ACA Pen Llŷn a’r Sarnau SAC

Prosiect Morwellt Porthdinllaen Seagrass Project

Dyluniad o astudiaeth cost effeithiol i ymchwilio i adfer creithiau angori o fewn ardal islanwol y gwely morwellt ym Mhorthdinllaen

Design of a cost effective study to investigate recovery of mooring scar areas within the subtidal area of the seagrass bed at Porthdinllaen

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Crynodeb Gweithredol

Mae dolydd morwellt ym Mhorthdinllaen yn gynhyrchiol, yn eang ac yn darparu ystod o wasanaethau ecosystem pwysig yn cynnwys cynefin meithrinfa bysgod. Mae'r dolydd hyn yn agored i ddifrod gan angorfeydd sefydlog sy'n creu creithiau angori mawr ar unrhyw forwellt. Fel rhan o ymrwymiad Ardal Cadwraeth Arbennig Pen Llŷn a'r Sarnau i reoli a gwrthdroi'r effeithiau hyn, datblygwyd proses reoli ar sail y gymuned ym Mhorthdinllaen. Disgwylir y bydd hyn yn arwain at sefydlu mesurau (e.e. systemau angori â llai o effaith) fydd o bosib yn galluogi'r morwellt i wella.

Ni wyddys pa mor dda na pha mor sydyn fydd yr ardaloedd creithiog hyn yn cael eu hadfer pan na fyddai unrhyw effaith, neu lai o effaith, gan yr angorfeydd. Er mwyn pennu effeithiolrwydd unrhyw adferiad, mae angen rhaglen fonitro briodol sy'n addas i'r pwrpas, sy'n gadarn yn ystadegol, yn ymarferol a chost effeithiol.

Mae'r adroddiad presennol yn adolygu'r wybodaeth sydd ar gael er mwyn darparu dyluniad ar gyfer astudiaeth maes i ymchwilio i adferiad ardaloedd a greithiwyd gan angorfeydd yn ardal islanwol gwely'r morwellt ym Mhorthdinllaen. Mae angen y gwaith yma i gael dealltwriaeth am ddifrifoldeb a hirhoedledd effeithiau'r angorfeydd ar y morwellt ym Mhorthdinllaen.

Gwneir saith argymhelliad bras ynglŷn â sut i asesu a monitro unrhyw adferiad morwellt yn yr ardaloedd a greithiwyd ar ôl i fesurau cadwraeth gael eu gosod. Elfen allweddol o'r argymhellion hyn yw bod plymwyr gwirfoddol yn cael eu defnyddio er mwyn uchafu effeithiolrwydd cost y gwaith.

- Asesiad cychwynnol o faint (amcangyfrifon bras) y creithiau ym mhob safle angori addasedig neu newydd.
- Ymarfer mapio creithiau cychwynnol manwl (yn defnyddio dwysedd *'shoot'*) ar gyfer o leiaf chwe angorfa addasedig neu newydd yn defnyddio SCUBA. Gallai hyn gynnwys y defnydd o blymwyr gwirfoddol dan arweiniad gwyddonwyr profiadol. Byddai hyn yn dilyn dulliau presennol a ddefnyddiwyd gan Stamp a Morris 2012, ond gyda delweddau llawer mwy eglur (higher resolution) lle canolbwyntir yn bennaf ar y radiws 5m cyntaf o amgylch yr angorfa ble gwelir y mwyafrif o ddifrod.
- Ymgymryd â gwaith monitro tymhorol o chwe chraith yr angorfeydd drwy ddefnyddio cwadratau wedi'u rhannu ar hap a osodwyd drwy greithiau'r angorfeydd (yn seiliedig ar y mapio cychwynnol). Byddai pob amser samplo newydd yn defnyddio pwyntiau samplo newydd ar hap. Mae angen i rifau sampl ddefnyddio'r dechneg gwahaniaeth canfyddadwy lleiaf er mwyn sicrhau bod samplo yn ddigonol. Bydd samplo yn asesu dwysedd, atgynhyrchiad, morffoleg, algâu a chyflwr y morwellt.
- Cynnal asesiadau tymhorol paralel mewn pwyntiau rheoli (cyfeirio) fel y gellir gwahanu amrywioldeb naturiol cefndirol yn y morwellt oddi wrth ail-dyfiant ac adferiad naturiol.
- Cynnal asesiadau isfilod gwaddodion (*sediment infauna*) gwaelodlin mewn creithiau angorfeydd sy'n gymharol ag ardaloedd morwellt. Ail-wneud hyn ar ôl i'r morwellt wella nes ei fod yn cyrraedd cyflwr nad yw'n sylweddol wahanol yn ystadegol i'r dolydd amgylchynol.

- Yn seiliedig ar arsylwadau adferiad morwellt mewn 24 mis mewn lleoliadau eraill, cynigiwn fod rhaglen fonitro gychwynnol yn cael ei sefydlu dros gyfnod tebyg o amser.

- Er mwyn cynorthwyo gyda'r gwaith o gyfathrebu canfyddiadau, dylid casglu tystiolaeth ffotograffig drwy gydol yr astudiaeth ynglŷn â statws unrhyw adferiad a dylid ei rannu drwy gyfrwng cyfryngau cymdeithasol gyda budd-ddeiliaid lleol.

Executive Summary

Seagrass meadows at Porthdinllaen are productive, expansive and provide a range of important ecosystem services including fish nursery habitat. These meadows are subjected to damage by fixed moorings creating large mooring scars denude of any seagrass. As part of the Pen Llŷn a'r Sarnau Special Area of Conservation commitment to managing and reversing these impacts a process of community based management has been developed at Porthdinllaen. It is anticipated that this will result in the establishment of measures (e.g. reduced impact mooring systems) that will potentially enable seagrass recovery.

It is not known how well or how quickly these scar areas will recover in the absence or reduction of any mooring impact. In order for the effectiveness of any recovery to be determined an appropriate monitoring programme is required that is fit for purpose, statistically robust, practical and cost-effective.

The present report reviews the available literature to provide a design for a field study to investigate recovery of mooring scar areas within the subtidal area of the seagrass at Porthdinllaen. This work is required to inform understanding about the severity and longevity of the impacts by moorings on the seagrass at Porthdinllaen.

Seven broad recommendations are made as to how to assess and monitor any seagrass recovery within these scar areas after conservation measures have taken place. A key component of these recommendations is that volunteer divers are utilised in order to maximise the cost effectiveness of the work.

