing moorings

In contrast to traditional swing moorings, AMS can typically include two common features: 1) a drilled/screwed anchor that penetrates the seabed and 2) a rode and buoy system that makes little to no contact with the surrounding substrate despite changes in tides and other environmental conditions. An anchor that is screwed into the seabed has a smaller impact area than a block anchor which relies on weight (and therefore often size) to secure the vessel. This anchor type coupled with the rode/buoy suspended above the seabed means AMS significantly reduce the chance of mooring scars while still being able to safely secure vessels at sea (Musson et al. 2015).

This report found accounts of nineteen types of AMS in use today, with the main differences between them relating to the rode and buoy system, and/or the method of attachment to the seabed. Generally, the designs can be categorised into four types:

1. Displacement buoy systems
2. Elastic or floating rodes
3. Shock absorbing systems
4. Custom AMS moorings for specific environmental conditions or systems which adapt the traditional swing mooring

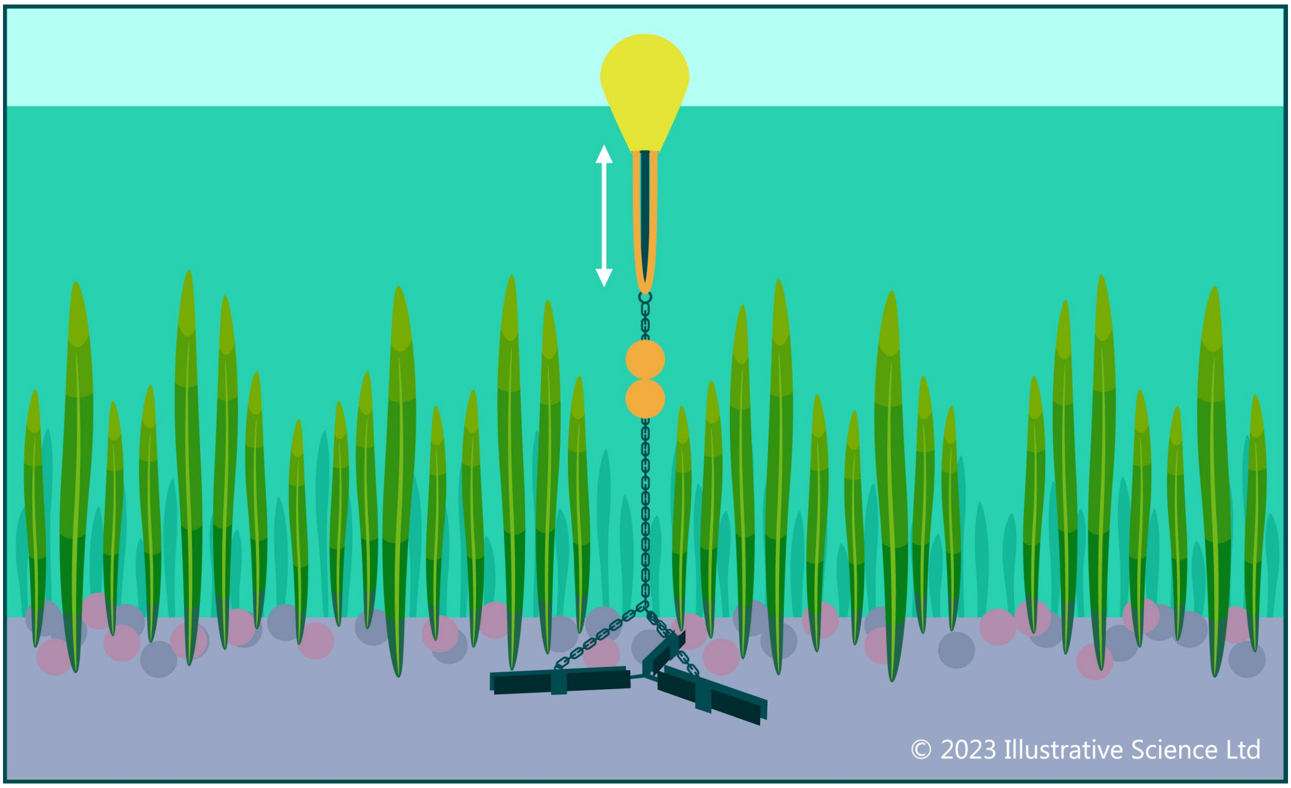

Figure 1. Digital illustration showing the generalised configuration for a displacement buoy mooring system. Image credit: Illustrative Science Ltd, 2023. Commissioned by Natural England for the LIFE Recreation ReMEDIES project.

3.3.1 Displacement buoy systems

EzyRider Mooring

https://www.fishhabitatnetwork.com.au/environmentally-friendly-moorings-fish-friendly-marine-infrastructure

Company: Global Moorings, WA, Australia

Description: A displacement buoy moves freely up and down a stainless steel shaft attached to a down-line chain at one end and a surface line at the other. Strong rubbers connect from the base of the buoy to the bottom of the shaft that lift and hold the chain up off the seabed. When pulled (i.e. attached to a vessel) the rubbers stretch and the buoy moves up the shaft. When tension is released the rubbers contract and the buoy moves back down the shaft, without causing the down-line chain to become slack. The EzyRider Mooring can be installed with various anchoring systems, in different applications and in most marine locations (soundingsonline.com, 2009).

