



The decline of UK seagrass habitats and the importance of advanced mooring systems

Tevi

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Tevi (Cornish for 'grow') is an EU-funded programme which aims to create both economic and environmental growth in Cornwall and the Isles of Scilly.

The initiative, which runs until 2021, provides small and medium-sized enterprises across the county with expert consultation, opportunities for recognition and certification, and grant funding. Our objective is to help enterprises make the most of the prized asset upon which they rely – our beautiful natural environment – by helping them grow their business.

We support enterprises to play a proactive role in growing and protecting the region's unique natural environment, while also becoming more efficient with their natural resource use and minimising their waste in smart and innovative ways, as part of the global transition towards a circular economy.

Tevi's Challenge Networks bring organisations together to collectively identify, and bring to market, solutions to environmental challenges that no one organisation can solve alone. Over the course of the three year programme Tevi will run a number of Challenge Networks, of which protecting seagrass through accelerating advanced moorings uptake, is one.

Tevi is led by the University of Exeter, and is delivered in partnership with the Cornwall Wildlife Trust, Cornwall Council and the Cornwall Development Company. Find out more about the programme at www.tevi.co.uk.



This report outlines the importance of protecting threatened seagrasses along Cornwall and the Isles of Scilly coastlines through the implementation of advanced mooring systems.

Seagrasses are protected species that provide many ecosystem services including habitat for threatened marine species, nursery environments for commercially important fish, reduction of coastal erosion, and the capture of carbon. The use of traditional mooring systems is one of the greatest threats to these endangered habitats as mooring chains and ropes drag on the seabed and create mooring scars. Advanced mooring system designs reduce these impacts by removing abrasion pressures and reducing anchor footprints in seagrass. These systems anchor boats to the seabed using buoyant or rigid tethers that raise mooring equipment above the seabed to prevent abrasion of seagrass meadows.

The reliability, safety, and cost of advanced mooring systems are key considerations in assessing their use as a management strategy. Trials comparing the effectiveness of traditional and advanced moorings have been commissioned in America, Australia, and the UK, and have found that advanced moorings provide both a secure tether for boats in many environments and a less environmentally impactful mooring system

that facilitates the recovery of seagrass meadows. However, advanced mooring system trials in exposed areas with large tidal ranges have reported issues regarding the safety and security of these systems.

Seagrass beds are one of the UK's most threatened marine habitats and as such, Tevi recognise that the installation of advanced mooring systems could offer an effective solution to habitat loss, however the extreme tidal ranges, exposure and weather conditions common across the region's coastline may potentially limit the use of models that are currently available. These challenges were identified during discussions with harbours, mooring providers, boat users and conservationists over the course of Tevi's Advanced Moorings Challenge Network. In response to this need Tevi agreed to collate the findings of advanced mooring system trials in the UK, outline the key considerations needed to guide the installation of advanced moorings, and present a view on the viability of market-available advanced moorings as a solution that provides ecological protection for seagrasses without risking mooring performance.

This report finds that there is sufficient evidence to recommend the use of advanced mooring systems in sheltered areas with tidal ranges <5metres, but that further testing is required to assess whether they offer secure and safe mooring options in exposed areas with tidal ranges >5metres.



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1. Importance of seagrass

Seagrasses are flowering aquatic plants that typically grow in underwater meadows (Lefebvre et al 2009; Photo 2). Seagrasses are the only true marine plant able to photosynthesise and pollinate whilst submerged in water (Ducker & Knox 1976; Jackson, Griffiths & Durkin 2013). They are found globally in shallow, sheltered coastal waters (Ducker & Knox 1976), with three eelgrass species found along the UK coastline - common eelgrass (*Zostera marina*), dwarf eelgrass (*Zostera noltei*) and narrow-leaved eelgrass (*Zostera angustifolia*) (Foden & Brazier 2007).

Seagrass habitats are globally threatened, with current decline levels indicating a global crisis (Duarte et al 2009) – over 110km² / year have been lost since 1980 (Waycott et al. 2009; Jackson, Griffiths & Durkin 2013). The UK coastline has experienced significant declines within the last century, with 92% of seagrass beds lost (Swansea University). Research has shown that human disturbance is the greatest threat to seagrass meadows through mooring damage, intertidal vehicle use, pollution, and coastal development (McCloskey & Unsworth 2015). Seagrass beds are a priority habitat under the UK Biodiversity Framework and are identified as Features of Conservation Importance (FOCI) in the creation of marine conservation zones (MCZs) (Jackson, Griffiths & Durkin 2013).

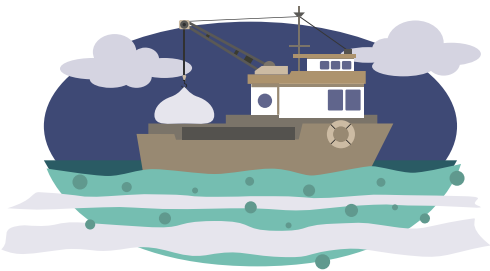


The importance of seagrass

Habitat for threatened species:



Commercial fish nurseries:



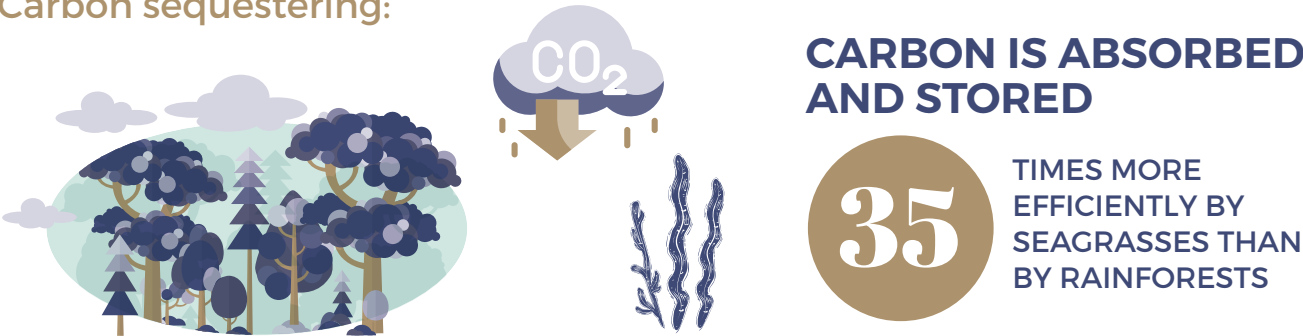
SEAGRASS BEDS SUPPLY 50% OF THE FISHING GROUNDS FOR THE WORLD'S FISHERIES

Coastal defences:

ONE OF THE **most effective** NATURAL DEFENCE SYSTEMS ALONG THE UK COASTLINE



Carbon sequestering:



1.1 Seagrass ecosystem services

Seagrass meadows provide several important ecosystem services: providing habitat for endangered/threatened species, acting as nurseries for several key commercial fish species, aiding coastal defences, and capturing carbon from the environment in carbon sinks. Seagrass beds are ranked as one of the most valuable marine ecosystems per hectare due to the many ecosystem services they provide (Costanza et al 1997; Jackson, Griffiths & Durkin 2013).

