ACA Pen Llŷn a’r Sarnau SAC

Prosiect Morwellt Porthdinllaen Seagrass Project

Arolwg angorfeydd yn yr harbwr allanol a’r effaith ar y morwellt

A survey of moorings in the outer harbour and their impact on the seagrass

2012

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CRYNODEB GWEITHREDOL

Hen bentref pysgota yw Porthdinllaen ar arfordir gogleddol Llŷn ac mae o fewn Ardal Cadwraeth Arbennig Pen Llŷn a'r Sarnau. Yno hefyd y mae'r hyn sydd wedi'i ddisgrifio fel un o'r gwlâu mwyaf a mwyaf trwchus o forwellt yng Nghymru. Fel yn y rhan fwyaf o wledydd Prydain, un rhywogaeth nodweddiadol o forwellt sydd yn y gwely ym Mhorthdinllaen, *Zostera marina*. Oherwydd budd y gwelyau morwellt i ecosystemau gyda'r glannau, y crebachu arnyn nhw yn y gorffennol oherwydd darfodedigaeth a'u prinder cymharol yng ngwledydd Prydain, diffinnir gwelyau o *Z. marina* yn y Cynllun Gweithredu Bioamrywiaeth fel cynefin â blaenoriaeth. Mae'r gwely o *Z. marina* yn harbwr Porthdinllaen hefyd yn rhan bwysig o Ardal Cadwraeth Arbennig Pen Llŷn a'r Sarnau.

Mae'r gwelyau morwellt i'w canfod yn harbwr mewnol a harbwr allanol Phorthdinllaen ac mae'n ymestyn dros ardal tuag un cilometr o hyd a hyd at 650 metr o led mewn mannau. Dangosodd gwaith blaenorol fod angorfeydd cychod yn creu patrymau rheiddiol amlwg yn y *Z. marina*. Fel rhan o reolaeth Ardal Cadwraeth Arbennig Pen Llŷn a'r Sarnau, bu Swyddog yr Ardal Cadwraeth Arbennig yn gweithio gyda'r Ymddiriedolaeth Genedlaethol, yr Awdurdodau Perthnasol[1], pysgotwyr lleol, perchnogion cychod a rhanddeiliaid eraill i ystyried y dewisiadau ar gyfer lleihau effeithiau angorfeydd ar *Z. marina* ym Mhorthdinllaen.

Fel rhan o'r prosiect yn cael ei ariannu gan Cydnerthedd ac Amrywiaeth Ecosystemau a chyda grant gan Bartneriaeth Bioamrywiaeth Cymru, gosododd y swyddog Ardal Cadwraeth Arbennig gontract fis Hydref 2012 i Marine Ecological Solutions Ltd. (Marine EcoSol) i gynnal arolygon yn yr harbwr allanol gan ddefnyddio gwirfoddolwyr o blymwyr SCUBA. Nod arolygon 2012 oedd cofnodi nifer a dyluniadau'r angorfeydd yn harbwr allanol Porthdinllaen ac asesu perthynas yr angorfeydd hynny gyda dwysedd *Z. marina*, uchder canopi cyfagos *Z. marina* a faint o'r planhigion oedd yn gwywo.

Yn 2012, roedd nifer yr angorfeydd a welwyd yn yr harbwr allanol yn cynyddu rhwng mis Mai a mis Hydref ac roedd eu dwysedd yn amrywio o fan i fan yn yr harbwr. Canfuwyd 45 o angorfeydd ac archwiliwyd 31 fel rhan o'r astudiaeth hon. Gwelwyd dau ddyluniad ar gyfer yr angorfeydd: rhai 'bloc concrid' a rhai 'dwy angor'. Ar gyfartaledd, roedd dwysedd ac uchder canopi *Z. marina* rhwng 25% a 36% yn llai rhwng 5 metr a 10 metr o'r angorfeydd dwy angor. Ni welwyd unrhyw newid yn nwysedd y morwellt 10 metr a mwy o'r angorfeydd. Oherwydd maint bychan y sampl, ac mai yma ac acw yr oedd *Z.marina* yn tyfu o gwmpas y ddwy angorfa bloc concrid a arolygwyd, ni ellir dweud i sicrwydd sut y mae dyluniad yr angorfeydd hyn yn effeithio ar y *Z.marina* o'u cwmpas.

Canfuwyd fod dwysedd ac uchder canopi *Z. marina* yn hynod amrywiol ledled yr harbwr allanol. Ychydig o dystiolaeth a welwyd fod y *Z. marina* yn gwywo ac roedd hynny a welwyd yn cael ei briodoli i brosesau naturiol yn hytrach nag i bresenoldeb haint. Roedd y canlyniadau, fodd bynnag, yn cadarnhau am y drydedd flwyddyn fod y gwely morwellt yn angorfeydd harbwr allanol Porthdinllaen yn hynod glytiog ac wedi'i ddarnio lawer iawn gan yr angorfeydd. Dangosodd trafodaethau gyda rhanddeiliaid lleol fel rhan o'r prosiect hwn fod llawer o'r angorfeydd hamdden yn cael eu tynnu bob blwyddyn ac nid o angenrheidrwydd yn cael eu gosod yn ôl yn yr un fan. Byddai hynny'n arwain at lawer iawn mwy o fannau wedi'u sgwrio ar wely'r môr nag sydd o angorfeydd a gallai hynny egluro'n rhannol pam fod y gwely'r morwellt mor glytiog.

Dangosodd y canlyniadau y gallai fod yna nifer o ffactorau'n effeithio ar wely'r morwellt ym Mhorthdinllaen. Symud yr angorfeydd bob blwyddyn (sy'n debygol o achosi natur glytiog gwely'r morwellt gan fod effeithiau sgwrio pob angorfa'n digwydd mewn lle ychydig yn wahanol bob tro y mae'n cael ei ail osod), dwysedd yr angorfeydd, effeithiau'r tonnau, dyfnder. Efallai y byddai'n well i iechyd cyffredinol gwely'r morwellt ym Mhorthdinllaen yn y dyfodol agos, yn hytrach na buddsoddi arian mewn newid dyluniadau'r angorfeydd, pe gellid lleihau natur glytiog y gwely ac arbrofi gyda rhai angorfeydd parhaol neu newid dyluniadau'r angorfeydd mewn mannau o forwellt trwchus ond i ffwrdd oddi wrth yr angorfeydd presennol yn y gwely. Mae'r argymhellion pellach sy'n cael eu trafod yn yr adroddiad yn awgrymu sut y gellid gwneud hyn.

Yr argymhellion sydd yn yr adroddiad ar gyfer gwaith yn y dyfodol yw:

1. Sefydlu cynllun monitro blynyddol i asesu maint a pha mor glytiog yw'r gwely a meintioli faint o algae chwyn wifren brown ymwthiol (*Sargassum.muticum*) sydd yno.
2. Meintioli pa mor gyflym y mae *Z. marina* yn adfer ym Mhorthdinllaen ar greithiau'r angorfeydd.
3. Yn olaf, meintioli effeithiau nifer yr angorfeydd fesul uned o arwynebedd ar gyfartaledd yn ôl dwysedd ac uchder y canopi o *Z. marina* er mwyn gallu penderfynu ble i osod yr angorfeydd ar hyn o bryd ac, efallai, rai parhaol yn y dyfodol.
4. Defnyddio plymwyr gwirfoddol mewn rhaglen fonitro sylfaenol ar *S.muticum* a *Z.marina.*

Mae'r Awdurdodau Perthnasol ar gyfer Ardal Cadwraeth Arbennig Llŷn a'r Sarnau SAC yn cynnwys Cyngor Gwynedd, Cyngor Ceredigion, Cyngor Powys, Cyfoeth Naturiol Cymru, Dŵr Cymru, Hafren Trent, Trinity house ac Awdurdod Parc Cenedlaethol Eryri.