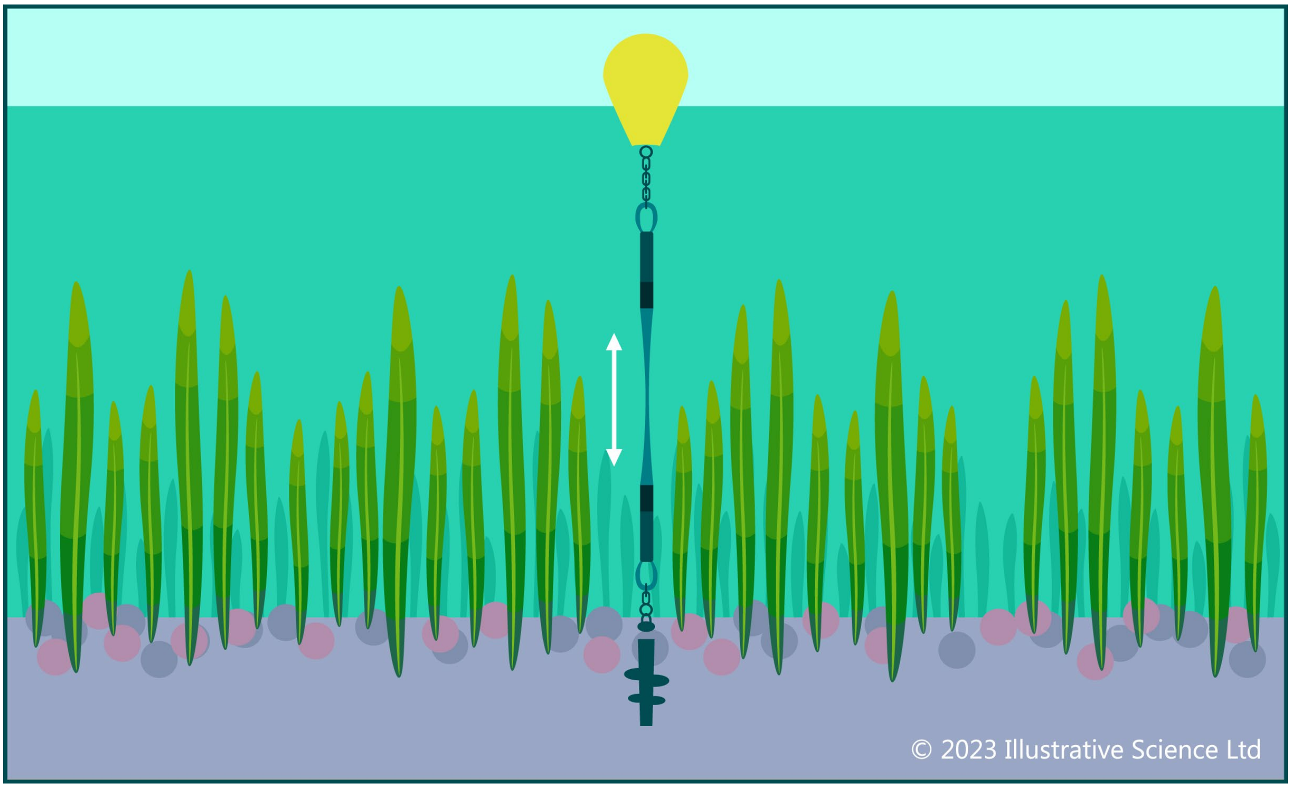

Figure 2. Digital illustration showing the generalised configuration for an elastic or floating rode mooring system. Image credit: Illustrative Science Ltd, 2023. Commissioned by Natural England for the LIFE Recreation ReMEDIES project.

3.3.2 Elastic/floating rode systems

Eco-Mooring System

http://www.boatmoorings.com/

Company: boatmoorings.com, NH, USA

Description: The Eco-Mooring Rodes system comprises of neutrally buoyant elasticised rope and attached buoy which can be attached to either deadweight or embedment anchors. However, the suggested method for anchoring is the use of Helix Anchors, also supplied by the manufacturer. Eco-mooring systems produce a dozen standard size Eco-Mooring Rodes and offer custom fabrication upon request. The elastic rodes are designed and manufactured to withstand high strain (32,000lbs tensile strength) (boatmoorings.com, 2017).

Ecomoor

https://www.ecocoast.com/ourproducts/ecomoor/

Company: Ecocoast, Dubai, UAE

Description: Ecomoor is a lightweight mooring line which floats in all marine conditions and environments. It requires no heavy lifting and handling equipment during installation, reducing transport and installation costs at the same time. Lengths range from 2 up to 20 meters, however, can be extended or connected together to create longer lengths, depending on project requirements. Ecomoor can be used for different applications, from navigation buoys and deep moorings, to floating solar structures and aquaculture parks. It is compatible with various anchor systems requiring only a galvanised steel shackle bolt to attach the end of the line with the anchor (Ecocoast, 2023).

Environmentally Sensitive (ES) mooring

https://publications.csiro.au/rpr/download?pid=csiro:EP195633&dsid=DS1

Company: CSIRO, Australia

Description: System consists of a floating strop and a shock absorbing synthetic section, which are neutrally buoyant. Can be adapted to various anchoring methods and is composed of off the shelf components enabling it to be serviced using traditional methods (Lynch et al. 2019).

Hazelett Conservation Elastic Mooring

https://hazelettmarine.com/products/single-point-swing-mooring-systems/

Company: Hazelett Marine, VT, USA

Description: The system consists of galvanised h

Hardware for attaching to a Helix anchor (recommended) or block anchor, hard trawl floats to keep the components afloat, one or more elastic rodes, a spar buoy, and a stainless steel swivel. The rodes are manufactured of an advanced polyurethane elastomer blend, with polyethylene thimbles pressed into the ends. Hazelett Marine makes two types of spar buoys: one made of aluminium is suitable for freshwater only, the second is made from polyethylene. Manufacturer claims that the Hazelett Conservation Elastic Mooring system can increase mooring field density by 40%, as it can be installed with a 1-to-1 scope instead of the 3-to-1 scope of traditional ball and chain systems (Hazelett Marine, 2019).

Mooring Anchoring Device

For further information contact Greg Hill (Cape Marine Pty Ltd), located at Coffs Harbour (New South Wales).

Company: Cape Marine Pty Ltd, NSW, Australia

Description: The Mooring Anchoring Device consists of an anchor device and a “stormrider system” comprising of an elastometric riser, subsurface floats, chain and swivel. The StormSoft down-line of industrial rubber multi-strand cords surrounded by a braided polyester shell/rope. A continuous inner core of braided polyester maintains the position of the shock absorbing rubber. The system has a very tight braid design to keep marine life out of the interior of the assembly and the system has no complex metal connections (RSP APSA PTY LTD, 2014).

Safe-Moor Mooring Solution

https://www.safemoor.com/spec-information

Company: EOM Offshore LLC, MA, USA

Description: Mooring tether comprised of stretch controlling nylon and vulcanized rubber, aramid strength members in center core. Safe-Moor™ is near neutrally buoyant, with an air weight of about 25lbs, category 1 hurricane resistant and has a lifespan of 10-12 years. Modular design can be used in parallel for higher working loads or in series for increased depth deployment. Two options/sizes available (2.5m and 5m). The 2.5m (8 ft) hose stretches 2.5x to 6.25m (20 ft). The 5m (16.5 ft) hose stretches 2.5x to 12.5m (41 ft) (Safemoor LLC, 2020).

SEAFLEX Mooring System

https://www.seaflex.com/products/

Company: Seaflex, Sweden

Description: Seaflex is a versatile elastic mooring system that can be used with either mooring buoys or pontoons, and is anchored using either deadweight or embedment anchors. The Seaflex mooring system consists of a reinforced homogenous rubber hawser, built around a homogenous rubber core. A specially braided cord is wrapped around the core, and the outer layer consists of a durable rubber cover which forms the outer shell of the hawser. The system also often includes an “integrated-by-pass” which is engaged as the rode reaches 80% elongation, preventing the system reaching maximum elongation (Seaflex, 2023).

Sealite Synthetic Mooring

https://www.sealite.com/wp-content/uploads/SPEC_SYNTHETIC-MOORING-SOLUTION.pdf

Company: Sealite, Dubai, UAE

Description: The Sealite synthetic mooring solution consists of a positively buoyant mooring line which can be attached to a deadweight or embedment anchoring system. The mooring line incorporates load bearing nylon fibres laid in parallel construction into galvanised wire rope thimbles or high performance stainless steel thimbles. The entire construction is covered in a vulcanised industrial rubber to protect the nylon core and thimbles from corrosion in salt and fresh water. The design of the embedded thimbles protects the nylon fibres from fraying, whilst the abrasion and cut resistant rubber is UV stabilised and salt water resistant (Sealite, 2022).

StormSoft mooring

https://jwilburmarine.com/elastic-moorings/1-storm-soft-elastic-moorings

Company: J. Wilbur Marine, FL, USA

Description: The StormSoft mooring system consists of a down-line of industrial rubber multi-strand cords surrounded by a braided polyester shell/rope. A continuous inner core of braided polyester maintains the position of the shock absorbing rubber. The system has a very tight braid design to keep marine life out of the interior of the assembly and the system has no complex metal connections. Designed to be compatible with deadweight or embedment anchors. Supplied in two lengths with mooring pennant and spar buoy included (J. Wilbur Marine).