- An initial rapid assessment of the size (broad estimates) of scars at all modified or new moorings sites.

- An initial detailed scar mapping exercise (using shoot density) of at least six modified or new moorings using SCUBA. This could involve the use of volunteer divers under the guidance of experienced scientists. This would follow existing methods used by Stamp and Morris 2012, but at a higher resolution and focus effort within the first 5m radius around the mooring where most damage appears.

- Conduct seasonal monitoring of the six mooring scars using randomly assigned quadrats placed throughout the mooring scars (based upon the initial mapping). Each new sampling time would use new random sampling spots. Sample numbers need to utilise the minimal

detectable difference technique to ensure sampling is sufficient. Sampling will assess seagrass density, reproduction, morphology, algae, and condition.

- Conduct parallel seasonal assessments in control (reference) spots so that background natural variability in the seagrass can be separated from natural regrowth and recovery.
- Undertake baseline sediment infauna assessments in mooring scars relative to seagrass areas. Repeat this after seagrass has recovered to the point that it is statistically not significantly different to the surrounding meadow.
- Based on the observed recovery of seagrass in 24 months in other locations we propose that an initial monitoring programme be set up over a similar time period.
- To aid with communication of findings photographic evidence should be collected throughout the study about the status of any recovery and communicated via social media to local stakeholders.

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1. Purpose of report

There exist conservation management concerns at Porthdinllaen with respect to the impact that fixed moorings are having on seagrass. Specifically these moorings are thought to result in the creation of mooring scars that are mostly denude of any seagrass [1-5]. As part of the Pen Llŷn a'r Sarnau Special Area of Conservation commitment to managing and reversing these impacts a process of community based management has been developed at Porthdinllaen. It is anticipated that this will result in the establishment of measures (e.g. reduced impact mooring systems) that will potentially enable seagrass recovery.

It is not known how well or how quickly these scar areas will recover in the absence of any mooring impact. In order for the effectiveness of any recovery to be determined an appropriate monitoring programme is required that is fit for purpose, statistically robust, practical and cost-effective.

The present report reviews the available literature to provide a design for a field study to investigate recovery of mooring scar areas within the subtidal area of the seagrass at Porthdinllaen. This work is required to inform understanding about the severity and longevity of the impacts by moorings on the seagrass at Porthdinllaen.

Plate 1. Seagrass at Porthdinllaen is extensive throughout the intertidal and subtidal areas and contains an abundant and diverse fish fauna. The seagrass is of particular importance as a fish nursery habitat for species such as plaice.

2. Introduction to seagrass at Porthdinllaen

In Wales, subtidal seagrass meadows (*Zostera marina*) are restricted to only a handful of locations (Skomer, Pen-Y-Chain, Criccieth, Milford Haven and Porthdinllaen). Additional subtidal *Z. marina* is also present in the inland sea between Anglesey and Holy island. The largest of the meadows is at Porthdinllaen which is located within the Pen Llŷn a'r Sarnau Special Area of Conservation (SAC) on the Llŷn Peninsula in North Wales, UK (52°56'35.30"N 4°33'58.74"W). It is a small natural harbour protected by a headland to the north, sheltering the bay from all except northerly through to northeasterly winds. As a result of this shelter the seagrass at Porthdinllaen is extensive, covering over 28 hectares [4, 6]. It is identified as being an important feature of the SAC under Regulation 35 management advice produced by Natural Resources Wales [7]. The meadow at Porthdinllaen spans the full range from the intertidal to the sub-tidal.

Seagrass meadows are a highly valued marine ecosystem that support the coastal environment by, amongst other things, filtering water, providing habitat that supports biodiversity and creating extensive nurseries for many commercially important fish species [8, 9]. The benefits that seagrass meadows provide to the human population are termed "ecosystem services". The majority of these ecosystem services can be generically applied to seagrass meadows globally, however the extent of services may in some cases vary locally and depend upon the health of the meadow and the specific seagrass plant species present. There is growing evidence that seagrass meadows in Porthdinllaen and throughout the UK do have a high level of ecosystem service provision, for example supporting high biodiversity [10], assisting with particle trapping for coastal defence [11], and providing fish nursery habitat for commercial stocks [12, 13].

3. Impacts on seagrass at Porthdinllaen

In the UK *Z. marina* is most commonly restricted to a maximum water depth of about 7 m (below chart datum) due to its requirement, as a photosynthetic organism, for high light intensity. Estimates from across its geographical range suggest that it requires between 12 and 37% of surface irradiance to survive in the long-term [14]. Anything that disrupts this availability of light has the potential to negatively impact the seagrass.

Seagrass is delicate in nature and because of this is limited to a distribution in sheltered environments where it can hold together sand and fine sediment. This delicate nature also makes it susceptible to a variety of direct and indirect impacts, in particular physical disturbance. Like any angiosperm, seagrasses require a sufficient supply of nutrients, however elevated levels can result in reduced water quality and smothering of the plants by macro and microalgae [15]. *Z.marina* generally requires sand or muddy substrate in which to grow ; to survive in anoxic muddy environments it generally dependent on a symbiotic relationship with Lucinid bivalves [16].

Physical damage and disturbance caused by permanent and annual moorings is probably the anthropogenic impact of greatest concern for the Porthdinllaen seagrass. The moorings are located across both intertidal and subtidal areas and numerous studies have documented the extensive damage that they have caused the seagrass [2-4, 17].

The tourist value of Porthdinllaen has increased rapidly over the last few decades and the bay now hosts a large number of summer visitors to the bay. Some of these visitors arrive by yachts and other water craft, with the majority using anchors to moor up. The potential for this activity to damage the seagrass has also been acknowledged in several studies [18-20].

Plate 2. Seagrass at Porthdinllaen is being damaged by a range of disturbances, particularly boat moorings.

Of additional concern to the Porthdinllaen seagrass are the impacts associated with the intertidal use of tractors and four wheel drive vehicles [6]. The above mentioned anthropogenic impacts are all taking place at the same time as the world is experiencing increasing levels of environmental change associated with climate change and ocean acidification [21]. This may be potentially reducing the resilience of the Porthdinllaen seagrass meadow to severe weather related impacts [22].

4. Impacts of fixed moorings on seagrass at Porthdinllaen

There is extensive evidence from the international peer reviewed academic literature of the damage caused by boat moorings on seagrass [19, 23-26] and this has been corroborated at a local scale at Porthdinllaen [1-5]. It can be concluded, with a very high degree of certainty, that boat moorings damage seagrass. In addition to the plants themselves, moorings may also damage the their associated fauna and may affect the important role that seagrass plays in providing ecosystem services to the coastal zone [27, 28].