EXECUTIVE SUMMARY

Porthdinllaen is a small historic fishing village located on the North coast of Llŷn Peninsula, North Wales, within the Pen Llŷn a'r Sarnau Special Area of Conservation (SAC). It is also the location of what has been described as one of the largest and densest seagrass beds within Wales. As with the majority of the United Kingdom the seagrass bed at Porthdinllaen is typified by one species, *Zostera marina*. Due to the benefit of *Z. marina* beds to inshore ecosystems, previous mass declines caused by a wasting disease and their relative scarcity within the UK, *Z. marina* beds are defined as Biodiversity Action Plan (BAP) priority habitat. The *Z. marina* bed within Porthdinllaen harbour also constitutes an important component of the Pen Llŷn a'r Sarnau SAC.

The seagrass beds at Porthdinllaen is present throughout the inner and outer harbour areas and spans an area of around 1km in length and up to 650m wide in places. Previous work has found that boat moorings create distinct radial scour patterns within the *Z. marina*. As part of the management of the Pen Llŷn a'r Sarnau SAC, the SAC Officer has been working with the National Trust, Relevant Authorities[2], local fishermen, boat owners and other stakeholders to look at options to reduce the impact of the moorings on *Z. marina* at Porthdinllaen.

As part of an Ecosystem Resilience and Diversity Funded project, granted from the Wales Biodiversity Partnership, in October 2012 Marine Ecological Solutions Ltd. (Marine EcoSol) was contracted by the SAC officer to conduct surveys within the outer harbour using volunteer SCUBA divers. The aims of the 2012 surveys were to record the number and designs of moorings used within Porthdinllaen outer harbour, and assess how these moorings relate to the density of *Z. marina*, adjacent *Z. marina* canopy height, and presence of wasting.

In 2012 the number of moorings observed within the outer harbour increased from May to October, and the mooring density varied across the outer harbour. A maximum of 45 moorings were encountered, 31 of which were surveyed as part of this study. Two mooring designs were identified: the "concrete block" and "two anchor" moorings. On average *Z. marina* density and canopy height were found to be 25% and 36% lower between 5 and 10m from the two anchor moorings. At greater than and equal to 10m from the moorings no observable change in seagrass density could be found. Due to a small sampling size and the patchy condition of the *Z.marina* surrounding the 2 surveyed concrete block moorings, no certain comment can be made as to how this mooring design interacts with the surrounding *Z.marina*.

Z. marina density and canopy height were found to be highly patchy and spatially variable across the outer harbour. The presence of *Z. marina* wasting was found to be relatively low and was attributed to annual natural die back rather than confirmed presence of wasting disease. The results, however, did confirm for a third survey year that the seagrass bed in Porthdinllaen outer moorings is very patchy and heavily fragmented by moorings. Discussions with local stakeholders as part of this project revealed that many recreational moorings are removed annually and are not replaced in the same place, which would result in many more patches of scoured seabed than there are moorings, and in turn may partially explain the patchy density of the bed.

Results indicated that there are several potential factors which may impacting the Porthdinllaen seagrass bed: Annual movement of moorings (likely to be resulting in patchiness of the seagrass bed as the scour effect of each mooring occurs in a slightly different location each time it is re-laid), mooring density, wave exposure, depth. It is possible that for the general health of the seagrass bed at Porthdinllaen it may be better in the immediate future that rather than investing money in changing existing mooring designs to instead aim to reduce patchiness and trial some permanent moorings or modified mooring designs in areas of dense seagrass but away from existing moorings in the bed. The further recommendations discussed within the report suggest ways in which to achieve this.

Recommendations in this report for future work are;

1. Establish an annual monitoring scheme to assess extent and patchiness of the bed, and quantify the abundance of the invasive brown macro algae wire weed (*Sargassum.muticum*).
2. To quantify the recovery rate of the *Z. marina* within Porthdinllaen in relation to the mooring scars.
3. Finally to quantify the impact of the number of moorings per unit area on the average *Z. marina* density and canopy height of the same area to inform the placement of current and potential permanent moorings of the future.
4. The use of a diving volunteer monitoring programme to achieve *S.muticum* and basic *Z.marina* monitoring.

The Relevant Authorities for the Pen Llŷn a'r Sarnau SAC include Gwynedd Council, Ceredigion Council, Powys Council, Countryside Council for Wales, Environment Agency, Welsh Water, Severn Trent, Trinity house and Snowdon National Park Authority

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INTRODUCTION

Seagrass beds are highly productive marine ecosystems that occur in shallow and sheltered locations in both temperate and tropical regions. Despite only covering approximately 0.1-0.2% of the global ocean (Duarte 2002), seagrass beds have been found to be a highly valuable ecosystem in terms of the ecosystem services they provide, worth an approximate value of 19,004 US$ ha^{-1} Yr^{-1} (approximately £12,735 ha^{-1} Yr^{-1}, Constanza *et al.* 1997). This high value is because seagrass beds are known to improve coastal defence, global carbon storage and nutrient recycling amongst other functions. Seagrass beds are presently recognised within the UK as a Biodiversity Action Plan (BAP) Priority habitat, and as such have been identified as requiring conservation action under the UK Biodiversity Action Plan (Maddock 2008). As part of the NATURA 2000 network Special Areas of Conservation (SACs) are established to assure the long term survival and enhancement of Europe's threatened species and habitats. Seagrass beds are also identified as key feature of the intertidal mudflat and sandflat habitat for which SACs can be designated. Seagrass beds are thus protected within the UK under both these legislations. Dense seagrass beds have been found within Porthdinllaen harbour, North Wales, and are an important component of the intertidal mudflat and sandflat feature of the Pen Llyn a'r Sarnau (PLAS) SAC. Previous surveys within Porthdinllaen harbour have indicated that moorings of resident vessels are having a detrimental impact upon the seagrass density in the immediate vicinity of the moorings. The PLAS SAC officer has been working with local stakeholders in an effort to minimise damage to the local seagrass beds of Porthdinllaen. The current report was commissioned by the SAC officer in order to conduct an in depth investigation into the impact of the moorings on the seagrass bed across Porthdinllaen outer harbour.