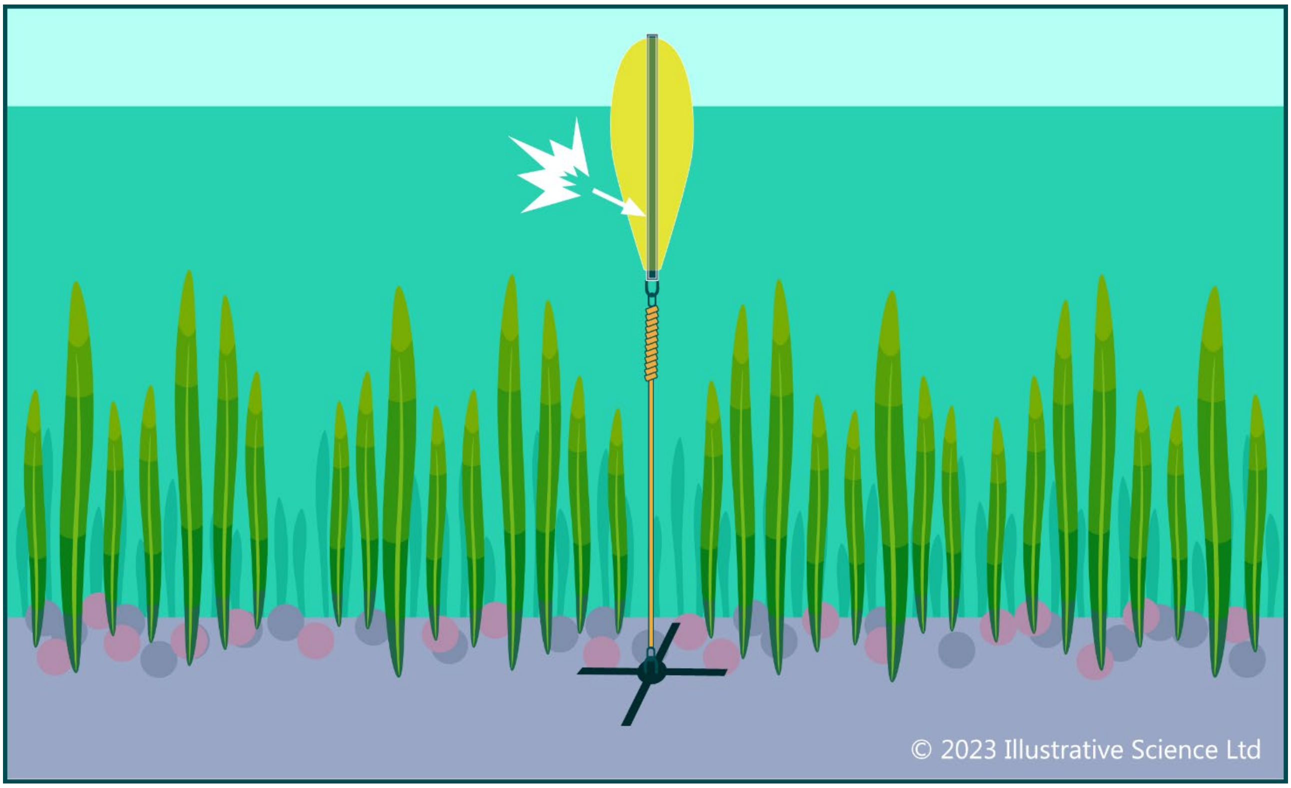

Figure 3. Digital illustration showing the generalised configuration for a shock-absorbing mooring system. Image credit: Illustrative Science Ltd, 2023. Commissioned by Natural England for the LIFE Recreation ReMEDIES project.

3.3.3 Shock absorbing systems

Seagrass Friendly Mooring

https://www.seagrassmooring.com.au/component/bt_media/5-gallery/27-gold-coast-marine-expo

Company: Sea Marine and Diving Services Pty Ltd, NSW, Australia

Description: Uses a pivoting raised arm attached to a 3.8m long mooring post screwed into the seabed as the anchor point. Attached to the mooring post just below the sea bed is a set of load spreaders to stabilise the post. An "Aquatec" UV stabilised marine grade riser is attached from the top of the anchorage at seabed level to the shock absorber located inside a specially designed surface buoy, a "hawser" or pick up line is then connected to the other end of the shock absorber. Available in three sizes (<15t vessels, 15t - 30t vessels, and marker buoy anchorages). Also available as a "Mooring in a Bag" system, designed to allow anyone to convert an existing chain mooring. The system comes fully assembled with only a shackle join required to the first chain link on top of a suitable sized dump weight/sinker (Sea Marine and Diving Services Pty Ltd, 2021).

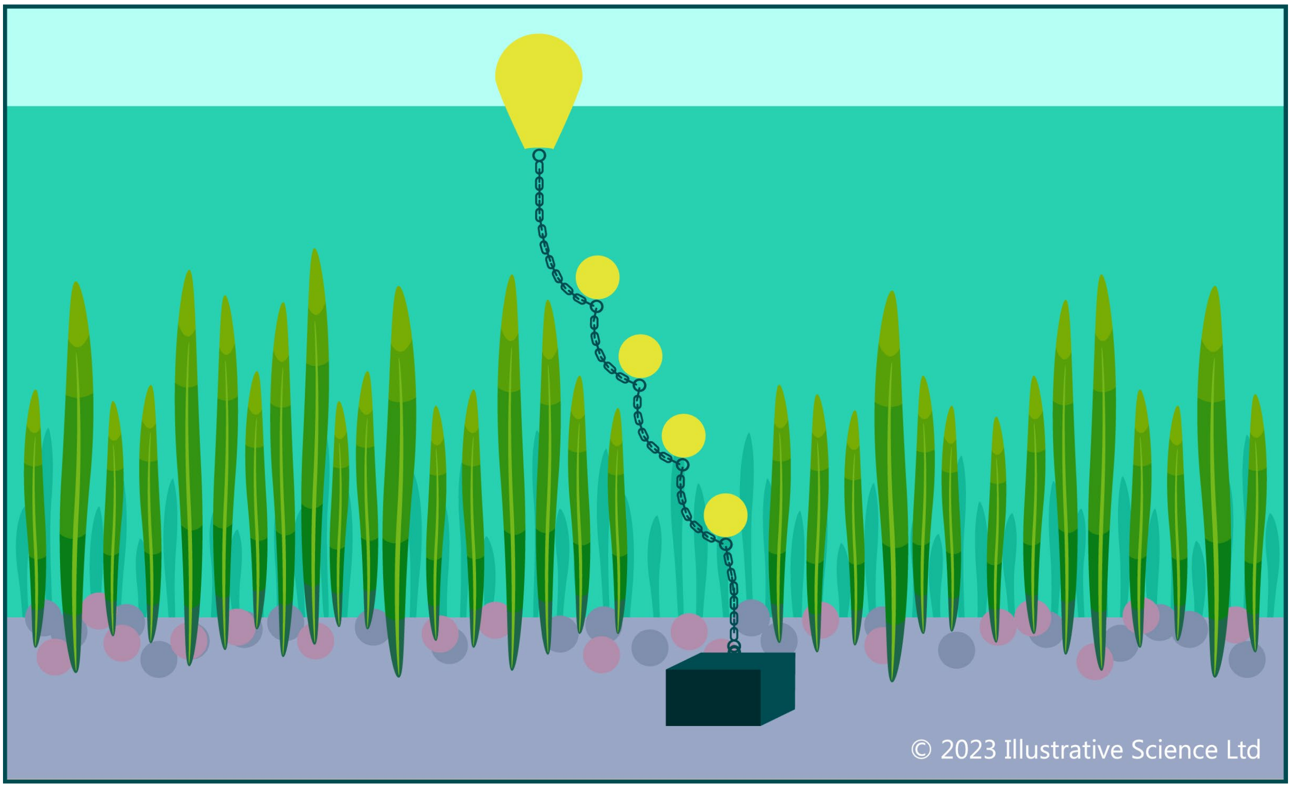

Figure 4. Digital illustration showing the standard configuration for a Stirling Advanced Mooring system, one example of a custom mooring design currently available on the market. Image credit: Illustrative Science Ltd, 2023. Commissioned by Natural England for the LIFE Recreation ReMEDIES project.