Plate 3. Intertidal seagrass mooring scar at Porthdinllaen.

5. Seagrass recovery from impact

The capacity of a seagrass meadow to recover from physical disturbance is a function of its ability to rapidly grow and spread through the processes of vegetative reproduction and sexual reproduction [29]. This will depend upon the health of the meadow and its ability to apportion energy to reproduction, the supply of propagules (seeds, fragments or rhizome extension) and the likelihood of another disturbance event (natural or anthropogenic) occurring before recovery is complete. Recovery must also happen within a background of natural temporal and spatial variability present within the meadow that will influence all these factors and potentially enhance or reduce recovery.

The recovery capacity of *Z. marina* (and other species of seagrass) following disturbance and loss has been examined by a number of studies. As disturbance is a natural structuring process within seagrass meadows it is therefore not surprising to learn that recovery is sometimes readily observed, often within a period of 12-24 months [29-33].

The studies referenced in the above paragraph utilised either clearance experiments to mimic disturbance regimes or followed recolonization after loss. They found that both sexual and vegetative reproduction processes were important for recovery.

Several similar studies have also illustrated the capacity of *Z. marina* to recolonize areas of lost habitat after disturbance [34]. Although recovery is usually possible from short-term small scale disturbance, there are many instances where recovery of seagrass has been unsuccessful, particularly where meadows have been subject to severe and widespread disturbance [35]. One explanation for this is that the seagrass ecosystem may have become locked into an alternative stable state [36]. Such a change is most likely when the system is already under cumulative anthropogenic stress and doesn't have the resilience to facilitate recovery, or if the scale of the disturbance is sufficient to alter the physic-chemical environment of the meadow beyond the limits of what is suitable for the species. Recent studies on *Z. marina*, for example, illustrate how seagrass recovery can be hampered by the presence of elevated nutrients [37].

For recovery from a small-scale mooring scar to occur the seagrass habitat must be in a healthy and resilient state and the bio-physical environment on which it depend must not be altered beyond tolerated levels. For example, factors critical to recovery such as the availability of a seed bank [31] have been found in *Z. marina* to be reduced by eutrophic conditions, which are arguably commonplace in UK seagrass meadows [38].

Recovery importantly also requires that the impact that has caused the loss is removed. Studies on seagrass recovery commonly study recovery following a major disturbance, or look at recovery after an experimentally induced disturbance. In reality, disturbance created by a static boat mooring is persistent and mostly prevents recovery until the mooring has been removed (or replaced with one that doesn't cause impact).

6. Factors of specific importance to seagrass recovery at Porthdinllaen

There are no example studies in the scientific literature pertaining to the recovery of seagrass from mooring damage. Trying to understand how recovery might occur and designing an effective monitoring programme to examine any response may require consideration of other factors of importance to seagrass at Porthdinllaen.

a. Patchy seagrass

Seagrass at Porthdinllaen in many places is patchy and in the subtidal environment there are areas where density is low. Therefore the habitat surrounding a mooring will likely vary widely. As a seagrass meadow becomes increasingly patchy its capacity to recover from impact will be reduced, its biological function will be altered and it will have more potential habitat for competitors to colonise. The likelihood of a rhizome being sufficiently proximate to the scar to facilitate recovery is less likely and the meadow may also have reduced sexual reproductive output [39, 40]. Once a meadow becomes fragmented it becomes less stable – the size of the seagrass patch is of importance in its ability to resist stress. Mortality risk has been found to be patch size-dependent and losses are often confined to the smaller patches below a certain threshold size [41]. Studies on *Z. marina* dominated meadows show that increased levels of fragmentation decreased the seagrass' capacity to resist the physical impacts of storm damage [42].

The potential impacts of seagrass patchiness and density on recovery suggests that at Porthdinllaen any recovery observed will be site specific and possibly vary widely, in order to understand recovery potential a study needs to either include sufficient numbers of moorings to observe any change or select only those where seagrass density in the surrounding area is high. Alternatively a comparison of recovery between sites surrounded by high and low density may be possible.

b. Sediment changes

The continuous movement of a mooring chain dragging back and forth on the seabed over a long period, for example, has the potential to alter the sediment composition surrounding the mooring. The sediment may also become more compacted as a result of the impacts of the chains. Examination of the sediment composition of a handful of moorings at Porthdinllaen suggests that such changes do occur and that the sediment becomes increasingly dominated by coarse gravels rather than fine sediment [27]. How sediment composition changes influence the recovery capacity of seagrass remains unclear but given that the sediment is altered from what is present in the seagrass suggests that recovery will be influenced by changing sediment composition. Monitoring of the recovery of seagrass needs to incorporate at least some level of understanding of particle size and potentially sediment compaction into the assessment methodology.

c. Invasive species

In UK seas the non-native invasive algae *Sargassum muticum* has become widely distributed and is now commonly observed in and around seagrass meadows. Studies have documented that it is highly effective at colonising bare substratum within seagrass habitat, particularly areas where sediment has been lost. It is known that damage to shallow seagrass from mooring scars opens up 'pockets of opportunity' for invasive marine macrophytes [43-45] and studies from the Salcombe-Kingsbridge Estuary have illustrated how invasive algae can have follow on negative effects upon seagrass [46], potentially inhibiting seedling and new shoot establishment. In Porthdinllaen *S. muticum* is already well established and has been observed in close proximity to moorings and their associated scars [17].

Designing an assessment of recovery needs to consider the presence of *Sargassum muticum* as this has the potential to limit seagrass recovery within mooring scars.

d. Mooring variability

There exist a range of different mooring types present at Porthdinllaen. These are also at different levels of depth and exposure. It is unlikely that all new or modified moorings are the same construction and size as each other and in the same environmental conditions. This variation between moorings needs to be considered in terms of the design of any monitoring programme.

7. Previous seagrass assessments in proximity to moorings at Porthdinllaen

To date, four separate surveys of seagrass surrounding subtidal moorings have been undertaken at Porthdinllaen. Two of these have been detailed examinations of the seagrass surrounding a number of moorings [27, 47], one was a rapid assessment of the presence or absence of seagrass surrounding all moorings [5] and one was an examination of the invertebrate infauna present within sediments surrounding moorings [27]. The detailed mooring studies were of particular interest [27, 47], as they examined changes in the seagrass with increasing distance from the centre of the mooring and documented shoot density as well as the presence of any invasive species, reproductive state and the condition of the seagrass (Figure 1). The studies examining sediments provided a useful baseline as to the species composition of the sediment near and far from moorings.