Seagrasses are colonial, photosynthetic plants that utilize a complex rooting system made of structures called rhizomes. This rooting system is used for nutrient transport, anchorage and a-sexual reproduction (Duarte 2002, Marba & Duarte 1998). Seagrasses are angiosperms (flowering plants) and as such are able to reproduce sexually. However this behaviour is uncommon in most seagrasses, except for species such as *Zostera marina* which regularly reproduce sexually (Olsen 1999). Typically seagrass colonises new areas via rhizomes spreading laterally beneath the sediment and new shoots sprouting short distances from the parent plant, but can also broadcast seeds (through sexual reproduction), in a process similar to that of some terrestrial plants (Olsen 1999). Seagrass colonisation via rhizome spread can create a rhizome matrix beneath the sediment surface. Within established beds this rhizome matrix within sediments can increase the stability of the sediments (Marba & Duarte 1998), oxygen transport and surface area for bacterial colonisation, which can potentially increase the bacterial and infaunal diversity of the sediments (Duarte 2002, Webster *et al* 1998). Furthermore the presence of the seagrass shoots above the sediments increases the topographic complexity of the relatively homogenous sand habitats that are likely to have been present prior to seagrass becoming established. This increased complexity creates cryptic spaces for small or juvenile species to seek refuge from predation (Duarte 2002), and has been cited by many authors as creating nursery grounds for a large number of commercially valuable fin and shell fish stocks (Nakamura *et al.* 2012 Beck *et al.* 2001, Heck & Thomas 1984, Young 1978). With increasing human settlement in coastal regions, human use of near shore coastal regions is likely to increase. Activities such as pleasure boating and mooring within seagrass beds have been found to cause a decline in local seagrass density, through the removal of both shoots and rhizome biomass (Uhrin *et al.* 2011, Collins *et al.* 2010), with the scale of disturbance greatly effecting the recovery time (Uhrin *et al.* 2011). It has been cited that approximately 15-50% of the total energy captured by seagrasses through photosynthesis is invested to the development of sub-sediment structures (Duarte 2002) and as such the removal of such structures is a great threat to the general health of seagrass beds and the species which rely upon them (Duarte 2002).

Z. marina, otherwise known as eel grass is 1 of 3 seagrass species that are found within the United Kingdom (*Zostera Marina, Zostera noltii & Ruppia maritima*). Overlap between each species does occur, however each species typically dominate an area creating mono-specific beds, whereas seagrass beds within tropical regions contain multiple species. The lack of competition from other subtidal seagrass species within the UK, as is the case within tropical seagrass beds (Duarte 2002), means that *Z. marina* beds are susceptible to disease outbreaks (Waycott *et al* 2009) because if it is impacted locally there is no other seagrass species to rejuvenate the bed. The worst recorded case of seagrass disease outbreaks was in the 1930's when *Z. marina* experienced a 90% population decline across its entire Atlantic distribution due to an outbreak of "wasting disease" caused by a fungal mould known as *Labyrinthula* spp., its presence typified by a blackening of the shoots (Figure 1) (Waycott *et al.* 2009). Since this outbreak there have been reports of small scale outbreaks of wasting disease within Europe and the USA (Duarte 202), however as the symptoms are similar to that of natural dieback it is difficult to identify true wasting disease *in situ* without laboratory confirmation.

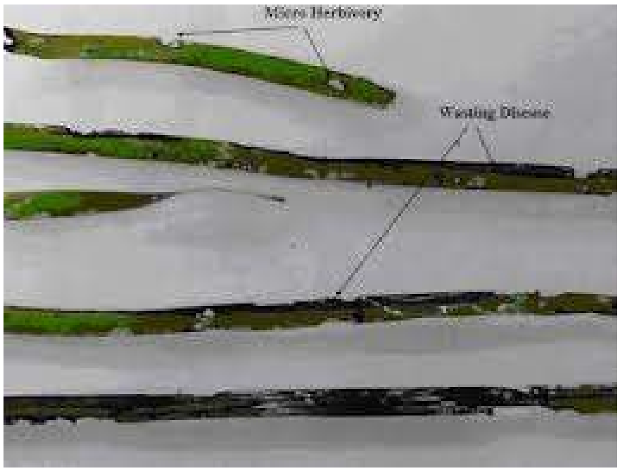


Figure 1: Image indicating the symptoms of black spot disease (*Labyrinthula sp*) within *Z. marina* shoots (taken from Boese *et al* 2008).

Porthdinllaen harbour, located on the North Coast of the Llŷn Peninsula, North Wales, is a historic fishing port that is now owned and managed by the National Trust (Egerton 2011). The area supports one of the largest and densest *Z. marina* beds within Wales (Morris *et al.* 2008, Egerton 2011). Porthdinllaen is situated within PLAS SAC, and the seagrass bed is identified as an important component of the intertidal mudflat and sandflat feature of the SAC within the Regulation 35[3] management advice (Countryside Council for Wales. 2009). The harbour is split into 2 areas, the inner and outer harbours. The inner harbour boundaries are marked by the breakwater/pier within the North of the bay (Figure 2 (1)), the rocks (Figure 2 (2)) and old slipway towards the south of the bay (Figure 2(3)). The outer harbour has no defined boundaries but no moorings are present beyond 600m from the shoreline. The inner harbour moorings are managed by the National Trust and are typically for smaller craft (approx <5m), the outer harbour is for large yachts (approx >5m), large recreational vessels and active fishing vessels of the area. The outer harbour moorings are self maintained and regulated by the boat owners (Egerton 2011). Boat activity in Porthdinllaen was traditionally dominated by the local fishing fleet, however in recent years tourism and recreational boating in the area has increased and as a result there has been a gradual increase in moorings within both the inner and outer harbour. The National Trust has currently capped the number of moorings within the inner harbour at 50, however within the outer harbour there is no such restriction (Egerton 2011). In peak season the number of visiting vessels, hence number of moorings, within the outer harbour increases (Jones *Pers Comm.* 2012, Egerton 2011). Over autumn and winter the majority of the moorings are removed for maintenance (Jones, *Pers. Comm.* 2012), reducing the number of moorings to those of the resident fishing vessels and local boat owners. The following early spring the seasonal moorings are replaced but no previous information is available to indicate whether the moorings are replaced within the same or different locations annually. As found within Studland bay (Collins *et al.* 2010), mooring scour does create distinct scarring within *Z.marina* beds. As such the annual removal and replacement of the moorings within Porthdinllaen is likely to have a great impact upon the patchiness and health of the *Z. marina* bed.

[3] Since revision of the Habitats Regulations 2010 this is now referred to as Regulation 35 advice, but the 2009 advice document is still titled 'Regulation 33'