3.3.4 Custom systems

Grouted Screw Moorings

https://www.pacificmarinegroup.com.au/services/moorings-fenders/

Company: Pacific Marine Group Pty Ltd, QLD, Australia

Description: The system has been developed in conjunction with James Cook University and an international patent is held by Pacific Marine Group for this system. Divers use an underwater drill rig to screw a 4m long screw shaft into the seabed. As drilling occurs, grout is pumped out through the lead helix (tip), resulting in a 4m deep, 600mm concrete column. Once the concrete is set, a pad eye is bolted on and the rigging attached. The system is typically used for vessels up to 35m / 300T, but larger vessels can be accommodated with the use of “Tri” moorings. Essentially three GSM’s linked together with a common pad eye (Pacific Marine Group, 2023).

Halas system

https://floridakeys.noaa.gov/30th/mooring-buoys.html

Company: EMI Inc., FL, USA

Description: Anchoring system depends on the substrate. For hard substrates installers cement a pin into the void created by a coring bit. After the cement sets, a shackle with a surface line is attached to the eyehole. On soft substrates a MANTA RAY® anchor is used which consists of a 5-foot-long galvanised ductile iron rod with a pivoting, spade like head on one end and a swivelling eyehole on the other (Altmeier, 2021). Attached to the anchor is a three part rope system; line 1: anchor pin to surface buoy; line 2: surface buoy to anchor line which is attached to line 3; line 3: pick up line. A weight is placed ~1m from the sea surface on the anchor line to avoid slack rope floating (RSP APASA PTY LTD, 2014).

Harmony System

https://www.ancrage-ecologique-harmony.fr/realisations

Company: Neptune Environnement, France

Description: The anchor line consists of polyamide rope. It is kept permanently under tension in open water by an intermediate float, so that even at rest, it is not in contact with the bottom. The top end forms a surface mooring loop, the other end is secured by a high strength shackle to the head of the anchor. The mooring buoy has a central chimney with an internal protection tube. The mooring line runs continuously through the surface buoy, avoiding the use of a metal rod with a ring. The total length of the line is calculated to obtain a maximum pulling angle of 45°. The surface swing radius is therefore equal to one times the water depth (in the traditional mooring system, the length of the mooring line must be equal to three times the water depth) (Neptune Environnement, 2019).

Jeyco and Cyclone Mooring Systems

http://www.jeyco.com.au/products-and-services/mooring-systems.html

Company: Jeyco, WA, Australia

Description: The Jeyco system uses three anchors to secure three chains in a tripod. Moorings have been designed and engineered to cope with large storms and cyclones. Once secured to the seabed the system is designed not to scour as a result of tidal variations and wave motion, thus protecting seagrass meadows. Similarly, the cyclone mooring configuration uses anchors to secure three chains to the seabed, which meet at a central ring and riser chain. (RSP APASA PTY Ltd, 2014). Although cyclone mooring configuration is considered 'seagrass-friendly', multiple studies have found mooring scars matching the layout of the system (Walker et al. 1989, Hastings et al. 1995, Demers et al. 2013).

Mermaid-K Mooring System

https://www.seaflex.com/news/seaflex-partners-with-blue-parameters/

Company: Partnership between English Braids, Blue Parameters and Seaflex

Description: The system comprises a High Density Lower Footprint anchor secured to three 8mm Dyneema Tethers attached to a buoyancy float. A variable length 14mm Polyester rope extends towards the surface with additional buoyancy floats and connects to the mooring buoy via a Seaflex rubber hawser (English Braids, 2023).

Stirling Advanced Mooring

https://saveourseabed.co.uk/wp-content/uploads/2021/06/Advanced-Mooring-System-Info-pack-for-harbour-authorities-Final-April-2020-with-intro-page.pdf

Company: Ocean Conservation Trust, UK

Description: Includes the attachment of high tensile rope to a mid-water and surface mooring buoy. The mid-water buoy is designed to ensure minimal to no drag and scour on the surrounding seabed. Can be used to retrofit existing moorings using deadweight anchors (<1m^2) or to create a newly installed mooring. The ideal installation setting, breakout force/holding capacity, associated costs and life expectancy will vary greatly according to the selected mooring components (LIFE ReCREATION REMEDIES, 2021).

Eco-designed mooring

https://www.icriforum.org/wp-content/uploads/2019/12/OVERVIEW of eco-mooring-light_0.pdf

Company: Pioch & Léocadie 2017

Description: The system consists of a block anchor that is designed to mimic local habitats (cavities, roughness, etc.), thus encouraging recolonisation by coral reef flora and fauna that has been damaged or destroyed by historic boat anchoring activity. Eco-designed moorings are designed for each specific context, considering hydrodynamics, yacht size (block weight), as well as local biodiversity (Pioch & Léocadie, 2017).

3.4 Global prevalence of Advanced Mooring Systems

3.4.1 Summary of AMS installations worldwide

In total this report identified 84 AMS trials or installations in 15 countries. The vast majority of reported locations for AMS moorings are in Australia (n=30) and North America (n=28). In Europe nineteen locations in England (n=11), France (n=1), Greece (n=2), Portugal (n=3), Spain (n=1) and the Republic of Ireland (1) are reported. Other international AMS locations are in Bermuda (n=1), British Virgin Islands (n=2), Guadeloupe (n=1), Philippines (n=1), Puerto Rico (n=1) and Thailand (n=1). The full dataset is available in Appendix 3 of this report.

Predominant AMS design by region

The predominant AMS designs installed in each region reflects the distribution of the major AMS manufacturers. In Australia 21 out of 30 locations have installed displacement buoy or shock absorbing AMS designs which are manufactured by two different companies based in Australia. In contrast, North American installations of AMS are largely elastic /floating rode systems (26 out of 28) for which this report has identified four leading manufacturers based in the USA. In Europe and the rest of the world the picture is less clear as the AMS model was not reported for many locations. However, in England eight of the reported AMS installations have custom designs and/or elastic/floating rode designs that are manufactured by either UK based or European companies.

Main drivers for AMS installation

The most widely cited reason to install AMS was to reduce environmental impact in some way. Only 5 locations out of the 59 that report incentives for AMS installation did not consider the potential environmental benefits of choosing that system. In 8 locations the potential improvements to operational performance of the moorings was the main driver for installation with specific incentives ranging from: reduced swinging of the vessel (and therefore improved space efficiency of moorings), reduced peak forces on vessels, increased security of vessels (particularly to withstand extreme weather such as hurricanes) and improved longevity/decreased maintenance costs of the AMS over it’s lifetime. Installing the AMS in response to legislative requirements was also cited as a driver in 9 of the reported AMS installation locations.

Environmental conditions at AMS installation locations

Data on mooring depth or prevailing tide conditions at each AMS installation was limited and this report only found 22 locations with information for these categories. The depth of AMS moorings ranged from 1.4m to 28.9m, with an average depth of 5.6m overall. The tidal range of moorings ranged from 0m to 3.7m.

Seagrass beds were the dominant benthic communities reported in 51 locations and all had a history of damage by boat mooring / anchoring. Coral reefs were present at three ASM installation locations.

Evidence of remedial work on mooring scars

This report found one example where remediation of mooring scars through seagrass transplantation was investigated. Seto et al. 2023 examined whether transplanting seagrass shoots into moorings scars following conversion to a floating rode AMS system impacted the extent or quality of seagrass habitat restored compared with AMS converted moorings with no transplants. They found that seagrass recovered into the mooring scars following installation of AMS (mooring scar radius decreased by 0.8m on average), but that two-years post-planting there was no evidence that recovery was increased in the scars with transplants compared to scars without (i.e. no significant difference in mooring scars radius between the two treatments). The characteristics of the recovered seagrass (shoot density, percent cover, canopy height) were similar to reference areas of unimpacted seagrass by the end of the study. However, the authors found no significant difference in seagrass quality between moorings scars with seagrass transplants and those without.