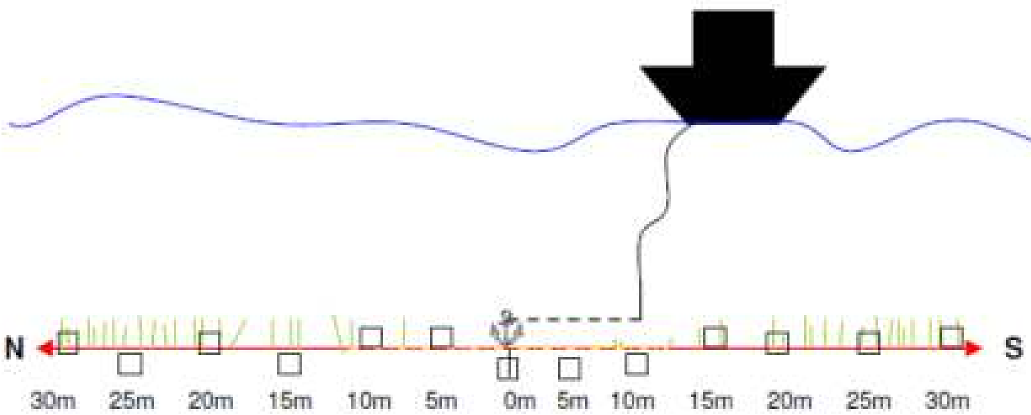

Figure 1. Design of sampling methodology used to examine the impact of fixed moorings on seagrass at Porthdinllaen [27, 47].

8. Monitoring seagrass mooring recovery at Porthdinllaen

Considerable potential exists to reduce the impacts caused by fixed boat moorings on seagrass by replacing existing moorings with alternative 'seagrass friendly' systems. In light of some of the known difficulties present with many of these 'seagrass friendly' systems it may also be appropriate to modify existing moorings to reduce seagrass impacts. For more information on potential moorings the reader is directed towards the report by Egerton 2011. If investment is to be made to reduce the impacts of fixed boat moorings on seagrass then it is essential that they are monitored into the future to determine whether or not recovery does occur and to determine whether intervention is required to stimulate recovery.

Recovery of the meadow to full health can only be considered completely successful once the seagrass is reproducing sexually and the plants have been recolonized with their associated fauna, so that there is essentially no difference in its structure or function relative to the rest of the meadow.

Although this aim for full recovery will be the long-term aim, this may not be achievable in the short-term it is possible that the meadow will not completely recover but may improve in density and function around the mooring scar. Although full recovery should be the aim, site improvement (e.g. significantly increased seagrass shoot density and reduction in site patchiness) might be considered as an initial milestone in the recovery process.

Monitoring of recovery therefore needs to consider not just the recolonization of the plants but their condition, reproductive processes, and associated fauna. As described above, other factors may also need to be considered in the design of a monitoring programme for seagrass recovery.

The review by Unsworth et al 2014 [48] describes in detail the different metrics available for monitoring seagrass meadows and their change in structure, health and function with time and space. That review examines key metrics which might be utilised for monitoring seagrass recovery and looks at how sampling strategies might be designed in order to maximise the effectiveness of the monitoring whilst also making the survey cost effective. The monitoring review [48] concludes by proposing six key monitoring actions, three of which are directly relevant to sub-tidal seagrass:

1) *An assessment of <u>sub-tidal</u> seagrass <u>extent</u> that determines seagrass presence or absence and depth repeatedly throughout the bay using GPS. Study can utilise freedivers, light weight dropdown video or a light weight hand grab.*

2) *<u>Detailed subtidal</u> SCUBA based surveys that assess seagrass status within randomly assigned quadrats radiating out from pre-determined seagrass sampling points spread in a stratified fashion throughout the whole seagrass meadow.*

3) *Assessment of <u>environmental conditions</u> using loggers (temperature and light) deployed over the long-term.*

Although the broad scale objectives of the outcomes of the monitoring review are not specific to monitoring change and seagrass recovery within mooring scars many of the specifics are relevant as are the use of appropriate low cost sampling methods (e.g. freedivers and volunteers where possible). Seagrass extent within the surrounding area of the mooring and the density and condition of the seagrass are key factors that require assessment in to assess whether recovery has occurred.

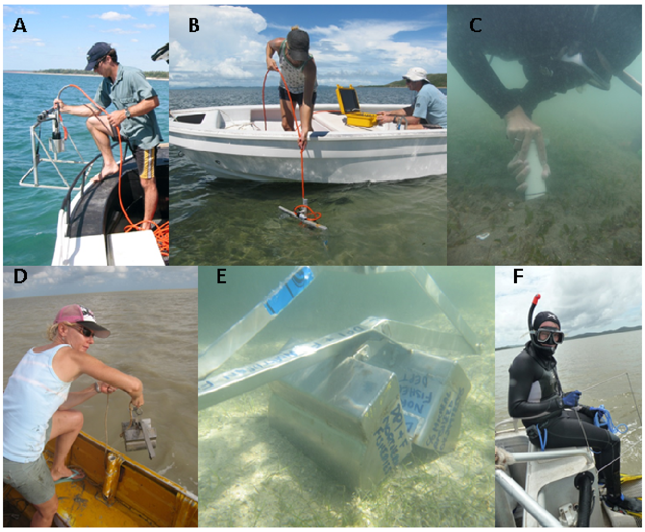

Plate 4. Techniques proposed as being suitable for seagrass sampling in Porthdinllaen: a and b) Light weight dropdown video, c) SCUBA diving, d and e) light weight grab, f) freediving. Methods a, b, d, e and f most suited to determining seagrass extent. Pictures - James Cook University Queensland.

a. Appropriate seagrass metrics for assessing recovery

In order to examine seagrass recovery within mooring scars it will be necessary to consider spatial recovery as well as metrics of density, reproduction and health. The following Table lists the proposed metrics for assessing mooring scars at Porthdinllaen.