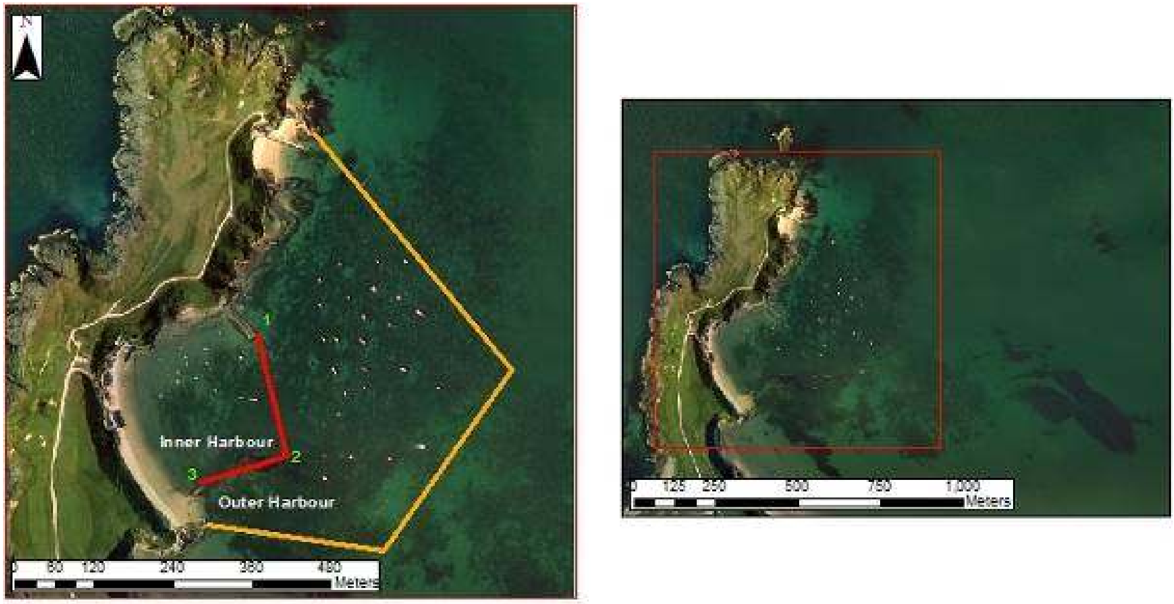


Figure 2:Aerial images indicating the area of interest and boundaries within Porthdinllaen harbour. Within and around the yellow boundary of the outer harbour dark patches in aerial images indicate the presence of Zostera marina beds. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

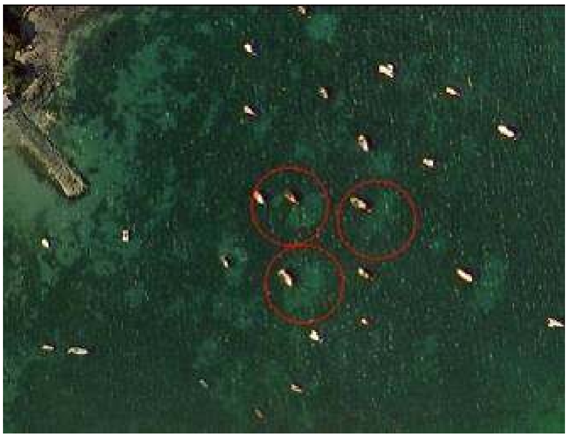


Figure 3: Image showing mooring 'scars' in Porthdinllaen outer harbour. In 2008 'scars' were found by volunteers have an average 10m radius around mooring structures (Morris *et al.* 2008). © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

Previous surveys within Porthdinllaen in 2008 and 2009 organised by the Countryside Council for Wales (CCW) investigating the extent and shoot density of the bed, indicated that *Z. marina* is present throughout the majority of the bay, with an average density of 184 shoots/ m^2. The density of *Z.marina* across the bed was also noted to be patchy with high densities of seagrass recorded within localized areas in the centre of the bed (206 shoots/m^2) and in the north of the bay (452 shoots/m^2) (Morris *et al.*2008, 2009). The surveys also identified that the moorings present within the outer harbour were having an observable impact upon *Z. marina* density; a reduction in *Z. marina* density was observed within an average 10m radius of each mooring surveyed (Figure 3) which was thought to be caused by a sweeping action of the rising chain of the mooring (Egerton 2011). A 10m radius equates to an area of 314m^2 affected per mooring. For 40 outer moorings this would lead to an area of 12,560m^2 (1.256 hectares) in the outer seagrass bed affected by the scouring effect of moorings (Morris *et al.* 2008). There are approximately 90 moorings in total at Porthdinllaen; if all the moorings are within the seagrass and the average area of impact is scaled up this would mean that approximately 28,260m^2 of seagrass at Porthdinllaen is affected by mooring scour annually (this equates to approximately 10%, of the seagrass bed[4]). An information note to local stakeholders, issued by Pen Llŷn a'r Sarnau SAC management in 2013, provided a few examples of what a 10% loss could mean for Porthdinllaen:

- "If each square meter of seagrass supports only 2 fish, this means we have lost 50,000 fish that could benefit local fisheries

[4] Estimate based on 2006 aerial photograph, underwater surveys and an estimate of mooring numbers

- The estimated value of the seagrass will be reduced by £36,422 (this refers to nutrient cycling alone)
- The number of litres of oxygen the seagrass can produce will be reduced by 286,000 litres, this is enough oxygen for 26 people a day.
- Instead of absorbing the treated effluence of 5,720 people it will be reduced to 5,148 people."

In the 2008 surveys only 5 moorings were surveyed and the 2009 surveys focused primarily on mapping the extent of the Porthdinllaen bed, not focusing on the mooring impacts. Since 2008 there has been no further research on the impact of moorings on the seagrass condition in Porthdinllaen. Further work has been identified as being required in order to build on the earlier surveys to confirm and quantify the impact of moorings on the seagrass and to investigate how best to improve mooring systems to minimise future potential impact.

In addition to the direct loss of seagrass, the mooring scars also fragment the seagrass bed so that it becomes patchy and no longer forms a continuous bed. Fragmented seagrass beds are more vulnerable to the effects of erosion and smothering/suffocation by loose sand because the surrounding sand is not being held in place by the rhizome network of the seagrass plants. This could become more of an issue with an increase in harsh weather conditions, and could lead to even greater loss of the seagrass bed. As part of the management of the PLAS SAC the SAC Officer has been working with the National Trust, Relevant Authorities[5], local fishermen, boat owners and other stakeholders to look at options to reduce the impact of moorings on *Z. marina* at Porthdinllaen. In August 2012 Marine Ecological Solutions Ltd. (Marine EcoSol) was contracted by the SAC officer to conduct surveys of the moorings within Porthdinllaen outer harbour in order to assess their designs, frequency, and how the moorings impact upon the adjacent *Z. marina*. The following report discusses the methods and results of these surveys.

Project Aims

The principal aims and objectives of the project were:

1. Survey and map the nature and extent of impact of the outer moorings at Porthdinllaen, so that this can be used to monitor future change and recovery as part of the wider Porthdinllaen seagrass project. The purpose of the work is to:

   - Establish the number and extent of moorings,
   - Confirm the presence and size of mooring scars, and
   - Confirm the degree of fragmentation of the seagrass bed due to the impact of moorings.

To address these points Marine EcoSol attempted to answer the following questions

1.a) What designs of moorings are presently deployed within Porthdinllaen outer harbour, and how many of each are present?

1.b) What is the average 'scar' size of moorings, both in terms of seagrass density and length?

A secondary aim of the project was to document the general ecology and condition of the seagrass bed, to note species of management interest that may be of conservation concern such as seahorses, *Hippocampus* spp., or species that may pose a threat to the seagrass bed, such as the invasive non-native brown alga wire weed *Sargassum muticum.*

The Relevant Authorities for the Pen Llŷn a'r Sarnau SAC include Gwynedd Council, Ceredigion Council, Powys Council, Natural Resources Wales, Environment Agency, Welsh Water, Severn Trent, Trinity house and Snowdon National Park Authority

METHODS

Prior to any survey work a meeting was held with the Porthdinllaen Project steering group which includes individuals with knowledge of the current moorings in the outer harbour. A combination of information sourced from this meeting and predetermined positions of the known moorings within the outer harbour were used to decide the strategic sampling locations of diver mooring surveys presented below.