Overall, these results indicate that mooring conversions to floating rode AMS need not be supplemented by planting to achieve seagrass restoration. As only one study was found examining the impact of transplanting into mooring scars this conclusion should be taken with care however. Further studies that investigate the effect of seagrass transplants in different locations, under various environmental conditions and which compare recovery under other AMS designs should be sought to increase confidence in this assessment.

3.4.2 Summary of AMS installations in the UK

There are 11 reported AMS trial locations around the UK, totalling 73 moorings in all. At the time of writing, two further Seaflex moorings are also due to be installed imminently at Porthdillaen.

Table 2. Location, model and mooring count of current UK installations of Advanced Mooring System (total mooring count is given in brackets for locations with multiple AMS models installed)

Region	Location	AMS model	Mooring count
Cornwall	Cawsands	Stirling Seaflex AMS swim markers	15 3 6 (Total = 23)
	Falmouth Harbour	Strop marker buoy Stirling	1 1 (Total = 2)
Devon	Fishcombe Cove	Stirling	3
	Jennycliff	AMS VNAZ markers	6
	Lundy Island	Seaflex	3
	Salcombe	Stirling	1
Dorset	Castle Cove	AMS VNAZ markers	6
	Studland	Hazelett Sealite	10 12 (Total = 22)
Isle of Wight	Cowes Harbour	Stirling marker buoys	2
Strangford Lough	Northern Ireland	Stirling Seaflex	1 1 (Total = 2)
Wales	Porthdinllaen	Safemoor	2

3.4.3 Summary of AMS performance

In total this report identified 47 trials or installations with accompanying data on users attitudes towards AMS and/or the performance of the moorings, either relating to ecological impacts or operational performance. The majority of these sites were seagrass habitat and at two locations the AMS were installed nearby coral reef habitat. Case studies with the most complete information in these categories are summarised in Section 3.4.4.

Users attitudes

Overall there was limited reporting of users attitudes towards AMS moorings in the literature. Anecdotal reporting of positive endorsements provided on AMS manufacturer/installers websites was available but the inherent bias towards positive recommendations must be considered. A summary of user endorsements reported from boatmoorings.com (2017) is as follows:

"I requested […] a mooring system that would secure my vessels during hurricanes and that is what I got." (Culebra Harbour, Isla de Culebra)

"…local legislation is incredibly pleased with the results of this system, which is still holding strong three years later." (Vinoy Yacht Basin, St Petersberg)

"We have a 39 foot Pearson center cockpit sailboat that stays on a mooring year-round in the British Virgin Islands […] and have been entirely satisfied. This product greatly reduces the swinging of the boat making it a lot easier on the boat and the mooring gear and has never failed. Wind is an ever-present factor in this area and the center cockpit configuration creates greater swing to the boat. After 2 ½ years under these conditions the […] System has fared much better than methods we've used in the past. We just ordered another before the next hurricane season. It is well worth the cost to have this security along with the extended life of the rest of the mooring tackle." (British Virgin Islands)

In the public survey conducted by this report we asked respondents to answer the question: How likely are you to recommend using an Advanced Mooring System over a traditional mooring system to other boaters / owners? And received the following responses:

Response 1: Likely (4 out of 5) "I believe that a good mooring system is very important for the preservation of our oceans and I am happy to help out in anyway I can to get a decent mooring system anywhere in the world. Don't hesitate to contact me for more information on experience on mooring lines system. Great job on your research, it's a very important subject for the preservation of our marine environments." (Koh Tao, Thailand)

Response 2: Very likely (5 out of 5) "We've had zero failures since the installation of the Hazelett system." (Malletts Bay, Vermont, USA)

At 13 locations assessment of mooring performance was significantly impacted due to poor retention of AMS by users following trial end.

Evans et al. 2019 reported that for one location "…none of the moorings originally monitored were conservation moorings and one of the moorings could not be found. The current Camp Harborview staff were contacted shortly after this site visit, and they stated that they were unaware of the mooring project and requirements to maintain the conservation moorings, stating that all moorings were replaced with chain systems based on recommendations by their mooring maintainer ..." (Camp Harbourview, Boston, USA)

In another study, Seto et al. 2023 found that "Improper installation compromised the function of half the moorings converted to floating rode CMS in Experiment I, and of the moorings converted to floating rode CMS that we tracked through 2019, retention of floating rode CMS also varied considerably among harbors from complete retention to complete reversion back to conventional block and chain moorings" (Manchester Harbour, Massachusetts, USA)

Various reasons for reversion were reported including: lack of awareness of the AMS trial and the environmental implications of reverting to a traditional swing mooring, recommendations to revert to traditional swing moorings by professional mooring installers at the time of mooring replacement or a lack of trust in the AMS systems to secure vessels safely.

Ecological performance

Out of 37 sites which reported data on ecological performance, 19 found AMS installation was positively correlated with improved environmental condition. A further 13 sites did not report any significant improvement in the seagrass habitat around the moorings, however only the preliminary analysis (9 months after installation) was available which was likely not enough time for seagrass recovery. Secondary reports of increased AMS uptake and seagrass recovery in the area support this (see Moreton Bay case study for further information). The positive environmental indicators reported include: evidence of seagrass and/or coral regrowth (increased density, areal extent, canopy height), recolonisation of pioneering species into bare patches, increased occurrence of targeted mobile species (such as juvenile lobster and groupers), and reduced diameter of mooring scars. One site reported a slower than predicted rate of seagrass recovery following AMS installation but this was attributed to colonisation of the seagrass bed by an invasive tunicate species rather than failure of the moorings.

Of the 6 sites which reported a negative impact on the local environment following AMS installation 3 locations had installed Cyclone moorings and the mooring scar pattern observed matched the tripod anchor design of these models. These installations were made in the 1980s and a more recent study (Demers et al. 2013) found that the tension in the chains attached to the three anchors may loosen over time and thus drag across the seabed. This report did not find any evidence of any more recent cyclone mooring installations. For the other 3 sites reporting negative environmental impacts the main indicator was an increased diameter of mooring scar. This was attributed to conversion back to traditional block and chain mooring, improper installation or biofouling of mooring components leading to drag.

Operational performance

This report found 34 sites that reported data on operational performance of the AMS installed. 13 sites reported no operational issues and / or gave positive endorsements for the performance of the AMS. The AMS installed at these locations were associated with reductions in peak force and improved ride of vessels while on the mooring, reduced swinging of the vessels resulting in greater space efficiency, increased vessel security due to storm resistance of the mooring (particularly hurricanes), and value for money due to increased longevity and reduced maintenance costs of AMS. A further 16 sites reported some minor modifications were required to the AMS at installation or that issues were found during inspections that were compromising function. However, these issues were resolved and users felt that this demonstrated flexibility of design rather than a negative attribute.

As reported in the previous section (Ecological performance), 3 AMS installations of Cyclone moorings were functionally compromised - likely due to decreasing chain tension with age. Only two instances of mooring failure were reported in two different locations. In one study, 1 AMS mooring out of 12 failed due to a grommet falling off over a year after installation. In the other location, multiple moorings failed but it was attributed to poor maintenance by boat users, “despite the mandatory twice-a-year inspections his company completed on the moorings, mooring owners were not regularly maintaining their moorings and expected a maintenance-free mooring” (Hill, 2012).