Habitat for threatened species

Coastal habitats are key biodiversity hotspots and provide shelter for endangered and threatened species (Duarte et al 2009). Evidence has shown that habitats containing seagrass meadows support a substantially greater number of marine species than those without (McCloskey & Unsworth 2015) – over 30 times more animals live within seagrasses than within sandy habitats (Save our seagrass). 2.5 acres of seagrass meadows can support over 100 million invertebrates and 80,000 fish (Dawes, Phillips & Morrison 2004). As such, seagrass species are considered foundation species – a species that supports high levels of biodiversity by providing habitat, is home to important and endangered species and is a key indicator of ecosystem health (Jackson, Griffiths & Durkin 2013). Seagrass beds provide habitats for the UK's two seahorse species – the Spiny and Short Snouted seahorses (Garrick-Maidment 2007; Photo 3), both of which are threatened with extinction and are legally protected from disturbance under the Wildlife and Countryside Act in England (Jackson, Griffiths & Durkin 2013).

Commercial fish nurseries

Seagrass meadows are also important nursery grounds for many commercially important or threatened fish (Duarte et al 2009), shellfish (Warren et al 2010) and wildfowl (Ganter 2000). Seagrass beds supply 50% of the fishing grounds for the world's fisheries and seagrasses are utilised by 32% of commercial fish species within their lifetime (Save our seagrass). Evidence suggests that seagrass meadows also support a range of the prey species of commercially important species, including Atlantic Cod (*Gadus morhua*), one study found that young cod raised in seagrass had faster growth rates and better survival rates (Tupper & Boutilier 1995).



Photo 3. A Spiny seahorse sheltering in a meadow of common eelgrass in Studland Bay, Dorset. Photograph taken by Alex Mustard/WWF-UK.

Coastal defences

Seagrasses provide natural coastal defences by reducing wave energy, stabilising and oxygenating sediment deposits and reducing seabed erosion and as such are one of the most effective natural defence systems along the UK coastline (Ondiviela et al 2014). As seagrasses are the only true marine plants, they provide key coastal defences by producing roots that both limit the erosion of the seabed by stabilising sediment and improving water quality (Widdows et al. 2008). Seagrass meadows also bind the seabed together by collecting and stabilising sediment deposition (Widdows et al., 2008).

Carbon sequestering

Additionally, seagrass beds act as carbon sinks by sequestering carbon within the sediment stabilised by their roots (Kennedy & Bjork 2009) and are responsible for 11% of annual ocean carbon storage, despite covering less than 0.2% of the seabed (Green, Chadwick & Jones 2018). Research has shown that carbon is absorbed and stored 35 times more efficiently by seagrasses than by rainforests (Save our seagrass). The organic carbon sequestered within marine environments – mangroves, salt marshes and seagrasses – has been termed 'blue carbon' (Nellemann & Corcoran 2009). The sediment organic carbon stocks of UK eelgrass are one of the largest sediment carbon stocks in Europe and so are essential to protect through education and legislation (Green, Chadwick & Jones 2018). Disrupting these habitats leads to the release of these carbon sinks and a substantial increase in carbon levels in the environment (Luff et al 2019).

2. Public perceptions

2.1 Marine protection & public opinion

Public awareness of the negative impacts of human activities on the ocean has been building over the past few decades with successful campaigns changing the way people view marine environments and increasing the desire to protect these threatened ecosystems (Bowen et al. 2014). Successful campaigns include the banning of plastic straws, the removal of free plastic bags in shops and the use of eco-labels on seafood products to inform the consumer of the fishing methods and food source (Gudmundsson & Wessells 2000). Additionally, the Ocean is now recognised as a key source of human wellbeing and of cultural importance (Knap et al. 2002).

2.2 Awareness campaigns

Recently, there have been many effective movements to encourage the transition toward more sustainable behaviours within marine environments, including more sustainable fishing practices (Roheim & Sutinen 2006), creating additional protected marine parks (O'Leary et al. 2012) and ecologically aware boating behaviours (Kim 2012). One key boating campaign that has had success around the UK's coastline is the creation of voluntary no anchoring zones – whereby the locations of seagrass meadows are indicated using marker buoys to discourage vessels from anchoring within and damaging the threatened habitat – as found in the Helford River, Cornwall and Studland Bay, Dorset. Along with the Save Our Seagrass campaign, the Seagrass Ocean Rescue project and the LIFE Recreation ReMEDIES

project both aim to promote the ecosystem services seagrass meadows provide and reduce the pressures of recreational boating activities on these habitats, so changing user behaviour and enabling large-scale restoration projects (Natural England, 2019).

Natural England and partners launched the ReMEDIES ('reducing and mitigating erosion and disturbance impacts affecting the seabed') project in England, after being awarded £1.5 million in 2019 by EU LIFE. The project aims to improve the condition of threatened seagrass and maerl bed habitats in five sites, reduce the negative impacts from recreational boating and provide model recovery systems to be replicated across Europe. The four-year long project will also involve several advanced mooring system trials, involving the removal of 60 traditional moorings and installation of 76 advanced mooring systems across the project sites, to determine which systems are most effective along UK coastlines and which best protect these threatened habitats.

The decline of seagrasses within UK waters has recently received National attention due to these project campaigns and the Guardian newspaper featured a front-page article on the topic on 10th March 2020 (<https://www.theguardian.com/environment/2020/mar/10/uk-lost-sea-meadows-to-be-resurrected-in-climate-emergency-fight>).

Changing public attitudes towards marine conservation and the increased awareness of negative impacts of human activity on aquatic environments are altering consumer behaviour. Mooring choice is one such critical behaviour, with research suggesting that some recreational boat users preferentially choose to moor their vessels in sites with advanced moorings over those with traditional chain moorings to reduce their negative impacts on the seabed (Parry-Wilson et al. 2019).




Photo 5. Seagrass mooring scars in St Marys, Isles of Scilly, caused by traditional mooring systems. Photo taken from Google Earth.

3. Mooring systems

Traditional systems have three main components: the anchor which attaches to the seafloor; the rode – the connection between the anchor and a float, often a metal chain; and the float – which allows the vessel to attach to the mooring. Traditional swing moorings have a sinker block on the seafloor with a heavy chain attached to a rope reaching a surface buoy, which attaches to the vessel (Luff et al 2019; Appendix image 1a). The changing tide and wind will pivot the chain and buoy, dragging the chain across the seabed and scarring the bed in circular areas, known as ‘mooring scars’ (Griffiths et al. 2017; Luff et al 2019). The weighted chains uproot seagrasses and can reduced their density to zero around the mooring anchor. These mooring scars can range in size from 3-300m² depending on boat size (Walker et al 1989; Photo 5): a recent study reported an average loss of 122m² of seagrass from swinging chain moorings across south Cornwall (Unsworth et al. 2017).