Mooring Density

On the dates of August 26th and October 7th 2012 all the buoys within the outer harbour were mapped using a Garmin GPS60 handheld device, this included all the moorings, marker buoys for keep pots and slipways. A SEACAMS project conducted on the 17th and 19th May 2012 had also marked all the positions of all the moorings within the inner and outer harbour (Appendix 1, displayed in Figure 7). The data from the SEACAMS project was combined with that from August 26th and October 7th in order to assess whether there had been any change in the number of moorings within the outer harbour between May and October within the 2012 season. The survey area was also split into 120 50m^2 cells and the number of buoys within each grid cell was then counted. This was used to assess whether the number of moorings/buoys were evenly distributed across Porthdinllaen Harbour.

Diving Health and Safety

Using a team of volunteer SCUBA divers Marine Ecological Solutions Ltd (Marine EcoSol) coordinated 6 survey dates within Porthdinllaen outer harbour with an aim of surveying a minimum of 30 moorings. Although a volunteer dive team was used throughout sampling, all dive surveys were conducted in the spirit of an HSE approved dive operation. As such an appointed dive marshal competently trained in first aid, knowledgeable of protocols in the event of diving/non diving related injury and familiar with the Porthdinllaen seagrass monitoring project plan was present at all times (Appendix 2). Prior to surveying, all survey divers received a copy of Marine EcoSol's "Diving Rules & Standard Operating Procedures" (Goudge 2012) with the relevant volunteer diving sections highlighted. All volunteer divers and dive equipment also had to be 'in date' and deemed competent for the tasks of the survey. To participate in survey operations all volunteers had to sign a document to state that he/she had read all relevant documentation provided to them; was trained to a minimum of BSAC sports diver/ PADI Rescue Diver or CMAS 2* equivalent; had a minimum of 60 UK sea dives; was medically fit to dive; and that all dive gear used in the Porthdinllaen seagrass monitoring project was within 6 months of service. Furthermore all participants were asked to provide personnel third party liability dive insurance. In addition prior to each survey date all participants were given an onsite briefing which covered;

- Survey specific safety issues, e.g. Boat traffic
- An overview of Marine EcoSol's diving rules and a reminder that all volunteers remain within the bounds of their particular training/training body,
- Survey methods + daily allocation of diving survey teams.
- Daily schedule
- Daily risk assessment

Due to access issues and the heavy use of Porthdinllaen harbour by both recreational watercraft and commercial fishing vessels, a survey vessel was used to deploy divers at specific target locations within the outer harbour, at either moorings or control sites. The survey vessel used "RIB Waterline" of Waterline Boat Charter, a 6.5m Tornado deep-V-hulled RIB (rigid-hulled inflatable boat) skippered by Paul Turkentine. On one occasion this vessel was not available, in this instance the Bangor University Sub-aqua vessel was used, a 6m Tornado deep-V-hulled RIB, skippered by Steven Barnard. Once divers were deployed at the target locations they were instructed to follow the methodology as set out in the following section. The dive boat displaying the A-flag and with a loud hailer were always close to the divers when underwater, to warn off other vessels.

Dive Survey Equipment

Each buddy pair of divers were provided with a 0.25m x 0.25m (or 25cm x 25cm) quadrat, slate and two separate 'proforma' recording sheets (pre-printed on waterproof paper and taped to each side of their slates), and a standard 30m tape measure (Figure 4). The proforma recording sheets were: (i) The seagrass density sheet (Appendix 2), which was used to record the mooring design, *Z. marina* density, presence of wasting disease and dominant epifauna species; and (ii) The seagrass canopy height sheet (Appendix 2), which was used to record the canopy height of the *Z. marina*.

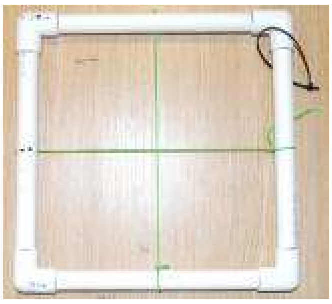
30m Tape Measure	25cm^2 Quadrat	Dive Slates
		
Standard tape measure	Split into 4 equal (12.5 cm^2) cells 24cm rule marked on the side of quadrat	Standard dive slate,

Figure 4: Survey equipment utilised by volunteer divers to assess *Z. marina* density, canopy height and the presence of wasting disease within Porthdinllaen outer harbour, 2012.

Dive Survey Methods

Positions of the moorings recorded in spring 2012 by SEACAMS were used to predetermine key moorings for dive survey and allowed survey effort to be spread equally across the outer harbour.

The daily dive team consisted of a maximum 6 participants, this was split into 3 diving buddy pairs. Diving buddy pairs were deployed on targeted moorings and control sites. The following dive survey method was used:

1) Dive buddy pairs were deployed on a predetermined mooring or control site. Divers sketched an annotated drawing of the design of the moorings and measured and noted the following features: (a) length of rising chain, (b) length of anchor chain, (c) depth. Where possible divers took photographs of the moorings.
2) A weight was placed at the base of the rising chain at the centre of the mooring/ control site (referred to from here on as the "central datum") to which a 30m tape measure was attached and deployed along a northern bearing (0°, Figure 5),
3) At 5m from the central datum divers placed 3 randomly distributed quadrats within an area 2m from the transect and 5m from the central datum (the 'sampling station'). Within each quadrat divers :
    a. Counted the number of *Zostera marina* live shoots within the quadrat,
    b. Measured the canopy height (cm) of 3 representative shoots of *Z. marina* (avoiding the shortest and longest shoots),
    c. Counted how many "quadrat cells" (Figure 4) contained seagrass which displayed signs of potential wasting disease (Figure 1). Symptoms of wasting disease are not easily distinguished from natural die back *in situ* and as such this will only give an indication of wasting within the Porthdinllaen outer harbour, natural or otherwise.
4) This was then repeated at 5 meter intervals along the transect until a distance of 30m from the central datum was reached.

5) Diving pairs then returned to the central datum reeling in the tape measure and at the same time conducting a search within an area of 2 m either side of the transect and noting the dominant epifauna species as well as the presence of species of survey interest;

a. Snake Pipefish (*Entelerus aequoreus*),
b. Slipper limpets (*Crepidula* spp),
c. Stalked Jellyfish (Stauromedusae spp),
d. Sea horses (*Hippocampus* spp)
e. Wire Weed (*Sargassum muticum*),
f. Signs of seeding and/or flowering in *Zostera marina.*

6) On returning to the central datum the divers laid down a south bearing (180°) transect to a distance of 30m and steps 2-4 were repeated on this bearing (Figure 5).