3.4.4 AMS performance - international case studies

New South Wales, Australia (Gladstone 2010a, 2010b, 2011; Demers et al. 2013)

Background: A total of 19 Seagrass Friendly moorings were trialled at seven locations in New South Wales between 2008-2010 and reported in Gladstone (2010a, 2010b, 2011) and Demers et al. (2013). Three of the trial locations were in areas colonised by the endangered seagrass Posidonia australis, while the other four locations were mixed communities including Zostera spp. and Halophila spp.

Users attitudes: An evaluation of users attitudes to the AMS trials was not reported by Gladstone (2010a, 2010b, 2011) or Demers et al. (2013).

Operational performance: The moorings all functioned correctly and no evidence of mooring failure was reported except at one location where the screw anchor was sat deeper in the substrate which meant that the coupling of the mooring to the float line came into contact with the seabed.

Ecological performance: Gladstone (2010a, 2010b, 2011) report an average decrease in the size of mooring scars at four out of five sites over 3 years following AMS installation. The occurrence of pioneering species such as Halophila spp. increased as well as percentage cover and canopy height of *Zostera capricorni*. The re-growth of *Posidonia australis* in mooring scars was inconclusive, however, the rate of regrowth for this species is slower than the length of the monitoring period of this study (Gladstone, 2011). In the two other locations, Demers et al. (2013) found that AMS moorings were highly effective in aiding seagrass recovery, with patterns of seagrass density and cover around the AMS similar to reference areas in undamaged seagrass beds at the end of the trial. However, Demers et al. (2013) did find some evidence of seabed scour (10cm width) around AMS moorings at one location, where the mooring sat lower in the substrate and the coupling between the mooring and float line made contact with the seabed.

Moreton Bay, Australia (DEEDI, 2011)

Background: One of each of three AMS designs were trialled in four locations around Moreton Bay where seagrass beds had been damaged by traditional swing moorings (12 AMS moorings installed in total). EzyRider and SEAFLEX moorings were installed with block anchors (except in silty areas where a Manta Ray anchor was used to secure the SEAFLEX mooring) while Seagrass Friendly Moorings used a screwed in mooring post for anchoring. Boat users opted in to be part of the trial and have their traditional swing moorings replaced with one of these designs. All of the moorings were installed in early 2010 and the trial lasted for 18 months, with two servicing inspections conducted at 6 months and 9 months.

Users' attitudes: Feedback on users' experiences of the AMS moorings was gathered through a combination of a questionnaire for trial participants, interviews with trial participants, AMS companies and a moorings contractor, and a public forum held at the end of the trial. Overall the feedback was very positive, with reduced environmental performance and ease of use highlighted, although satisfaction with AMS varied depending on issues experienced and insufficient documentation/instruction for owners and installers was reported. Key feedback from the interviews and forum included: overall support for the trial and for the AMS concept, cost being a key factor in AMS uptake, and the need for better promotion of AMS and government intervention/facilitation in AMS uptake.

Operational performance: An engineering study performed by the University of Queensland as part of this trial found that the Seagrass Friendly Mooring system anchor design was sufficient to hold vessels securely in Moreton Bay conditions (EzyRider and SEAFLEX moorings were not tested). Most moorings were installed successfully, with minor modifications to mooring design or location required in some instances. DEEDI et al. 2011 suggested that this demonstrated flexibility in AMS design to adapt to local conditions. During servicing inspections some issues were identified such as corrosion and biofouling but overall the study found that the mooring designs were suitable for environmental conditions. 3 out of the 12 moorings failed by the end of the trial due to the failure of shackles on two EzyRider moorings and a plastic grommet falling off the shaft of one SEAFLEX mooring.

Ecological performance: Only the preliminary results from the trial are reported by DEEDI (2011). They found no detectable effect of installing the AMS within existing mooring areas. On a larger scale (comparing the whole mooring site to areas outside of the mooring zone) there was some evidence of recovery as ‘benthic assemblages became less patchy’ (DEEDI et al.2011). The report suggests the addition of AMS and removal of traditional swing moorings had allowed seagrass rhizomes and other benthic fauna to regenerate, thus stabilising the sediment and contributing to a more uniform distribution of benthic communities. This hypothesis was to be tested in further analyses but the results from this are not publicly available. However, it is reported that more than 230 AMS moorings have now been installed across the Moreton Bay Area and more than 6ha of seagrass recovery (Healthy Land and Water, 2023). The Gold Coast Waterways Authority has put in place a Buoy Mooring Management Strategy which includes a commitment to transition every buoy moor to an AMS mooring from mid-2024 onwards, indicating strong support for AMS uptake in this area.

Massachusetts, USA (Seto et al. 2023)

Background: Between 2010 - 2013, Eco-Mooring, Hazelett Conservation Elastic Mooring and Stormsoft systems were installed across three locations in Massachusetts. The trial was to investigate whether AMS moorings would aid seagrass recovery in this area, and in one location AMS installations were coupled with seagrass transplants around the mooring to see whether this enhanced recovery.

Users’ attitudes: Retention of the AMS moorings by users varied considerably by location, from complete retention to complete reversion to traditional block and chain swing moorings. Seto et al. (2023) found that the main factors underlying the owners’ decisions to revert to block and chain moorings were: (1) lack of trust in the AMS mooring to secure their vessel, (2) advice from professional mooring installers to revert their moorings, and (3) lack of awareness that they required a permit to revert their moorings from floating rodes to chain moorings in seagrass areas.

Operational performance: Improper installation of the AMS moorings compromised the function of half of the moorings involved in the seagrass transplant trial. Specifically, moorings were installed without subsurface buoys meaning that the shackles around the anchor scoured the seafloor and the rodes were the wrong length for the environmental conditions of the harbour leading to tangle, drag and further scouring of the seabed. Both issues were fixed before the end of the trial.

Ecological performance: Overall, planting seagrass in mooring scars following the installation of AMS moorings did not affect the area of seagrass which recovered. AMS had a positive impact on seagrass recovery overall, but the location (i.e. environmental conditions) and size of initial mooring scar were important in determining the amount of seagrass regrowth at each site. Seto et al. 2023 found that less seagrass recovered in the deepest, most exposed harbour with the greatest tidal range and at moorings with smaller initial scars.

Deshaies, Guadeloupe (Pioch et al. 2018, Hein et al. 2020)

Background: Eco-designed moorings were developed for the specific environmental conditions and local habitats in the bay at Deshaies, Guadeloupe. The drivers for the installation were to (1) initiate a buoy mooring programme that would prevent future damage to corals from anchoring, and, (2) test a coral probation technique that would aid coral restoration by using the concrete mooring bock to promote coral recruitment. In 2013, three different designs of the anchor block were installed to assess the capacity of different concrete treatments and surface roughness to attract coral recruits (Hein et al. 2020).

Users attitudes: No evaluation of users attitudes to the AMS moorings were made in these studies.

Operational performance: The assessment of the performance of these moorings was focused on ecological indicators. However, both studies commented that dive surveys had found that the moorings and associated biota had survived “essentially unscathed” (Pioch et al. 2018) from “17m high waves” produced by Hurricane Irma in 2017.

Ecological performance: After four years targeted species such as juvenile lobsters and groupers were found to be settled in and around the moorings (Pioch et al. 2018). By six years post installation, a return of normal growth of coral and seagrasses was reported in the area (Hein et al. 2020). 52% of local coral species had settled on the anchor blocks and 43 species of fish were recorded on and around the base of the moorings.

Ko Tao, Thailand (survey response)

Background: The AMS installation on the island of Ko Tao, Thailand is one of the two self-reported locations submitted in response to the public survey created for this report. The respondent was Koh Exist, a non-profit marine conservation organisation operating in Ko Tao. Coral reefs have been damaged by boat moorings around the island and 30 elastic rode moorings have been installed in an attempt to promote reef recovery.