Advanced mooring systems or ‘eco-moorings’ are mooring systems that have been created to mitigate the impact of boating activities and to reduce the impact of human disturbance on seagrasses. Advanced mooring systems are technologically advanced mooring systems that utilise improved design to cope with extreme weather conditions – such as hurricanes - and tidal variability. Advanced mooring systems are designed with either rigid or buoyant sections to reduce the abrasion pressure of chains on the seafloor, whilst maintaining secure vessel moorings in all weather conditions (Luff et al 2019; Appendix Image 1). Advanced mooring systems have the same three common features as traditional moorings – a rode, a buoy and an anchor; however, the rode and buoy systems are designed to minimise contact and abrasion with the seabed. The rode can be a chain or rope kept afloat using inflated buoys or a taut elastic tether (Appendix Image 1B&C). Anchorage types are typically substrate embedment anchors such as helical, screw fixed anchor lines or eye bolt anchors, rather than concrete blocks, so reducing the system’s footprint on the seabed (Luff et al 2019).

3.1 Advanced mooring technology innovation

The use of elasticated mooring systems has become well established in other sectors, including offshore infrastructure. In order to cope with extreme tides and weather conditions, many offshore mooring systems include elasticated elements to reduce snap loads and prevent system failures (Arlt et al. 1999). These elements include elastic ropes, rubber tethers, riser and hoses and are often referred to as elastomeric tethers (Tsukrov et al. 2005).

One such product is the EOM offshore system which includes a Stretch EM cable which isolates the ocean's movements from the rest of the mooring, thus providing a stable platform and mooring for infrastructure and vessels alike (EOM Offshore). Elasticated elements in offshore mooring designs have become essential components and been in use for over 30 years (Paul 1995).

Studies comparing chain and elastomeric tether mooring systems in offshore environments have found that elastomeric systems coped with higher tension, were more stable and had reduced swing areas than chain moorings (Thies, Johanning & McEvoy, 2014). The report also stated that the systems require more regular maintenance than traditional chain moorings and that the systems are at a greater risk of damage from fishing gear (Paul et al. 1999).

3.2 Advanced mooring system trials

The use and development of advanced mooring systems is primarily in America and Australia, where these systems have been on the market for forty years. Use of the technology in these regions has illustrated the ecological benefits of adopting these systems on endangered seagrass habitats. Many studies have shown that the use of advanced mooring systems has resulted in the recovery of seagrass meadows, with densities mirroring those without moorings (Demers, Davis & Knott 2013). However, research has also shown that recovery can take many years and is not a straightforward process (Collins et al 2010). The

installation of advanced mooring systems prevents further damage (Egerton, 2011) and when installed in new mooring areas, advanced mooring systems are less impactful (Gladstone, 2011) but recolonization of scarred areas can be limited depending on the extent of the scarring – once rhizomes have been removed, recovery is less likely as it requires future pollination and seed dispersal, whereas if rhizomes have only been damaged, evidence suggests they are able to recover and regrow (Kendall et al 2006).

Current trials assessing the use of advanced mooring systems are taking place around the world in countries including Australia, America, Indonesia and the UK. One Mediterranean-based study found that using a 'Harmony' mooring system in a previously unmoored site had no negative impact on the surrounding seagrass (Egerton 2011). Additionally, trials investigating the safety and strength of different advanced mooring systems have demonstrated that they can be at least as safe and strong as traditional chain and block systems, if not more secure and stronger (Amec Foster Wheeler Environment & Infrastructure UK Limited 2017). Development of the Seaflex and Eco-Mooring Rode over 10 years has meant that the system can hold vessels of up to 45ft and is capable of 19ft of stretch. This research has resulted in several mooring areas around the world only installing advanced mooring systems. For instance in Morton Bay, Australia all new moorings must be advanced mooring systems to protect their endangered seagrass habitats.

Although there are many advanced mooring systems on the market, the UK has been slower to adopt these systems due to concerns from industry/stakeholders regarding securing vessels and stretch in areas with large tidal changes and extreme weather. Many systems are designed for relatively small tidal ranges (up to 3m), while UK coastlines experience tidal ranges of up to 15m. One key concern is the potential for vessels to collide due to the failure of a mooring system and whether the insurance market will cover these events. However, it should be noted that traditional mooring systems are not void of these risks as well – they can also move or break.

Some key advanced mooring trials have been conducted around the UK and several systems are in current use in Cornwall, Devon, Dorset, and the Isle of Man.

3.3 Case studies of advanced mooring system trials / private use in UK

CASE STUDY 1: Helford river & Falmouth, Cornwall: (Collins & Mallinson 2016)

Location		Helford River & Falmouth Docks, Cornwall
Advanced mooring system		Modified elasticated mooring systems
When		2014-2016
Tidal range		4.5m
Environmental conditions		Sheltered estuary
Marine habitat		Subtidal seagrass
Trial set up		<ul style="list-style-type: none"> • Transplantation of 2000 seagrass plants from Pendennis wet basin to Helford river as mitigation for construction of a wet dock in Falmouth. • 4 chain moorings within transplantation area were replaced with modified elasticated moorings.
Findings	Positive +	<ul style="list-style-type: none"> • Higher levels of seagrass growth and improved seagrass densities around advanced mooring systems than chain mooring systems. • Evidence of seagrass recolonization of scarred areas – 1,000m² of low-density seagrass by 2016.
	Negative -	<ul style="list-style-type: none"> • Failure of one advanced mooring system with a large vessel due to storm Ophelia in October 2016, resulting in the removal of all advanced mooring systems.

CASE STUDY 2: Data taken from RYA website:
https://www.rya.org.uk/SiteCollectionDocuments/legal/Web%20Documents/Environment/EFM_documents/1b_Parry.pdf) and from a presentation from National Marine Aquarium:
 'Seagrass condition following installation of mooring at Cawsand'

Location		Cawsand Bay, Cornwall
Advanced mooring system		Stirling mooring system – buoyant trawler floats along the chain
When		2015-Present
Tidal range		5.4m
Environmental conditions		Sheltered bay
Marine habitat		Subtidal seagrass
Trial set up		<ul style="list-style-type: none"> Compared Stirling mooring and swing mooring impacts on seagrass beds. Used small craft anchorage and moorings.
Findings	Positive +	<ul style="list-style-type: none"> Increased growth rates and higher densities of seagrasses around stirring mooring compared to swing mooring. Existing seagrass shoot count and length showed recovery from scarring and new growth was recorded.
	Negative -	<ul style="list-style-type: none"> When first installed there was a mooring failure, but this was due to a polyprop rope and insufficient floats being used within the construction of the mooring, resulting in the failure of the initial install in 2016/17. Since the mooring riser has been replaced with a 4mm steel rope and appropriate floats have been added there have been no further issues.