Table 1. Seagrass metrics and sampling methods for assessing seagrass mooring recovery

	Potential metrics	Sampling method	Pros/Cons
Scar mapping	Presence-absence	Drop camera, freediver	Low resolution and accuracy but rapid and low cost
	Absolute distribution	Aerial photography or sonar (with ground trothing)	High resolution and accuracy but costly
Seagrass density	Shoot density	SCUBA diver	Allows comparison with previous data but can only be collected by SUBA divers
	% Cover	SCUBA diver, drop camera or freediver	Rapid assessments with variety of methods
Seagrass condition	Shoot morphology	SCUBA diver	Time consuming underwater so may require sample collection
	Nutrient ratios	SCUBA diver	Requires further sample analysis and some limited destructive sampling
Reproduction	Density of flower, fruits and seeds	SCUBA diver	Reproduction can be spatially highly variable
Flora and fauna	Algae % cover	SCUBA diver, drop camera or freediver	Simple data collection
	Epiphytes % cover	SCUBA diver	Simple easy metric but data highly variable
	Fish community	Baited Video	Difficult to assess small areas
	Invertebrate Infauna	SCUBA diver cores of grab samples	Requires further sample analysis
Sediment characteristics	Particle size	SCUBA diver	Requires further sample analysis

i. *Scar mapping*

Prior to any monitoring of recovery on an individual mooring scar seagrass will need to be accurately mapped to create an accurate baseline assessment of habitat coverage. This will require a high frequency of quadrat observations at a presence/absence level at increasing distances away from the central mooring. Using the broad methodology conducted for previous mooring surveys but at a high sampling frequency would be sufficient to determine the extent of the mooring scar. It is proposed that surveys be conducted along transects away from the mooring at a minimum of 8 points of the compass rose and that sampling. Observations would be taken at least every 1m, preferably every 0.5m. All observations need to be marked spatially to a high level of accuracy using GIS. Mapping of the scar then needs to be conducted using ArcGIS and an estimate of reliability established for area estimate of the scar size [49, 50]. Establishing regular area estimates of the size of the scars may be labour intensive and as a result cost effectiveness could be limited throughout the period of monitoring.

ii. *Seagrass density*

Seagrass density will need to be assessed either via shoot density counts or using calibrated assessment of % cover. Conducting shoot density counts within large quadrats (e.g. 0.25m^2) can be time consuming and often difficult, dependent upon shoot density it may be necessary to utilise smaller quadrats to obtain density assessments. The use of shoot count estimates provides better potential than % cover data to make inter-study comparisons with data collected at Porthdinllaen and at other locations in the UK. Although the collection of shoot density data limits the data collection to SCUBA surveys for subtidal meadows on balance this is a more robust approach.

The density of quadrats used in any of the studies needs to be based on a Minimal Detectable Difference assessment [51]. In addition to assessing seagrass density, measurements of canopy height or shoot length would also provide information about seagrass status.

iii. *Wasting disease*

In addition to metrics of seagrass status, metrics that provide information on key issues of concern are important to consider as this has the capacity to impact upon the health of seagrass and any potential recovery. The seagrass wasting disease caused by the slime mould *Labyrinthula zosterae* is a particular issue of concern within all UK seagrass meadows and needs to be monitored. A clear methodology for assessing wasting disease on seagrass leaves already exists [52] and has been used extensively in the UK [53]. This should be applied at Porthdinllaen.

iv. *Reproduction and other key indicators*

Reproductive effort is often patchy and of a low density, therefore sampling regime may need to be altered to assess the presence of reproductive structures. It is proposed that in every 4^{th} quadrat the presence of any reproductive structures are counted within a 1m radius of the quadrat (assuming no overlap). In addition to the presence of reproductive structures it is suggested that the presence of seedlings also be counted within the larger quadrats as this provides an indication that sexual as well as vegetative reproduction is driving recovery.

Within 1m radius areas the density of invasive species (particularly *Sargassum muticum*) should also be assessed.

v. *Flora and Fauna*

The recovery of the seagrass cannot be complete until the function of the seagrass is sufficient to facilitate colonisation by biodiverse and abundant fauna in densities the same as the existing seagrass meadow. Assessing invertebrate infauna and attached invertebrate grazing fauna requires destructive sampling (e.g. sediment cores, shoot collections) and therefore can only be justified once seagrass has recovered to a high density. Sampling of fish fauna is also problematic due to the sub-tidal nature of the moorings that couldn't be easily and discreetly assessed by conventional netting methods. Baited video cameras may provide an alternative method of assessment of fish recolonization of recovering seagrass [54] but these may not adequately provide a representative and discrete assessment of the fish fauna of small area surrounding the mooring. Sediment infauna provides the most viable means of assessing the fauna present after recovery.

b. Sampling design

To date, the majority of the surveys and assessments of seagrass in close proximity to the fixed boat moorings at Porthdinllaen have been conducted based on stratified sampling of the benthic habitat at set distances away from the central mooring in multiple directions around the compass rose [2, 17]. These surveys have been conducted using SCUBA diving volunteers. Such a strategy has allowed for an estimate of the extent of the mooring scar to be established and a gradient of decreasing seagrass density away from the central mooring point to be determined. Although useful for examining mooring impacts this may not be an appropriate method of examining recovery, as monitoring will need to be targeted in areas where recovery is expected to be observed rather than over a gradient of changing habitat.

i. *Sampling design (meadow scale)*

It may be unrealistic to monitor the recovery of every mooring at high resolution. Therefore it may be appropriate to pick a sub-sample of moorings (randomly) from those potentially undergoing recovery and focus the efforts around them. Low resolution assessments of all moorings could be conducted as a supplementary data set to any high resolution assessments. We propose that at least six moorings are assessed at high resolution. These should be as spatially spread through the meadow as is possible.