7) If there was adequate time, this process was then repeated on east (90°) and west bearings (270°),

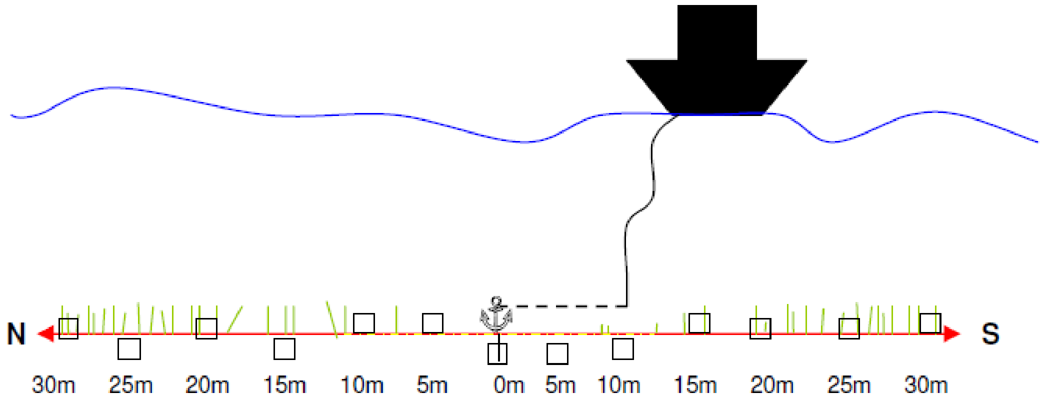


Figure 5: Illustration of proposed transect line on north and south cardinals, black arrow indicates entry point.

Control Sites

In order to compare the representative condition of *Z. marina* within Porthdinllaen 4 control sites were surveyed according to the methodology in "Dive Survey Methods".

Zostera marina density data sourced from previous surveys within the area (Morris *et al.*2008, 2009, Egerton 2011) was used to pre-determine control site locations within Porthdinllaen outer harbour. The control sites were selected on the basis that they had previously been recorded as areas of dense *Z. marina* which were located outside of the "mooring zone". The control sites were to be used to gather information on what the representative *Z. marina* canopy height, density and presence of wasting was within Porthdinllaen outer harbour away from the influence of the moorings. The data sourced from such locations was to be used as a comparison to the data sourced from the mooring surveys. The control sites were sometimes further from the outer harbour than desired, but were chosen so they were beyond the influence of the moorings.

Quality Assurance with volunteers

Marine EcoSol has many years experience of working with volunteers in the field. All volunteers were provided with training materials on the day, and laminated ID guides on survey days on the boat. An experienced co-ordinator was always on hand to ensure that any identification conundrums were answered as soon as the volunteers had the questions, and to ensure that all relevant data was recorded on the day straight after volunteer's dives.

Survey Data Treatment (Analyses)

Porthdinllaen Mooring Analyses

The number and position of the moorings within Porthdinllaen outer harbour was compared between the SEACAMS survey (17th and 19th May 2012) and those conducted by Marine EcoSol (August 26th and October 7th 2012). To compare mooring density across Porthdinllaen outer harbour, the harbour was split into a gridded matrix of 50-50m^2. The number of moorings within each gridded cell was then quantified and qualitatively described across the harbour.

The encountered mooring designs were then qualitatively described. The position of each mooring design across Porthdinllaen outer harbour was then assessed visually using GIS plots and statistically verified to assess whether there wre any relationships between mooring size and the depth or position of the moorings that were encountered.

Seagrass Surveys

All depth data sourced from the Porthdinllaen surveys were converted to depth below chart datum (BCD)

The 3 quadrats recorded at each 5m sampling station were treated as sub-samples, and the *Z. marina* canopy height, shoot density and wasting presence data from each quadrat were then treated as follows:

- Canopy height data was averaged across the sub-samples at each of the 5m sampling stations to provide a single representative figure for the average *Z. marina* canopy height (cm) at each 5m sampling station along each of the cardinal transects .
- For comparability with previous surveys density data was extrapolated from number of shoots per 0.25 m^2 to number of shoots per m^2 and averaged between the 3 sub-samples at each 5m sampling stations in order to provide a representative figure for the average number of shoots of *Z. marina* per m^2 at each 5m sampling station.
- The presence of *Z. marina* wasting within quadrat cells was averaged across the 3 sub-samples for each of the 5m sampling stations in order to provide a representative average no. of cells with plants showing *Z. marina* wasting symptoms per 0.25m^2 quadrat.

All the seagrass survey data was then displayed graphically, and with GIS plots to provide a spatial context.

RESULTS

Marine EcoSol Ltd. coordinated 6 surveys within Porthdinllaen outer harbour, detailed within Table 1. Due to bad weather conditions a total of 9 additional survey dates were organised and subsequently cancelled due to bad weather, delaying the majority of surveying until October.

The full data sets have been made available to Gwynedd Council and CCW, details of which are available in Appendix 3.

Table 1: Volunteer diving dates and teams for Porthdinllaen Seagrass project 2012, Pen Llŷn a'r Sarnau SAC

	Survey Date					
Volunteer Name	**26/08/2012**	**01/10/2012**	**04/10/2012**	**05/10/2012**	**07/10/2012 ***	**15/10/2012**
Antony Hughes					Present	
Aribella Taylor					Present	
Bernd Baufeld	Present					
Carol Horne	Present	Present				
Charles Ellis					Present	
Chris Bridge		Present	Present	Present		Present
Daniel Gill	Present	Present	Present	Present	Present	Present
David Hartley			Present			
Dylan Jones	Present					Present
Graham Cruickshank						Present
Jamie Mclean				Present	Present	
Jamie Ramday		Present	Present	Present	Present	
Jessica Lincoln						Present
Jonathon Easter	Present					
Mattias Biber		Present				
Mathew Sargent			Present			
Steven Barnard		Present	Present	Present	RIB Skipper	Present
Victoria Greenhalgh	Present	Dive Marshal				

Diving on all dates was carried out from RIB Waterline, except * which utilised the BUSAC RIB

31 moorings and 4 control sites were surveyed, with a total of 106 x 30m survey transects completed (Figure 6); a table with details of the location of the sites surveyed is provided in Appendix 1. The number of survey transects at each mooring and control site was variable; as per the diving methodology volunteer divers were instructed to survey the north and south transects first and, if time permitted, the east and west. Appendix 1 lists the surveyed transects on each mooring. Control site 288 (Figure 6) was found to be unsuitable for seagrass, instead a rocky reef habitat and no *Z. marina* shoots was recorded. Control site 288 was thus discounted as a valid control and subsequent references to control sites only refer to the data from control sites 279, 320 and 321.

Figure 6: Mooring locations (red dots) and control sites within Porthdinllaen outer harbour that were surveyed in August and October 2012 for the Porthdinllaen Seagrass Project. Red label for control site 288 highlights this as a discounted control site (see text for detail). The blue lines indicate the cardinal transects that were completed for each mooring. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

Moorings within Porthdinllaen Outer Harbour

Buoy Frequency

The SEACAMS survey found a total of 41 moorings within the inner harbour and 20 within the outer harbour. As the focus of the later Marine EcoSol survey was within the outer harbour, the number of moorings within the inner harbour were not counted in later surveys. Between the SEACAMS and the Marine EcoSol surveys the maximum number of moorings within the outer harbour had increased to 45, and was then found to decrease again to 41 on a later date (01/10/2012) (Figure 7). This showed that in the period between 19th May - 26-August 2012 the number of moorings within the outer harbour had increased by 25 additional moorings, a 125% increase. In addition during the Marine EcoSol surveys a number of small buoys, not large enough to be a vessel mooring labelled as Keep Pots within Figures 9 & 10, were also found scattered throughout the outer harbour, these were also counted. The number of keep pots was lowest (22 counted) on the earlier survey date (26/08/2012) and highest (34 counted) on the later date (01/10/2012). On the survey notes for the 26/08/2012 it was recorded that there was a large, dense area of keep pots within the north of the harbour that the survey vessel could not access (marked within Figure 9 as "unmapped area") and, as a result, the number of keep pots within this unmapped area was not counted; because of this the number of keep pots within the outer harbour on 26/08/2012 was higher than that displayed within Figure 7. Based on the spatial distribution of the marked keep pots it was also found their position differed between the dates 26/08/2012-01/10/2012.