CASE STUDY 3: Fishcombe Cove, Torbay, Devon: (Parry-Wilson et al. 2019)

Location		Fishcombe Cove, Torbay, Devon
Advanced mooring system		Stirling mooring system – swing mooring with buoys along chain
When		2017-Present
Tidal range		5.32m
Environmental conditions		Sheltered bay
Marine habitat		Sediment/mud with seagrass beds
Trial set up		<ul style="list-style-type: none"> • Ran an awareness campaign about the importance of seagrass and the ecological benefits from using advanced mooring systems. • Before awareness campaign and installation of advanced mooring system site 45.4% of vessels were anchored within mapped seagrass bed. • Advanced mooring systems were installed within site. • Advanced mooring system opinion questionnaire.
Findings	Positive +	<ul style="list-style-type: none"> • Advanced mooring alleviated 20% of traditional anchoring within mapped seagrass zones. • 89.6% of on-site respondents were positive about the implementation of further local advanced mooring system sites.
	Negative -	<ul style="list-style-type: none"> • Many of the systems were damaged by suspected vandalism – several of the buoys along the chains were disconnected. It was repaired and is still functioning effectively at present.

CASE STUDY 4: Salcombe, Devon: (Luff et al 2019)

Location		Salcombe, Devon
Advanced mooring system		Stirling mooring system – buoyant trawler floats along the chain
When		2014-Present
Tidal range		5.26 m
Environmental conditions		Sheltered estuary
Marine habitat		Intertidal seagrass
Trial set up		<ul style="list-style-type: none"> Compared impact of swing mooring system on seagrass beds with the impact of a stirring mooring system.
Findings	Positive +	<ul style="list-style-type: none"> Stirling mooring system reduced mooring scarring. Increased seagrass growth and higher levels of biodiversity around advanced mooring system. Shallower sediment deposits and higher levels of sediment disturbance around traditional swing mooring.
	Negative -	<ul style="list-style-type: none"> NIL

CASE STUDY 5: Lundy Island, Devon

Location		Lundy Island, Devon
Advanced mooring system		Seaflex rodes with helix helical anchors
When		2004-Present
Tidal range		9.0m
Environmental conditions		Sheltered bay
Marine habitat		Subtidal seagrass and soft sediment
Trial set up		<ul style="list-style-type: none"> Four Seaflex moorings permanently in use around island in 14m of water. Both for visitor and private use.
Findings	Positive +	<ul style="list-style-type: none"> Reduced abrasion on seabed Effective and safe moorings, which are still operating
	Negative -	<ul style="list-style-type: none"> Limited use in exposed areas and deep waters. Failure of one system due to a lack of maintenance.

CASE STUDY 6: Studland Bay, Dorset: (Axelsson, Allen & Dewey 2012)

Location		Studland Bay, Dorset
Advanced mooring system		Seaflex rode with helix helical anchors
When		2009-2011
Tidal range		6.0m
Environmental conditions		Sheltered bay
Marine habitat		Subtidal seagrass and soft sediment
Trial set up		<ul style="list-style-type: none"> • Installed six Seaflex rode systems with helix anchor. • Used to mark voluntary no anchor zone. • The Seaflex systems were not used to moor boats.
Findings	Positive +	<ul style="list-style-type: none"> • Eco-mooring rode systems coped well with large tidal ranges. • No additional mooring scarring on seagrasses.
	Negative -	<ul style="list-style-type: none"> • NIL

CASE STUDY 7: Garwick Bay, Isle of Man: (Private ownership – data taken from RYA website: <https://www.rya.org.uk/knowledge-advice/planning-environment/Pages/efm-projects-trials.aspx>)

Location		Garwick Bay, Isle of Man
Advanced mooring system		Modified Hazelett system
When		2009-2020
Tidal range		7.0m
Environmental conditions		Open bay
Marine habitat		Sand/rock
Trial set up		<ul style="list-style-type: none"> • Summer use only due to private use. • Only private moorings.
Findings	Positive +	<ul style="list-style-type: none"> • Testing suggests system is secure in all weather conditions. • The elastic rode helps the boat to stay in a stable position.
	Negative -	<ul style="list-style-type: none"> • Fairly regular maintenance is needed to remove weed and debris from the buoy and riser. • Some degradation to the outer cast of the riser from twisting. Continued trials using recently modified system to eliminate this problem.



Photo 6. Seagrass reflections. Photograph taken by Matt Slater of Cornwall Wildlife Trust.

3.4 Overview of findings

Positives – UK-based trials consistently found that the use of advanced mooring systems improved seagrass growth and densities by reducing the amount of mooring scarring.

Negatives – UK-based trials have seen some examples of failures – occurring during the initial period of use and due to a lack of maintenance or insufficient stretch in system to cope with tidal ranges or rough weather. In most cases the systems were adjusted and subsequently found to work well.

***Disclaimer** – This report only compares findings of advanced moorings trials. It does not include findings from strength/security/maintenance trials of traditional moorings. While traditional moorings have been used for decades in the UK, it should be recognised that these mooring systems are not immune to issues related to maintenance and boat security.*

3.4.1 Potential solutions

The UK-based advanced mooring system trials exposed some issues regarding the safety and security of the systems. Listed below are suggested solutions generated from this review of advanced mooring system trials to prevent such issues from occurring:

- a) Customise the elasticity of the rode to the vessel weight.
- b) Mooring owners/users must follow set guidelines for the appropriate size of vessel and the installation instructions for each advanced mooring system.
- c) Use local tidal conditions to determine the mooring spacing between vessels – to account for the increased swing space.
- d) Regular diver-servicing to maintain system and prevent system degradation.

4. Market solutions

4.1 Environmentally friendly anchors

The method of securing the mooring to the seabed varies depending on anchor choice. There are several key factors to consider when deciding anchor type – including the substrate type, the cost and the strength of the system (Table 1). The anchors with the smallest footprint on the seabed are helical, which screw into the ground – such as the Helix which can have either square or round shafts depending on the size of the boat, or the manta ray anchor, which is driven into the seabed and secured using a load locker. The helix/screw anchors are the most environmentally friendly option.

Concrete blocks are the most common official traditional anchor; however, these have large footprints on the seabed and so are more impactful on the environment. Other anchor types include mushroom or pyramid anchors which are large anchors that also sit on top of the substrate – an image of the different anchor types is found in the appendix (Appendix Image 2). Concrete block anchors are not recommended in seagrass habitats due to the high levels of disturbance, whereas helix/manta ray are.



Table 1. Comparing environmentally friendly anchors with traditional anchors for differing parameters, installation, lifespan, strength, substrate and depth requirements (Table data from Egerton 2011; Amec Foster Wheeler Environment & Infrastructure UK Limited 2017; and Unpublished data from Natural England).