There exists poor long-term understanding of the spatial and temporal variability of the seagrass at Porthdinllaen, this include limited understanding of seasonality and inter-annual variation in density and reproduction, two key metrics for examining recovery. It is therefore critical that any monitoring of seagrass recovery in static boat moorings at Porthdinllaen incorporates multiple control sites so as to examine recovery in the context of background variability. It is proposed that at least three control sites are created; preferably a control site would be established for each mooring being assessed. The assessment at each control site would be conducted exactly the same as it is at the mooring sites.

ii. *Sampling design (individual mooring)*

Given that the majority of the impact of the mooring appears to be within the first 5m radius of seagrass around the mooring [17] we propose that area to be the focus of the monitoring effort. Dependent upon the exact extent of the impact of the mooring additional concentric rings of focus may also be required (e.g. 5-10m radius from the mooring). A circular area of 5m radius surrounding the mooring creates a large area to sample (78.5m^2), if a 0.25m^2 quadrat (50cm x 50cm) were to be used sampling 10% of the area would equate to 32 samples. Given that seagrass density would be very low (if not zero at the beginning of any recovery assessment), such a sampling density may be sufficient initially, however in order to facilitate an effective monitoring programme, the sampling intensity may need to be altered based on a minimal detectable difference analysis [51]. Recovery of the seagrass may be in a clumped distribution; therefore sampling throughout any programme may have to remain flexible in order to accurately assess such variability.

iii. Sampling repetition and duration

Recovery of seagrass within mooring scars could occur over a period of 1-3 years; however it may also never happen. Therefore monitoring of recovery will have to occur over a prolonged period. Given our limited understanding of temporal variability within the system we propose that sampling occurs throughout the seasons, at least every 6 months so as to observe high and low density states. Based on studies from other areas of Europe and our local observations of Porthdinllaen we propose that sampling occurs in both March and September, the reason for such is that September is likely the peak biomass of the meadow (after the growing season) whilst the meadow will be at lowest density in March (after the winter die back and storms).

It is not yet clear to what extent seagrass moorings will be altered or replaced at Porthdinllaen however it is unlikely to be all moorings in the faceable future. Irrespective it will be unrealistic to monitor the recovery of all moorings. We propose that at least six moorings are examined for recovery. Depend upon available resources it may be possible to monitor five in detail but make rapid assessments periodically of a larger number (e.g. using freedivers).

iv. Adaptability

The creation of any programme of mooring improvement will be dependent upon availability of funds and therefore the number of moorings trialled may actually be very low initially. This may necessitate that the associated monitoring is adaptable to this but remains sufficiently robust.

v. Analysis

In order for recovery to be fully understood it is imperative that appropriate statistical analyses are conducted to determine whether the seagrass significantly increases in density within scars and whether this becomes increasingly similar to the surrounding seagrass. Appropriate General Linear Modelling ANOVA should be used to determine with a high degree of certainty the validity of the results of individual metrics. Principal Component Analysis will enable multiple metrics to be analysed together to observe broader trends.

9. Mode of assessments

The use of SCUBA diving, Dropdown video (very light weight), and Freediving are three techniques deemed suitable for sample collection in the subtidal seagrass in and around mooring scars. SCUBA diving is the most suited to the collection of detailed seagrass metrics but is expensive and requires extensive HSE considerations. Previous mooring studies at Porthdinllaen have used SCUBA diving volunteers effectively to collect information. Such a methodology remains viable but will be ineffective if volunteer programmes using citizen scientists cannot support the work. Assessments might be more cost effective if when possible alternative low cost methods (e.g. freedivers and drop down video) are used. The use of Freediving, and Light weight drop down video all provide a rapid and simple system to determine seagrass presence and absence in geo-referenced locations and can therefore be used from a small boat to accurately assess seagrass extent.

10. Recommendations

We recommend the following methodological design for assessing seagrass recovery within mooring scars at Porthdinllaen:

- An initial rapid assessment of the size (broad estimates) of scars at all modified or new moorings sites. This would include the collection of photographic evidence.
- An initial detailed scar mapping exercise (using shoot density) of at least six modified or new moorings using SCUBA. This could involve the use of volunteer divers under the guidance of experienced scientists. This would follow existing methods used by Stamp and Morris 2012, but at a higher resolution and focus effort within the first 5m radius around the mooring where most damage appears.
- Conduct seasonal monitoring of the six mooring scars using randomly assigned quadrats placed throughout the mooring scars (based upon the initial mapping). Each new sampling time would use new random sampling spots. Sample numbers need to utilise the minimal detectable difference technique to ensure sampling is sufficient. Sampling will assess seagrass density, reproduction, morphology, algae, and condition.
- Conduct parallel seasonal assessments in control (reference) spots so that background natural variability in the seagrass can be separated from natural regrowth and recovery.
- Undertake baseline sediment infauna assessments in mooring scars relative to seagrass areas. Repeat this after seagrass has recovered to the point that it is statistically not significantly different to the surrounding meadow.
- Based on the observed recovery of seagrass in 24 months in other locations we propose that an initial monitoring programme be set up over a similar time period.
- To aid with communication of findings photographic evidence should be collected throughout the study about the status of any recovery and communicated via social media to local stakeholders.

11. Indicative schedule, tasks and costings

Table 2. Proposed sampling timetable for observing seagrass recovery at Porthdinllaen over first two years

Month	Task	Methods	Requirements	Scientist days	Volunteer days
0	Rapid scar mapping	Freediving	1 boat, team of three scientists, GPS, 2 days	6	0
0	Detailed scar mapping	SCUBA diving	1 boat, three or four pairs of divers (volunteers), two weekends, 2 lead scientists	8	32
0	Baseline infauna and sediment assessment	SCUBA diving	1 boat, one pair of divers, 1 lead scientist, 2 days	2	4
6	Seasonal monitoring	SCUBA diving	1 boat, two pairs of divers (volunteers), one weekend, 2 lead scientists	4	4
12	Seasonal monitoring	SCUBA diving	1 boat, two pairs of divers (volunteers), one weekend, 2 lead scientists	4	4
18	Seasonal monitoring	SCUBA diving	1 boat, two pairs of divers (volunteers), one weekend, 2 lead scientists	4	4
24	Seasonal monitoring	SCUBA diving	1 boat, two pairs of divers (volunteers), one weekend, 2 lead scientists	4	4
24	Infauna and sediment re-assessment	SCUBA diving	1 boat, one pair of divers, 1 lead scientist, 2 days	2	4
24	Rapid scar re-mapping	Freediving	1 boat, team of three scientists, GPS, 2 days	6	0
24	Detailed scar re-mapping	SCUBA diving	1 boat, three or four pairs of divers (volunteers), two weekends, 2 lead scientists	8	32

Table 3. Indicative costs for the proposed seagrass mooring scar sampling at Porthdinllaen. All costs are broad estimates and assume the regular availability of suitable volunteer divers.