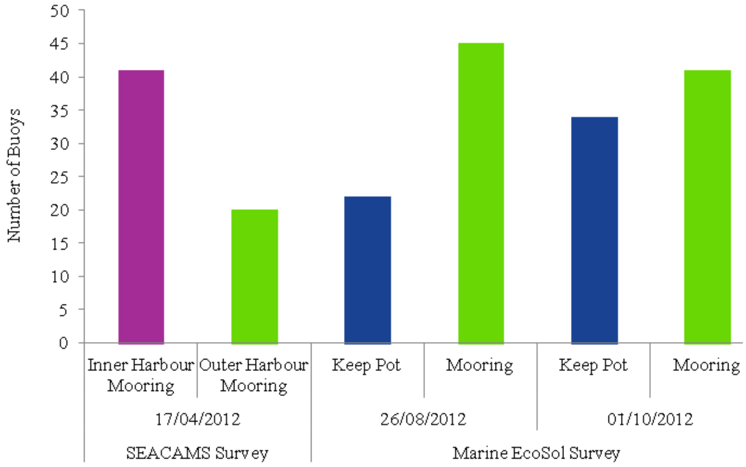


Figure 7: The number of mooring, and keep pot buoys counted within both SEACAMS survey and Marine ECOSOL survey with Porthdinllaen Harbour from May - October 2012

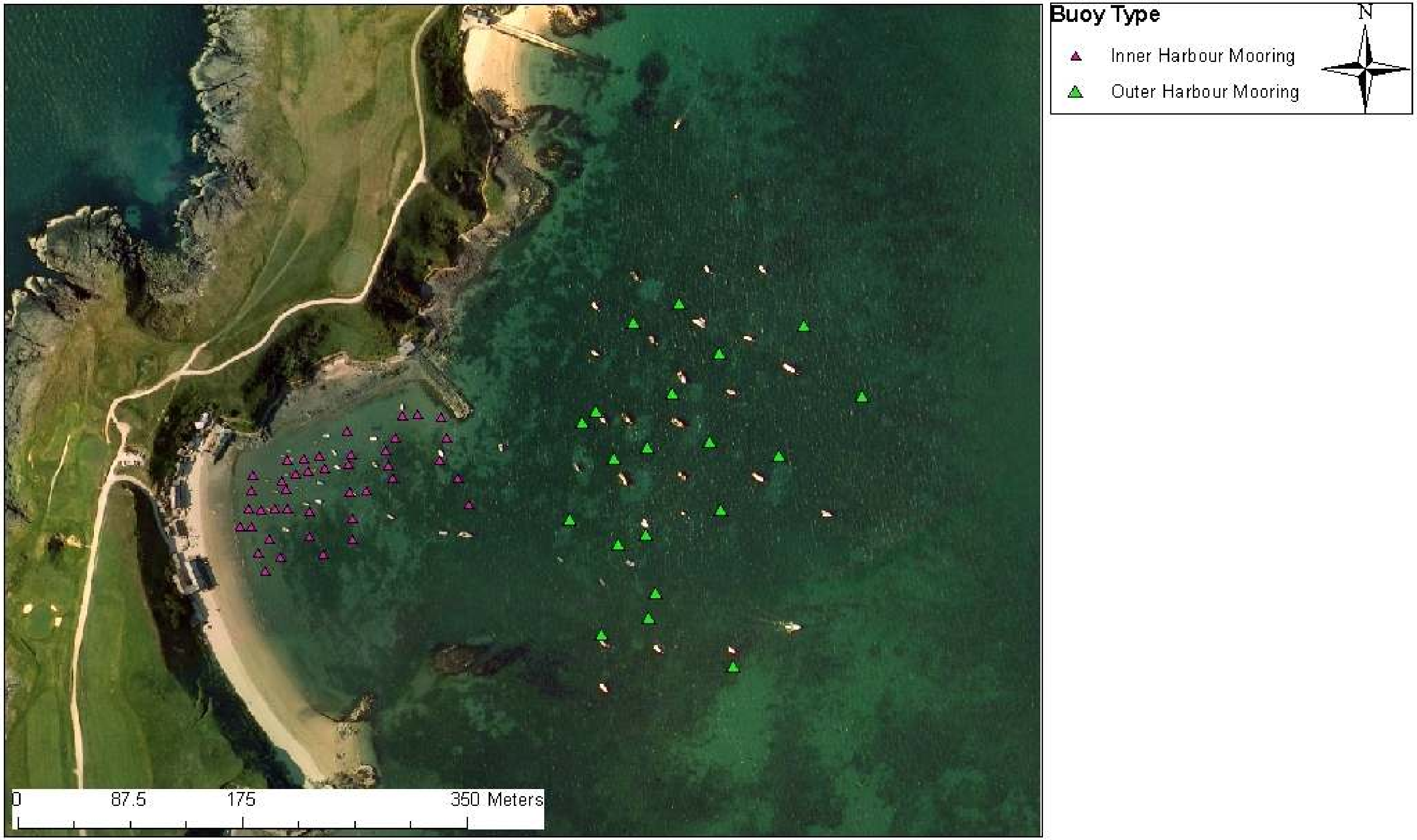


Figure 8: Moorings encountered within Porthdinllaen inner and outer harbour by SEACAMS survey (17th & 19th May 2012). Purple triangles depict moorings within the inner harbour and larger green triangles indicate moorings within the outer harbour. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