Anchorage type	Anchorage parameters	Average costs	Installation	Lifespan	Maintenance	Substrate	Required substrate depth
Helix / screw	Different sizes of Square shaft or round shaft anchors available for different sized vessels and conditions.	£250 + installation costs (dependent on depth & hourly rate of installer).	Requires trained divers – barge installation being trialled.	15 years	Annual checks are required to ensure anchor not pulled out. Divers required.	Soft clay/mud	5ft
Manta Ray	3 different anchor heads* to allow installation in a range of substrates (MR-SRM = soft, MR-1M = normal, MR-2M = hard).	MR-1M c. £175 MR-SRM c. £220 Total Installation cost c. £16,000**	Handheld installation using hydraulic equipment. Requires trained divers – barge installation being trialled.	15 years	Trained divers needed to inspect that anchors have not pulled out or deteriorated. Replace as needed.	Loose fine sand, alluvium, soft clays; fine saturated silty sand.	4-8.6' finished installation depth***
Concrete block	Standard	Standard + installation costs (dependent on depth & hourly rate of installer).	Barge or trained divers – divers must check all advanced mooring installations.	10 years	All anchors should be checked annually.	Any	NA

* Anchors include anchor head, 1" x 7' rod, and swivel oval eyenut ** Installation cost includes one-time purchases of 8' drive steel kit, hydraulic load locker (used to lock anchors in soil and proof test them), 90 lb class hydraulic jack hammer, hydraulic power unit, 100' total of hydraulic hosing. *** Deeper installation depths may be required to reach sufficient load bearing soils. 3.5' extension rods available if increased installation depths are needed. D10031/2C £29.93 each. Manta Ray anchor prices given in USD\$ - conversion rates to £ taken on 10/04/20.

4.2 Advanced mooring rode & buoy systems

There are many different rode and buoy advanced mooring systems on the market, which differ greatly in price, strength and suitability for different environmental conditions (Table 2). These systems fall into two broad categories: 1) systems with elasticated components for tension between the anchor point and the buoy; and 2) modified chain moorings with additional floats to lift the chain off the seabed (Appendix Image 1B&C).

4.2.1 Elasticated rode systems

Hazelett:

Elasticated rode, able to stretch evenly due to smooth extension components eliminating snatch in heavy weather, maintaining a stable position even in rough conditions. The elasticated rode is attached to a spar buoy. Recommended to be attached to Helix or concrete block anchors. According to manufacturers, the use of Hazelett systems can increase mooring density by 40% and can reduce the load on deck hardware by 50%. The system can stretch up to four times unloaded length. Regular maintenance is needed to remove vegetation build up, but the system is very lightweight, meaning that a single person can lift the riser to clean the system.

- More information can be found here:
<https://hazelettmarine.com/>
- The manufacturer's quote form for single point moorings is in the appendix (Appendix Form 1) or can be found here:
<https://hazelettmarine.com/product/elastic-mooring-system/>

Seaflex:

Elastic rode system using a powertext round sling with over 10kN break-load. Can be attached to any anchor type. The system has been developed and tested in the UK and is reportedly able to withstand high tidal variability due to its shock absorbing design that reduces swing space.

- More information can be found here:
<http://www.seaflex.net/>
- The manufacturer's quote form for single point moorings is in the appendix (Appendix Form 2) or the contact information can be found here:
<http://www.seaflex.net/how-to-order/>

4.2.2 Modified chain mooring systems

Stirling system:

Modified pre-existing traditional mooring systems with helix anchors to replace the block anchors, removal of the thrasher chain, and added subsurface floats to the chain rode to lift it off the seabed. The catenary fixing between the seabed and the pickup buoy allows it to rise and fall with the tide. This system was developed by the Ocean Conservation Trust in conjunction with Harbour authorities on the South Coast of England to provide a cost-effective and secure advanced mooring system.

Table 2. Comparing mooring systems for their parameters, installation method, lifespan, maintenance requirements, tidal range, strength and where a UK trial took place (Table data from Egerton 2011; unpublished data from Natural England and directly from Hazelett & Seaflex manufacturers).

* System sizing is done through close consultation with Hazelett Marine engineering team. Site conditions data and vessel type are used to calculate forces to appropriately size each mooring system. **Hazelett system prices are based on the 3m long elastic rodes, as these were deemed most appropriate for Cornish mooring depths. *** Full systems include shackles, elastics, down line and buoy. Elastics can be supplied individually for retrofits or to be used with alternative buoys, downlines, etc. + Required rope length depends on depth at HWL (m) – 0-7m = 10m rope, 7-10m = 15m rope, 10-15m = 25m rope, 15-20m = 30m rope. Rope cost – 24mm = £4/m; 32mm – £7/m. ++ Waves over 2m require project specific design. # Retrospective fitting of Stirling Riser to existing block and surface buoy possible on request. ## Prices based on current stock prices Apr 2020, all costs plus VAT. ### Assumes minimum of 5 moorings per order, additional moorings in multiples of 5. #### Additional 2m extension to the screw pile supplied and installed for £121.65 each.