Users attitudes: Reported misuse of the moorings by users indicates a lack of awareness of the new system and the environmental impacts of improper mooring on the reef. A particular issue has been multiple boats using one mooring leading to the block anchor shifting too close to the reef. Despite this the survey respondent gave a positive endorsement for the AMS moorings overall, stating that they would be likely to recommend AMS over traditional moorings to other boat users and added this comment “I believe that a good mooring system is very important for the preservation of our oceans and I am happy to help out in anyway I can to get a decent mooring system anywhere in the world.”

Operational performance: Some operational issues were reported due to misuse of the system such as ropes breaking, damage to buoys and the loss of some buoys. Slack ropes were also reported leading to the ropes either sinking to the bottom or floating on the water surface and introducing a danger of entanglement with boat propellers. Despite these issues, the AMS moorings have resulted in a “dramatic improvement” in reducing peak forces on moored vessels as well as a “small improvement” in the ride of the vessels on the mooring.

Ecological performance: No detailed environmental data was provided but the a “dramatic improvement” in the condition of the environment in the vicinity of the AMS moorings was reported. Two of the main drivers for installing the AMS were to reduce to the environmental footprint of the moorings and to protect the nearby coral reef, when asked to report on the performance of the AMS in relation to these drivers the respondent gave the highest score for these factors (i.e. installation of the AMS had a positive impact).

5. Summary

This report found nineteen different AMS models currently available on the market with designs based on elastic or floating rode systems the most prevalent in terms of the number of different manufacturers and the number of AMS installations worldwide. Custom designs which are specific either to the local conditions at the site (i.e. adapted for hard substrates, anchors for habitat recreation, storm resistance) or designed for a specific purpose (i.e. large vessels (35m/330T), adapting traditional swing moorings) are the second most numerous category available in the current market, although their unique design is reflected in the limited number of installations of each worldwide. Two other AMS designs using displacement buoy systems or shock absorbing systems are only supplied by two separate manufacturers based in Australia, and make up the majority of AMS installations in that country.

Overall this report found that reducing environmental impact on the seabed was the main driver for installing AMS systems across all reported locations. However, this should be interpreted with caution, as the majority of sources used in this report are from academic literature and commissioned reports for environmental or management organisations who have specific environmental objectives. The incentives for individuals who use or install boat moorings might be expected to place at least equal importance on operational performance of the mooring or space efficiency in busy harbours, however the limitations of the methods employed in this report and implications for these findings are discussed further in Section 5.1.

Installations of AMS moorings in areas with historic damage to benthic communities, such as seagrass meadows or coral reefs, were overwhelmingly associated with recovery of these habitats from a year after installation (89% of AMS installation locations with ecological performance data). Reports of environmental damage following AMS installation were due to ageing Cyclone moorings or reversion of the AMS to block and chain moorings by users (6% of all AMS installation locations with ecological performance data).

Overall AMS moorings performed well in terms of operation and user satisfaction, with no issues reported and / or positive endorsements for 28% of locations that reported evidence in these categories. In 34% of locations that had data on operational performance minor modifications were required at installation and / or minor issues were identified during servicing inspections. However, at these sites such issues were resolved before function was significantly compromised and the possibility for adapting AMS design to suit local conditions was considered an asset rather than a negative attribute. Where AMS moorings performed poorly was often due to improper installation or poor retention, which may reflect a need for greater communication and awareness around the use of AMS for both boat users and mooring installation companies.

5.1 Evidence gaps

This project aimed to gather evidence from a wide variety of sources with the primary focus on international AMS installations, outside of the UK. As such, the data collected and summarised herein is not necessarily comprehensive but is based on the best available information that could be compiled within the project timeframe. The database can be updated as further examples are identified or reported in the future.

The literature search proved to be effective in identifying AMS locations but information such as the environmental conditions of the mooring site or the specifications of the vessels using the moorings was scarcely reported online. The approach taken by this project was to try to fill such data gaps by following up with individuals or organisations through personal communication (telephone / email), however, this method had limited success. In some cases a positive response to the initial email did not lead to further communication due to being unable to arrange a follow up interview within the project timeframe. In many cases only an email address was available and few responses were received to electronic communications. There could be a number of reasons for this but without independent feedback any speculation must be taken with care. There was no specific incentive for the individuals approached to provide information, except to contribute to widening existing knowledge, and in the case of organisations / companies the email addresses were for general information enquiries and it is not known how well attended such accounts are. Additionally, there could have been communication barriers or a lack of recognition of Natural England as a legitimate entity outside of the UK.

In one interview conducted with James Scott-Anderson of Blue Parameters, UK, it was suggested that manufacturers of AMS technology might be reluctant to discuss the details of AMS installations where there is no record of regular monitoring or servicing inspections. The reason given for this was due to the possibility of compromised function or failure of moorings being wrongly attributed to the design of the mooring itself, rather than improper installation, misuse, or poor maintenance of the mooring. Indeed, when engaging with AMS manufacturers this report found a willingness to share information regarding the specification and engineering reports for their products, but did not obtain any information regarding existing moorings. Furthermore, the majority of the issues reported in studies of AMS moorings were attributed to issues with installation or maintenance of moorings by users, lending some legitimacy to this concern.

The public survey undertaken for this report received very low engagement with only two respondents in total. To improve the representation of different groups of users of AMS technology an alternative method of dissemination should be considered to reach more people. Ideally online newsletters, magazines and organisations or companies related to boats or marinas in multiple countries could be asked to help promote the survey to other users over a longer timeframe.

Closed answers questions do not allow detailed responses from the participants, and sometimes it can be difficult to infer what a respondent really thinks or believes. Therefore, in person interviews should continue to be a focus of any future data gathering exercise. The possibility of offering incentives in exchange for providing information should be considered in order to encourage greater participation. Different groups of users are likely to respond to different types of incentives so any future scheme would need to take this into account. Online focus groups could also be tested to see how opinions diverge between different users of the marine environment and receive more in depth answers.

The identification of three AMS trials / projects which have been initiated within the last year provides a novel opportunity to investigate how users attitudes to AMS installations might change over the course of the studies. Any future work to expand on this report should make contacting the agencies involved in those projects a priority.

5.2 Recommendations

The information gathered in this report will be of value to inform management options for sensitive seabed habitats, to answer queries from harbour authorities, stakeholders and boaters, and to inform the development of long-term online resources on AMS. Consideration must be given for how best to make this information available to these diverse groups of people and variety of purposes.

Maintenance of an online database allows instantaneous collaboration and information sharing, but whether the data is open-source or moderated through requests for information needs to be weighed in terms of the potential benefits and drawbacks. An open-source database that allows users to submit information directly and exchange knowledge with other users presents fewer barriers and may encourage greater participation. However, oversight by a moderating body would be required to make sure that data is checked for accuracy. Conversely, a database operating through requests for information from a central authority would increase the reliability of the data contained therein and can also be curated in different ways that may be useful to specific groups of stakeholders, allowing them to access the information more efficiently. This approach would require a greater time commitment from the moderator however, and both cases require a decision to be made about who is responsible for maintenance of such a database.

Greater engagement with the project could also be encouraged through creation of a role or additional duty to existing role that seeks to build and maintain relationships with AMS companies and stakeholders. More regular contact with these groups could help to fill the evidence gaps highlighted in the previous Section, as well as identify new installations that could provide novel information about the use of AMS in different environmental conditions, changing attitudes of users through time, or new innovations in AMS technology available on the market.