	Year 1 Days/ samples	**Cost**	**Year 2 Days/ samples**	**Cost**	**TOTAL Cost**
Field Scientist (at £300/day)	20	6000	28	8400	14400
Volunteers (at £15/day expenses)	40	600	48	720	1320
Boat use (at £500/day)	10	5000	14	7000	12000
Sample analysis (at £30/sample)	64	1920	64	1920	3840
Report writing and data analysis (at £300/day)	10	3000	12	3600	6600
TOTALS	**144**	**16520**	**166**	**21640**	**£38160**

References

1. Stamp TEM: **Porth Dinllaen seagrass bed, Pen Llŷn a'r Sarnau SAC: a survey of moorings in the outer harbour and their impact on the seagrass 2012. A report to Gwynedd Council.** In.; 2013.
2. Morris ES, Goudge H: **Piloting the Use of Volunteer Divers in Subtidal Marine Monitoring in Wales: Preliminary Seagrass Surveys in Porth Dinllaen and Milford Haven**. *CCW Marine Monitoring Interim Report* 2008.
3. Morris ES, Hirst N, Easter J: **Summary of 2009 Seagrass Surveys in Porth Dinllaen**. *CCW Marine Monitoring Interim Report* 2009.
4. Egerton J: **Management of the seagrass bed at Porth Dinllaen. Initial investigation into the use of alternative mooring systems**. In.: Report for Gwynedd Council.; 2011.
5. Unsworth RKF, Bertelli CM: **Porthdinllaen mooring survey - April 2012**. *A report by SEACAMS for the National Trust* 2012.
6. Boyes S, Hemingway K, Allen JH: **Intertidal monitoring of *Zostera marina* in Pen Llyn a'r Sarnau SAC in 2004/2005**. In.: Countryside Council for Wales, Bangor (UK); 2008.
7. CCW: **Pen Llyn a'r Sarnau /Lleyn Peninsula and the Sarnau Special Area of Conservation. Advice provided by the Countryside Council for Wales in fulfilment of regulation 33 of the consveration (Natural habitats, &c.) Regulations 1994.** 2009.
8. Cullen-Unsworth LC, Unsworth RKF: **Seagrass Meadows, Ecosystem Services, and Sustainability**. *Environment* 2013, **55**(3):14-27.
9. Cullen-Unsworth LC, Nordlund L, Paddock J, Baker S, McKenzie LJ, Unsworth RKF: **Seagrass meadows globally as a coupled social-ecological system: implications for human wellbeing**. *Mar Poll Bull* 2014, **83**(2):387-397.
10. Bowden DA, Rowden AA, Attrill MJ: **Effect of patch size and in-patch location on the infaunal macroinvertebrate assemblages of Zostera marina seagrass beds**. *J Exp Mar Biol Ecol* 2001, **259**(2):133-154.
11. Wilkie L, O'Hare MT, Davidson I, Dudley B, Paterson DM: **Particle trapping and retention by Zostera noltii: A flume and field study**. *Aquat Bot* 2012, **102**(0):15-22.
12. Bertelli CM, Unsworth RKF: **Protecting the hand that feeds us: Seagrass (Zostera marina) serves as commercial juvenile fish habitat**. *Mar Poll Bull* 2014, **83**(2):425–429.
13. Lilley RJ, Unsworth RKF: **Atlantic Cod (Gadus morhua) benefits from the availability of seagrass (Zostera marina) nursery habitat**. *Global Ecology and Conservation* 2014, **2**(0):367-377.
14. Erftemeijer PLA, Lewis RRR: **Environmental impacts of dredging on seagrasses: A review**. *Mar Poll Bull* 2006, **52**(12):1553-1572.
15. Burkholder JM, Tomasko DA, Touchette BW: **Seagrasses and eutrophication**. *J Exp Mar Biol Ecol* 2007, **350**(1-2):46-72.
16. van der Heide T, Govers LL, de Fouw J, Olff H, van der Geest M, van Katwijk MM, Piersma T, van de Koppel J, Silliman BR, Smolders AJP *et al*: **A Three-Stage Symbiosis Forms the Foundation of Seagrass Ecosystems**. *Science* 2012, **336**(6087):1432-1434.
17. Stamp T, Morris E: **Porth Dinllaen seagrass bed, Pen Llyn a'r Sarnau SAC: a survey of moorings in the outer harbour and their impact on the seagrass 2012**. *A report by Marine EcoSol to Gwynedd Council* 2012.
18. Ceccherelli G, Campo D, Milazzo M: **Short-term response of the slow growing seagrass Posidonia oceanica to simulated anchor impact**. *Mar Env Res* 2007, **63**(4):341-349.