Mooring system type	Rode system	Rode system parameters	System specification			System & prices (Conversion rates taken on 14/04/2020)	Installation	Lifespan	Maintenance	Water depth / tidal range	UK Trial
Elasticated rode	Hazelett	Four different system sizes based on moored vessel weight: Single = <5 tonnes Double = 6-15 tonnes Triple = 16-25 tonnes Quad = 26-35 tonnes Four different lengths of elastic: 1.5m, 2m, 2.4m, 3m Elastic number & length determined by vessel length/weight, mooring depth, tidal range, wind speed, wave height, current & fetch*.	Number of elastic rodes:			Relevant System & price:	Requires a professional mooring installer – costs dependent on depth & hourly rate of installer. Helical screw anchor requires a trained diver. Block anchor – can be attached before and lowered from barge, but trained diver still required to ensure correct attachment and ensure system has been installed to specification.	25-year design life. Recommend 10-year replacement cycle.	Recommend annual inspection by divers to check for degradation and wear. Costs depend on depth and hourly rate of inspection team.	Tidal range no greater than low tide depth due to tangling issues. Min. water depth 2.5-3m.	Garwick
			Single (<5 tonnes)			3m** elastic c. £700 Full system c. £1,460***					
			Double (6-15 tonnes)			3m** elastic c. £1,280 Full system c. £2,000***					
			Triple (16-25 tonnes)			3m** elastic c. £2,000 Full system c. £3,150***					
			Quad (26-35 tonnes)			3m** elastic c. £2,550 Full system c. £3,760***					
	Seaflex	The number of and length of rubber hawsers in unit is customisable depending on tidal variation, depth, forces, and fetch. System choice depends on wind velocity, wave height and vessel length. Different rope sizes+ : 24mm if Seaflex has two hawsers (2020 TTBPMTH); 32mm rope for more than two hawsers (4020 BPBMTH, 6020 TTBPMTH, 8020 BPBMTH, 10020 BPBMTH).	Max. wind velocity (m/2)	Max. wave height (m)	Vessel length (m)	Relevant System & Price:	Splice rope to Seaflex thimbles, following installation guide. Helical screw anchor requires a trained diver. Block anchor – can be attached before and lowered from barge, trained diver not necessarily as long as system was connected correctly before deployment.	Expected lifespan 20 years.	Recommend annual inspections for first 2-3 years after installation, but can be extended to every 2 years after. Can use boat and pull Seaflex out of water.	Up to 8m Design is altered accordingly.	Studland Lundy
			20m/s	1m	Up to 12m	2020 TTBPTH Buoy model c. £1,060					
					12-18m	4020 TTBPTH Buoy model c. £1,480					
					18-20m	6020 TTBPTH Buoy Model c. £2,320					
					20-25m	8020 TTBPTH Buoy model c. £2,860					
>25m					Customised design – contact Seflex AB						
30m/s			2m ++	Up to 10m	2020 TTBPTH Buoy model c. £1,060						
				10-15m	4020 TTBPTH Buoy model c. £1,480						
				15-18m	6020 TTBPTH Buoy Model c. £2,320						
				18-25m	8020 TTBPTH Buoy model c. £2,860						
				>25m	Customised design – contact Seflex AB						
Chain with additional floats	Stirling Advanced Mooring System (SAMS)	Traditional chain mooring with helix anchor and subsurface buoys to raise off seabed. Able to modify existing chain systems with additional buoys or purchase new system#.	Vessel weight:			Relevant system & price:	Helical screw anchor diver deployment. Block barge deployment.	15 years	Annual visual inspection c. £150. Component life expectancy of 3 years.	Up to 8m Design is altered accordingly.	Cawsand Fishcombe Salcombe
			<3.5 tonnes = 16mm chain assembly with buoyancy			£1,545 helical##,###					
			<9.5 tonnes = 20mm chain assembly with buoyancy (Heavier moorings on request). £1,710 helical##,###			£1,710 helical##,###					

4.3 Advanced mooring considerations

Advanced mooring system costs – advanced mooring systems typically have an annual cost circa double that of traditional swing moorings once the depreciated value of the system/anchor, installation and maintenance costs are incorporated (Amec Foster Wheeler Environment & Infrastructure UK Limited 2017). Costs are bespoke and derived through the submission and consideration of a set of parameters relating to the environmental conditions and mooring requirements, per the example quote forms (Appendix Forms 1&2). In order to control the swing and snatch in the full range of prevailing weather conditions, various component sizes and weights are considered in discussion with mooring operators.

Installation requirements – if adapting pre-existing moorings then installation has similar or lower costs to traditional moorings and can be adapted using either a winch or divers to install the system. However, if an advanced mooring system is installed as new it may require trained drivers or crane machinery and will generally have higher costs and be more time consuming (Amec Foster Wheeler Environment & Infrastructure UK Limited 2017). Although, ABC anchors are currently trialling installation from barges, which would be quicker and cheaper (Information from correspondence with Natural England).

Maintenance – whilst all mooring systems require annual maintenance, evidence from the trials demonstrate that advanced mooring systems generally require more regular maintenance than traditional chain moorings in order to maintain their buoyancy and to avoid degradation of the more complex systems. These often require trained divers to carry out maintenance on the systems, however as many of these systems are much lighter and smaller than traditional mooring systems, they can be serviced easily without the need for winches or cranes (Amec Foster Wheeler Environment & Infrastructure UK Limited 2017). Further investigation comparing differences between maintenance efforts for traditional and advanced mooring systems should be conducted to determine whether advanced mooring systems actually require more frequent inspection.

Insurance – the cost of potential mooring failure on the vessels attached to them is a further consideration. Insurance rates do not currently appear to be adjusted based on mooring type and a review of mooring fees found that the type of mooring system was not stated (Amec Foster Wheeler Environment & Infrastructure UK Limited 2017). The complexity of advanced mooring systems creates a greater potential for system failure compared to simple traditional chain moorings (Amec Foster Wheeler Environment & Infrastructure UK Limited 2017). Advanced mooring systems fall under the cover of swing moorings and so should be covered by existing policies; but owners need to inform their insurers of any transitions to advanced mooring systems as these might be considered a 'material change' and therefore alter cover.

5. Conclusions

The main conclusion of this report is that although trials have shown that advanced mooring systems offer an environmentally friendly option that enables the recovery of seagrass beds, there is insufficient evidence to suggest that advanced mooring systems are appropriate and safe in all UK marine environments. Also, the advanced mooring system literature lacks clear guidance regarding which system is most appropriate in different environmental conditions. Currently consumers must use the subjective and potentially biased performance information from the manufacturer which is not always backed-up by in-situ trials.

Future trials must investigate a more holistic set of factors including safety and stability, as opposed to focusing solely on the ecological benefits of advanced mooring systems. Additionally, there is a need for more standardised testing across trial sites – with the same type and quantity of systems installed over a set period and exact weather/tide conditions recorded to determine which systems are effective and safe within differing environments. Clear guidelines should then be generated using the findings from these trials to inform advanced mooring system purchasers of which system would be most appropriate for their site. Alternatively, this research may lead to the development of a new system, designed especially to cope with large Cornish tidal ranges and frequently rough weather conditions.

Evidence collected from the UK-based trials was generally quite inconclusive, with many reporting seagrass bed recoveries but also a small number of advanced mooring system failures or the need for system adaptation to cope with the environmental conditions.

The UK-based advanced mooring system trials suggest that either the Eco-mooring rode or Seaflex rode with a Helix anchor would be the best option to cope with the extreme Cornish tides and variable weather conditions. Both options have been reported to cope with large tidal ranges and vessels up to 50ft long and so appear to be able to cope with most recreational moorings along UK coasts. Alternatively, modified swing mooring systems offer an effective and cheaper option for modifying pre-existing moorings. The findings of this report suggest that these systems would be most relevant for further testing in Cornish waters. However, owners of these advanced mooring systems need to be aware that these systems, similarly to traditional mooring systems, will require regular maintenance and upkeep to ensure full functionality, which will add to annual costs.

It is clear however, that advanced mooring systems are both safe and highly beneficial in sheltered areas with small tidal ranges and should be adopted in these areas as quickly as possible. Further testing is recommended in areas that fall outside of these parameters.