This report found that the greatest barriers to retention of AMS by users related to a lack of awareness or information regarding the purpose, maintenance requirements, proper installation methods, or the efficacy of the moorings. The information gathered here goes some way to address these issues, and building upon this project through continued engagement with these groups could increase AMS uptake by providing further examples of improved performance when compared to traditional swing moorings, both from an ecological and operational perspective.

Appendices

Appendix 1 - List of public survey questions

Appendix 2 - Table of Advanced Mooring System locations and details of mooring installation, environmental conditions, incentives and performance indicators for each site.

Appendix 1 - List of public survey questions

ReMEDIES: Global Moorings Review

The ReMEDIES project would like to gather better evidence on the effectiveness of Advanced Mooring Systems around the world and in particular evaluate feedback from users. You may have heard these systems being referred to by other names such as: "eco-mooring", "conservation mooring", "elastic mooring", "Stirling advanced system", and others. We are interested in hearing about all of them - any mooring system that has been designed to reduce abrasion on the seabed.

This survey is designed to gather detailed information about the location, environmental conditions and type of advanced mooring systems being used in a specific location. If you are unable to provide all of the details we ask for that's ok - please just fill out as much information as you can.

As part of this survey we would like to collect some information about you and/or the organisation you represent in order to evaluate how different groups use these mooring systems. We will be asking you to provide some contact information so that we are able to get in touch if we have follow up questions in relation to your responses to these questions. Your personal information will not be used to contact you other than for the express purposes outlined in this survey and neither the contractors nor Natural England will share your information with any other third parties.

Traditional single-point or **swing moorings** typically consist of an anchor, chain (rode) and float. However, they can result in abrasion to sensitive habitats through the action of the chain being dragged across the seabed as the tide and wind direction changes.

Advanced Mooring Systems (AMS) are designed to have less impact on the seabed by **reducing the interaction between the rode and the seafloor**, as well as providing practical benefits to boaters and owners.

Manufacturers of AMS with elastic risers report **reduced loads** on boat connections in harsh weather, **reduced motion** during normal conditions, **less maintenance and greater longevity** than traditional chain moorings, which typically need replacing every few years.

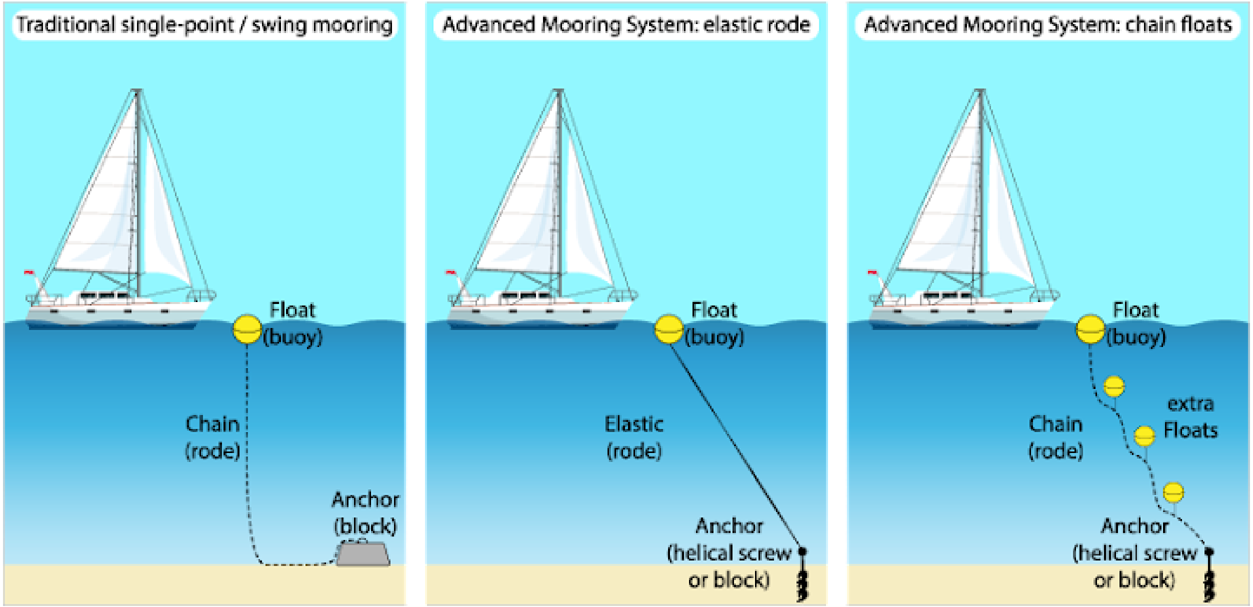

Figure 5. Digital illustration comparing a traditional single-point / swing mooring to two types of Advanced Mooring System using either an elastic rode or subsurface floats on the chain. Image source and credit: Illustrative Science Ltd, 2023. Commissioned for this report by Natural England.

Section 1: Location and installation details

1. Please tell us your name or the name of the organisation you represent:

2. Please provide a contact email address:

3. To report the location of an Advanced Mooring you can add the location to our interactive map. Alternatively you can type the location in the box below (please include GPS coordinates if possible):

4. Is the Advanced Mooring System a new installation or replacing/modifying an existing mooring?

5. How long has the Advanced Mooring System been installed for?

6. What type of Advanced Mooring System has been installed?

7. What anchor type is being used with the Advanced Mooring System?

8. What is the name of the company that manufactured the Advanced Mooring System?

9. What is the purpose of the Advanced Mooring System?

Section 2: Mooring details

10. How many single point moorings have been installed at this location using an Advanced Mooring System?

11. What type of vessels use these moorings?

12. What is the maximum length of the vessels which use these moorings? Please indicate feet (ft) or metres (m) in your answer.

13. What is the maximum weight of the vessels which use these moorings? Please indicate pound (lb), kilogram (kg), US ton (ton), or metric tonne (tonne) in your answer.

Section 3: Environmental conditions

14. Water type at mooring location? (Freshwater/Saltwater/Brackish)

15. Mean water level at mooring location? Please indicate feet (ft) or metres (m) in your answer.

16. Depth at mooring location: highest astronomical tide? Please indicate feet (ft) or metres (m) in your answer.

17. Depth at mooring location: lowest astronomical tide? Please indicate feet (ft) or metres (m) in your answer.

18. Bottom type? (Sand/Mud/Rock/Other)

19. Presence of sensitive habitat / species? (Seagrass/Maerl bed/Other)

Section 4: Evidence of remediation

20. Since installing the Advanced Mooring System has there been any evidence of recovery of the seabed habitat? (Regrowth in areas with history of abrasion/Increased abundance of associated species/Increased species diversity/Other)

Section 5: Incentives and performance

21. Using the list below please indicate which were the main drivers for installation of the Advanced Mooring System? (Legislative requirement/Reduced maintenance costs/Reduced peak forces/Reduced mooring swing/Improve ride of vessel/Unsatisfied with other mooring system/Other) *Respondents were asked to mark these options on a scale from "Strongly disagree", "Disagree", "Agree", "Strongly agree", "Not a consideration"*

22. If you selected other in the previous question please tell us what the main driver for installing an Advanced Mooring System at this location?

23. How would you rate the performance of the Advanced Mooring System in relation to the drivers you selected in the previous question? *Respondents were asked to mark these options on a scale from "Dramatic improvement", "Small improvement", "No improvement", "It's worse", "With the AMS installed it's no longer a consideration"*

24. Were there any unforeseen issues that arose during installation of the Advanced Mooring System or since it's been installed?

25. How likely are you to recommend using an Advanced Mooring System over a traditional mooring to other boaters / owners? *Respondents were asked to mark these options on a scale from 1 (Not likely at all) to 5 (Very likely)*

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