19. Montefalcone M, Chiantore M, Lanzone A, Morri C, Albertelli G, Bianchi CN: **BACI design reveals the decline of the seagrass Posidonia oceanica induced by anchoring**. *Mar Poll Bull* 2008, **56**(9):1637-1645.
20. Okudan ES, Demir V, Kalkan E, Karhan U: **Anchoring Damage on Seagrass Meadows (Posidonia oceanica (L.) Delile) in Fethiye-Gocek Specially Protected Area (Eastern Mediterranean Sea, Turkey)**. *Journal of Coastal Research* 2011:417-420.
21. Short FT, Neckles HA: **The effects of global climate change on seagrasses**. *Aquat Bot* 1999, **63**(3-4):169-196.
22. Waycott M, Collier C, McMahon K, Ralph PJ, McKenzie LJ, Udy JW, Grech A: **Vulnerability of seagrasses in the Great Barrier Reef to climate change - Chapter 8:** . In: *Climate Change and the Great Barrier Reef: A Vulnerability Assessment, Part II: Species and species groups.* Edited by Johnson JE, Marshall PA: Great Barrier Reef Marine Park Authority 2007: 193-236.
23. Short F, Wyllie-Echeverria S: **Natural and human-induced disturbance of seagrasses**. *Environ Conserv* 1996, **23**(1):17-27.
24. Demers MCA, Davis AR, Knott NA: **A comparison of the impact of 'seagrass-friendly' boat mooring systems on Posidonia australis**. *Mar Env Res* 2013, **83**:54-62.
25. Hastings K, Hesp P, Kendrick GA: **SEAGRASS LOSS ASSOCIATED WITH BOAT MOORINGS AT ROTTNEST-ISLAND, WESTERN-AUSTRALIA**. *Ocean & Coastal Management* 1995, **26**(3):225-246.
26. Walker DI, Lukatelich RJ, Bastyan G, McComb AJ: **EFFECT OF BOAT MOORINGS ON SEAGRASS BEDS NEAR PERTH, WESTERN-AUSTRALIA**. *Aquat Bot* 1989, **36**(1):69-77.
27. Stamp T: **Porth Dinllaen seagrass project (Pen Llŷn a'r Sarnau SAC) - Sediment Core Sampling October 2012, summary report**. *A report to Gwynedd Council* 2012.
28. McCloskey RM: **Investigating fish assemblage response patterns to temporal and habitat variation within a seagrass meadow** *MRes Thesis, Swansea University, UK* 2013.
29. Rasheed MA: **Recovery of experimentally created gaps within a tropical Zostera capricorni (Aschers.) seagrass meadow, Queensland Australia**. *J Exp Mar Biol Ecol* 1999, **235**(2):183-200.
30. Jarvis JC, Brush MJ, Moore KA: **Modeling loss and recovery of Zostera marina beds in the Chesapeake Bay: The role of seedlings and seed-bank viability**. *Aquat Bot* 2014, **113**(0):32-45.
31. Jarvis JC, Moore KA: **The role of seedlings and seed bank viability in the recovery of Chesapeake Bay, USA, Zostera marina populations following a large-scale decline**. *Hydrobiologia* 2010, **649**(1):55-68.
32. Boese BL, Kaldy JE, Clinton PJ, Eldridge PM, Folger CL: **Recolonization of intertidal Zostera marina L. (eelgrass) following experimental shoot removal**. *J Exp Mar Biol Ecol* 2009, **374**(1):69-77.
33. Unsworth RKF, McKenna SA, Rasheed MA: **Seasonal dynamics, productivity and resilience of seagrass at the Port of Abbot Point: 2008-2010. DEEDI Publication**. *Fisheries Queensland, Cairns* 2010:68.
34. Greve TM, Krause-Jensen D, Rasmussen MB, Christensen PB: **Means of rapid eelgrass (Zostera marina L.) recolonisation in former dieback areas**. *Aquat Bot* 2005, **82**(2):143-156.
35. Waycott M, Duarte CM, Carruthers TJB, Orth RJ, Dennison WC, Olyarnik S, Calladine A, Fourqurean JW, Heck KL, Hughes AR *et al*: **Accelerating loss of seagrasses across the globe threatens coastal ecosystems**. *Proceedings of the National Academy of Sciences of the United States of America* 2009, **106**(30):12377-12381.
36. McGlathery KJ, Reidenbach MA, D'Odorico P, Fagherazzi S, Pace ML, Porter JH: **Nonlinear Dynamics and Alternative Stable States in Shallow Coastal Systems**. *Oceanography* 2013, **26**(3):220-231.

37. Soissons LM, Han Q, Li B, van Katwijk MM, Ysebaert T, Herman PMJ, Bouma TJ: **Cover versus recovery: Contrasting responses of two indicators in seagrass beds**. *Mar Poll Bull* (0).
38. Jones B: **Development of a potential indicator of ecological status in the British Isles, using the seagrass, Zostera marina**. *MRes Thesis, Swansea University, UK* 2014.
39. Vermaat JE, Rollon RN, Lacap CDA, Billot C, Alberto F, Nacorda HME, Wiegman F, Terrados J: **Meadow fragmentation and reproductive output of the SE Asian seagrass Enhalus acoroides**. *J Sea Res* 2004, **52**(4):321-328.
40. Cabaco S, Santos R: **Seagrass reproductive effort as an ecological indicator of disturbance**. *Ecological Indicators* 2012, **23**:116-122.
41. Duarte C, Fourqurean J, Krause-Jensen D, Olesen B: **Dynamics of Seagrass Stability and Change**. In: *SEAGRASSES: BIOLOGY, ECOLOGYAND CONSERVATION.* Springer Netherlands; 2006: 271-294.
42. Fonseca MS, Bell SS: **Influence of physical setting on seagrass landscapes near Beaufort, North Carolina, USA**. *Mar Ecol Prog Ser* 1998, **171**:109-121.
43. Kiparissis S, Fakiris E, Papatheodorou G, Geraga M, Kornaros M, Kapareliotis A, Ferentinos G: **Illegal trawling and induced invasive algal spread as collaborative factors in a Posidonia oceanica meadow degradation**. *Biological Invasions* 2011, **13**(3):669-678.
44. Walker DI, Kendrick GA: **Threats to macroalgal diversity: Marine habitat destruction and fragmentation, pollution and introduced species**. *Bot Mar* 1998, **41**:105-112.
45. Ceccherelli G, Pinna S, Cusseddu V, Bulleri F: **The role of disturbance in promoting the spread of the invasive seaweed Caulerpa racemosa in seagrass meadows**. *Biological Invasions* 2014, **16**(12):2737-2745.
46. Deamicis SL: **The Long-term Effects of Sargassum muticum (Yendo) Fensholt Invasion on *Zostera marina* L. and its Associated Epibiota**. PhD Thesis, University of Plymouth; 2012.
47. Morris ESG, H. : **Piloting the Use of Volunteer Divers in Subtidal Marine Monitoring in Wales: Preliminary Seagrass Surveys in Porth Dinllaen and Milford Haven. CCW Marine Monitoring Interim Report.** In.; 2008.
48. Unsworth RKF, Bull JC, Bertelli CM: **Options for long-term seagrass monitoring at Porthdinllaen, Wales**. *Report produced by Swansea University on behalf of Gwynedd Council* 2014.
49. McKenzie LJ, Finkbeiner MA, Kirkman H: **Methods for mapping seagrass distribution**. In: *Global Seagrass Research Methods.* Edited by Short FT, Coles RG: Elsevier Science B.V., Amsterdam; 2001: 101-121.
50. Rasheed M, Unsworth R: **Long-term climate-associated dynamics of a tropical seagrass meadow: implications for the future**. *Marine Ecology-Progress Series* 2011, **422**:93-103.
51. Burdick DM, Kendrick GA: **Standards for seagrass collection, identification and sample design**. In: *Global Seagrass Research Methods* Edited by Short FT, Coles RG: Elsevier, Amsterdam; 2001: 82-100.
52. Burdick DM, Short FT, Wolf J: **An index to assess and monitor the progression of wasting disease in eelgrass Zostera marina**. *Marine Ecology Progres Series* 1993, **94**:83-90.
53. Bull JC, Kenyon EJ, Cook KJ: **Wasting disease regulates long-term population dynamics in a threatened seagrass**. *Oecologia* 2012, **169**(1):135-142.
54. Unsworth RKF, Peters JR, Mccloskey RM, Hinder SL: **Optimising stereo baited underwater video for sampling fish and invertebrates in temperate coastal habitats**. *Estuarine Coastal And Shelf Science* 2014, **150**:281–287.