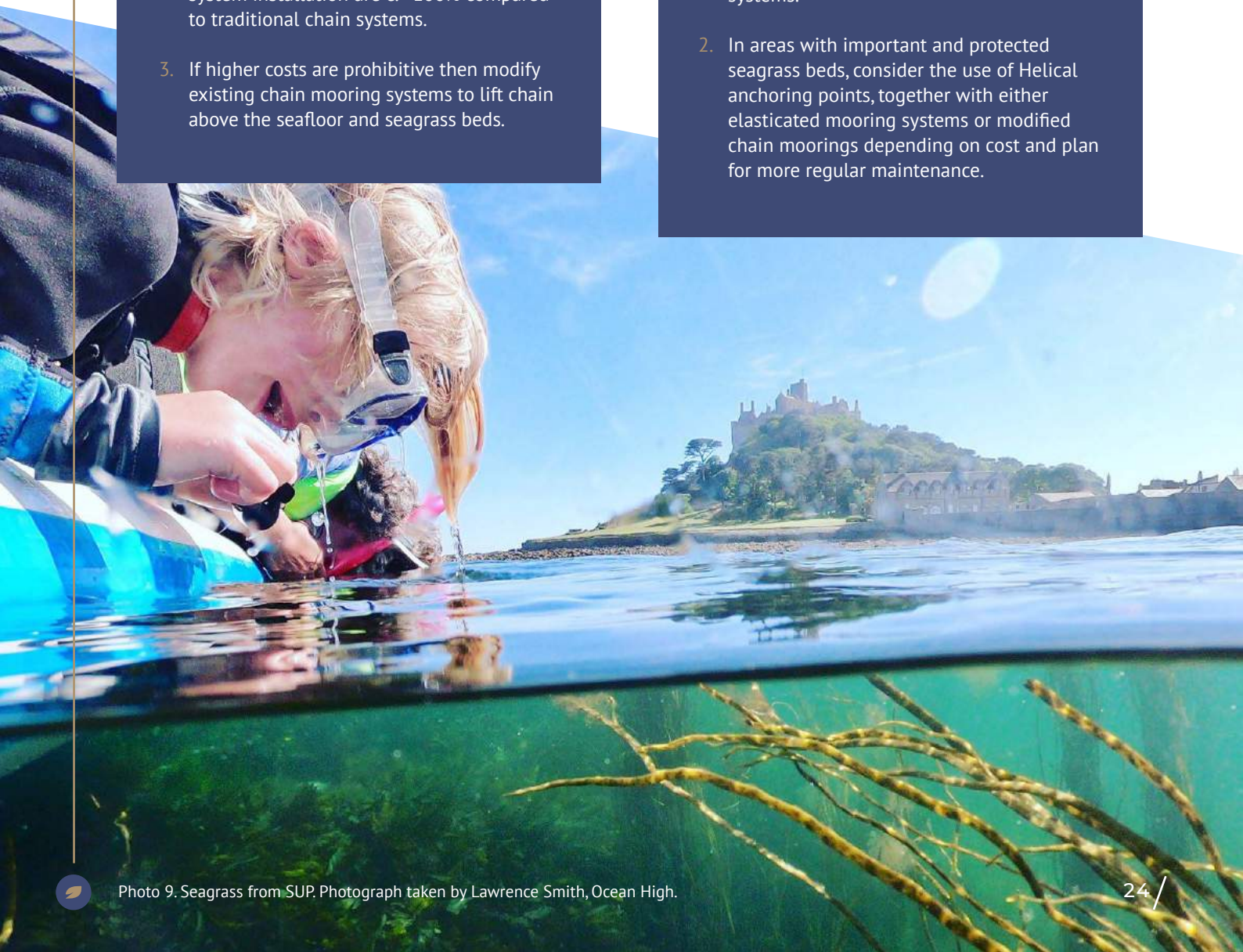
6. Recommendations for moorings in Cornwall

6.1 Sheltered areas with tidal ranges <5metres

1. Transition from traditional anchors that sit on top of substrate and damage seagrass beds (Concrete block, Mushroom or Pyramid anchors) to helical anchors that are screwed into the substrate (Helix or Manta Ray anchors) in areas with a substrate depth >1.5 metres.
2. Transition to elasticated advanced mooring system, but note that annual running costs including the depreciated cost of system installation are c. +100% compared to traditional chain systems.
3. If higher costs are prohibitive then modify existing chain mooring systems to lift chain above the seafloor and seagrass beds.

6.2 Exposed areas with tidal ranges >5metres

1. Further trials testing the security and safety of advanced mooring systems should be commissioned to take place in exposed areas with greater tidal ranges. These trials must be standardised across sites – with the system type, number of systems and maintenance effort kept consistent to determine whether these systems offer a reliable and safe mooring option in Cornish waters. These trials should also aim to draw a comparison vis-à-vis traditional mooring systems.
2. In areas with important and protected seagrass beds, consider the use of Helical anchoring points, together with either elasticated mooring systems or modified chain moorings depending on cost and plan for more regular maintenance.



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8. Appendix

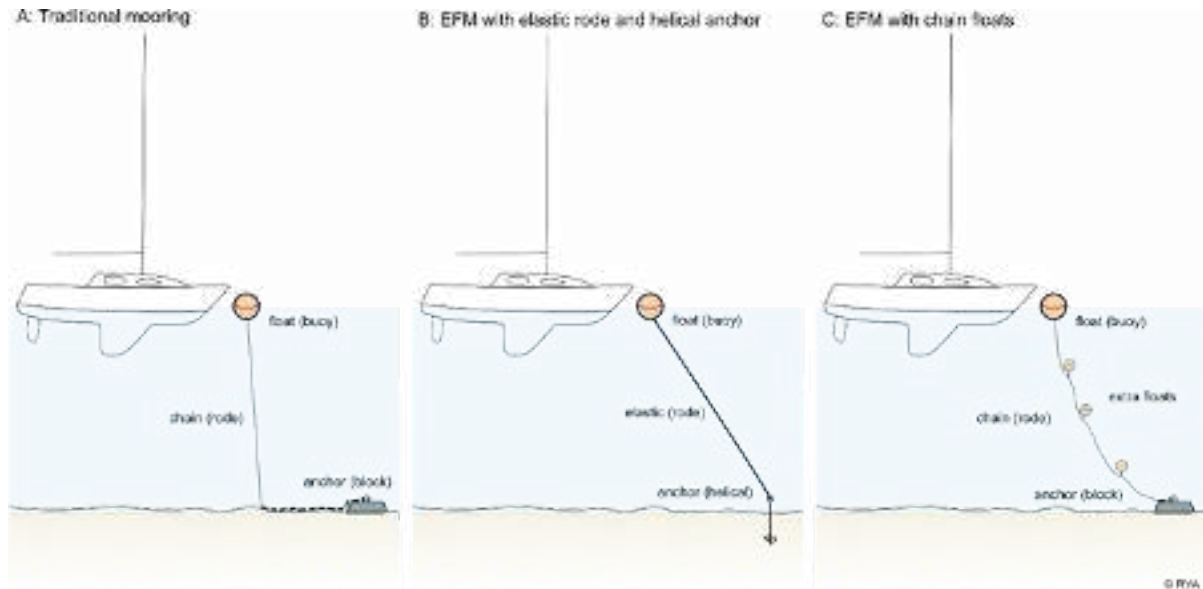


Image 1. Comparing different mooring systems. A = traditional swing chain mooring systems – showing chain dragging on seabed. B = advanced mooring system with elasticated rode. C = modified swing mooring with chain floats to keep chain off seabed. Image taken from RYA website, accessed at: <https://www.rya.org.uk/knowledge-advice/planning-environment/Pages/types-of-efm.aspx>

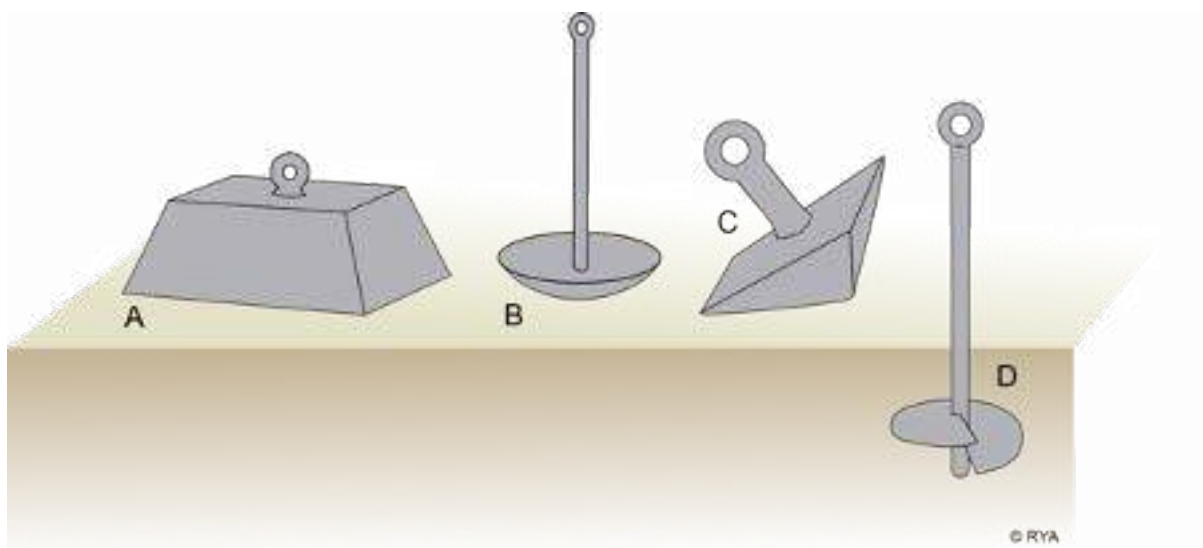


Image 2. Different anchor types, demonstrating how they interact with the substrate – A-C sit on top, while D is screwed into the substrate. A = concrete block, B = mushroom anchor, C = pyramid anchor, D = helical anchor. Image taken from RYA website, accessed at: <https://www.rya.org.uk/knowledge-advice/planning-environment/Pages/types-of-efm.aspx>

BOAT MOORING QUOTE FORM

Please supply us with the following:



NAME:

PHONE:

EMAIL:

INSTALLATION LOCATION:

DEPTH AT MOORING LOCATION

HIGHEST ASTRONOMICAL TIDE:

LOWEST ASTRONOMICAL TIDE:

BOAT TO BE MOORED

SAIL BOAT:

POWER BOAT:

LENGTH:

WEIGHT:

CONDITIONS

PREDOMINANT WIND DIRECTION:

FETCH:

MAX WAVE HEIGHT:

MAX WIND SPEED:

CURRENT (IN KNOTS):

BOTTOM

SAND:

MUD:

ROCK:

OTHER:

ANCHOR TYPE

CONCRETE BLOCK:

HELIX:

OTHER:

SYSTEM COMPONENTS NEEDED:


Full system includes helix anchor, shockie(s), trawl floats, elastic(s), uniline, spar buoy, swivel and pennant

Hazelett Marine • info@hazelettmarine.com • www.HazelettMarine.com • (802) 399-2627

Form 1. Hazelett mooring system quote form for mooring system purchasers

Project Data Sheet (PDS)

PDS for Buoys



Project Information:

Project name:

Amount of boats:

<input type="checkbox"/> x 6m	<input type="checkbox"/> x 12m	<input type="checkbox"/> x 20m
<input type="checkbox"/> x 8m	<input type="checkbox"/> x 15m	<input type="checkbox"/> x 25m
<input type="checkbox"/> x 10m	<input type="checkbox"/> x 18m	<input type="checkbox"/> x <input style="width: 40px;" type="text"/> m

Estimated installation date:

Installation city & country:

Latitude and longitude coordinates:

Layout information

Please attach a drawing, preferably in CAD format. If you do not have a drawing, attach a detailed description of what you are trying to moor. Include bathymetry or sketch of depth measurements if known.

Layout drawing file name:

Other information

Brief explanation of project:

Design environmental information (required)

Please provide the worst case scenario data that this location is ever anticipated to see. We use this data to determine the size, strength and amount of Seaflex needed for this particular location.

	Value <small>(specify unit of measurement)</small>
Water level variation	<input style="width: 100%;" type="text"/>
Water depth at lowest water level	<input style="width: 100%;" type="text"/>
Maximum wind velocity	<input style="width: 100%;" type="text"/>
Maximum wave height	<input style="width: 100%;" type="text"/>
Maximum current speed	<input style="width: 100%;" type="text"/>

Design environmental information (optional)

The following data is optional. It is recommended to fill in as much as possible.

	Value <small>(specify unit of measurement)</small>
Chart Datum (CD)	<input style="width: 100%;" type="text"/>
Lowest Water Level (LWL)	<input style="width: 100%;" type="text"/>
Highest Water Level (HWL)	<input style="width: 100%;" type="text"/>
Significant wave height	<input style="width: 100%;" type="text"/>
Wave period	<input style="width: 100%;" type="text"/>
Wind period	<input style="width: 100%;" type="text"/>
Water type (salt/fresh)	<input style="width: 100%;" type="text"/>
Type of anchor to be used	<input style="width: 100%;" type="text"/>

Contact information

Company:	<input style="width: 100%;" type="text"/>
Contact Person:	<input style="width: 100%;" type="text"/>
Phone number:	<input style="width: 100%;" type="text"/>
Email:	<input style="width: 100%;" type="text"/>
Address:	<input style="width: 100%;" type="text"/>
	<input style="width: 100%;" type="text"/>
	<input style="width: 100%;" type="text"/>

Sign and date:

Sign this to acknowledge that this is the data that will be used to dimension the type of Seaflex needed for this project. Confirm that this is not average data but in fact the worst case scenario forces for which you need the SEARLEX mooring system to handle.

Form 2. Seaflex advanced mooring system quote form for mooring system purchasers

Publication date:

May 2020

Contributors:

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With thanks to Natural England's LIFE Recreation ReMEDIES project team for their input and suggestions.

www.gov.uk/government/publications/life-recreation-remedies-project

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Development Fund