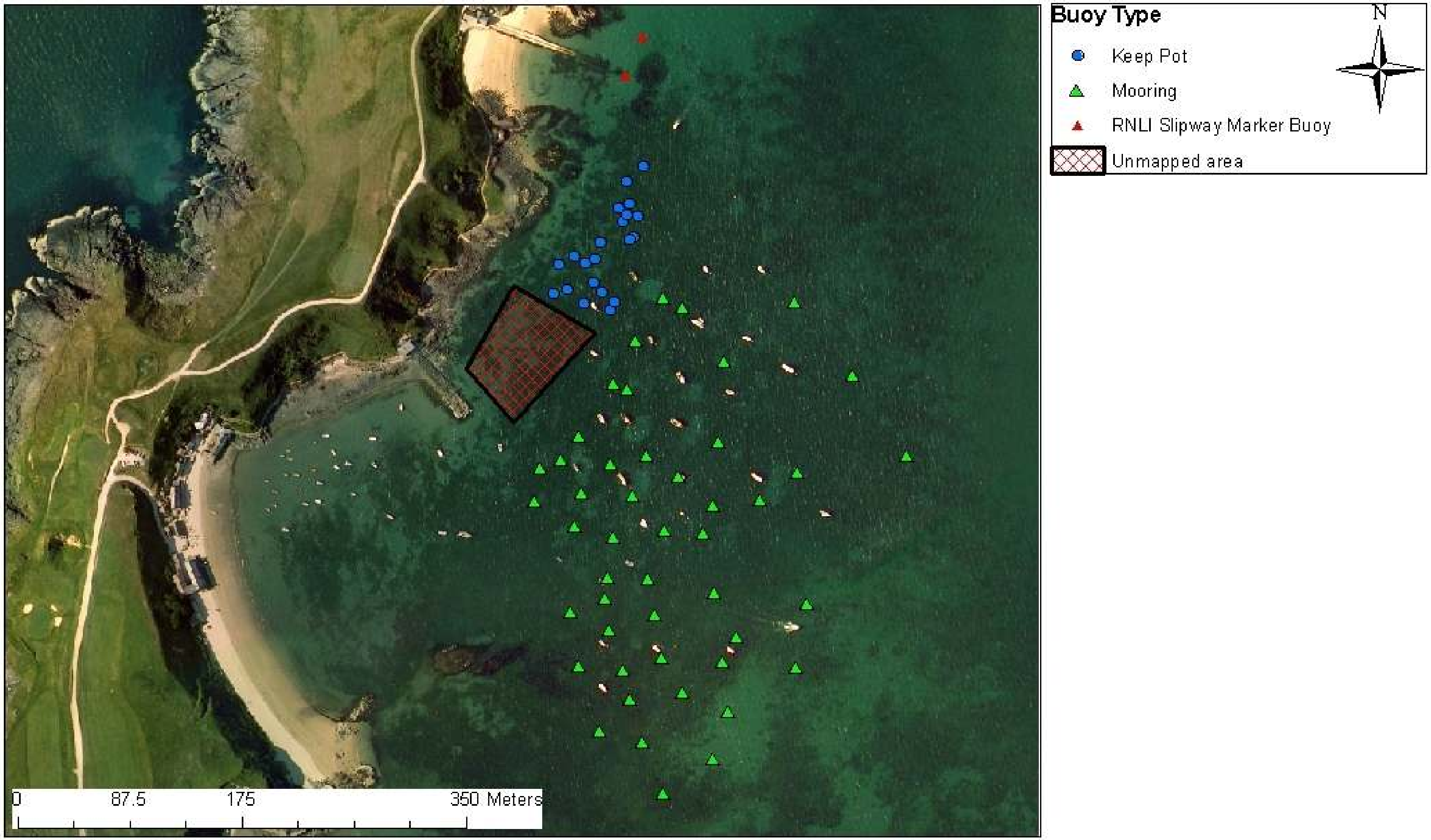


Figure 9: Moorings and keep pots recorded within Porthdinllaen outer harbour by Marine EcoSol survey 26th August 2012. Light green triangles depict moorings within the outer harbour, light blue circles potential keep pots, small red triangles RNLI slipway marker buoys. The area with Red hashing was an area with dense keep pot buoys that survey vessel could not access, so keep pots were not counted within this area. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

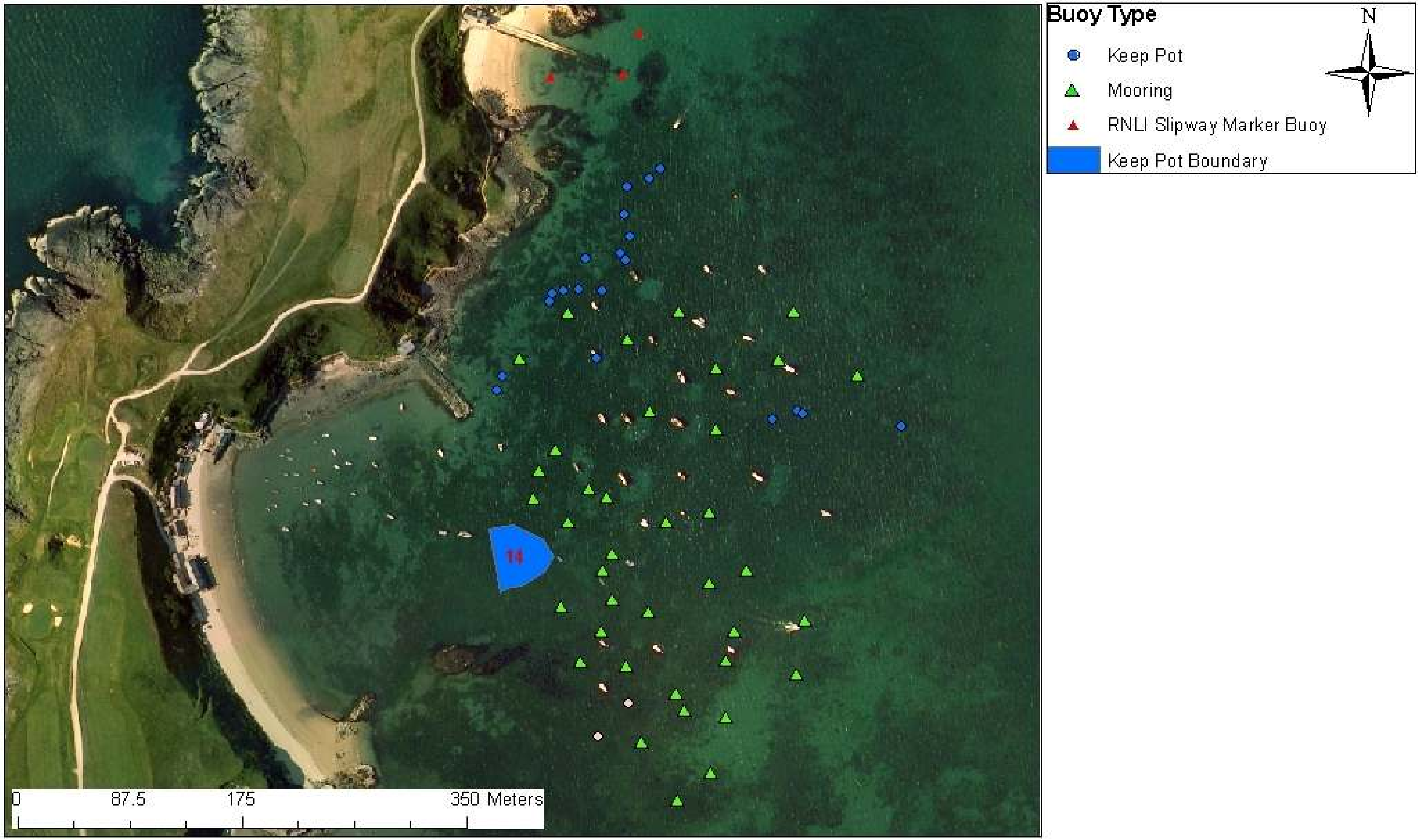


Figure 10: Moorings and keep pots recorded within Porthdinllaen outer harbour by Marine EcoSol survey 7th October 2012. Green triangles depict moorings within the outer harbour, light blue cuircles keep pots, red triangles RNLI slipwaymarker buoys. The blue area within the east of the harbour is an area of 14 densly packed keep pots © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

Buoy Density

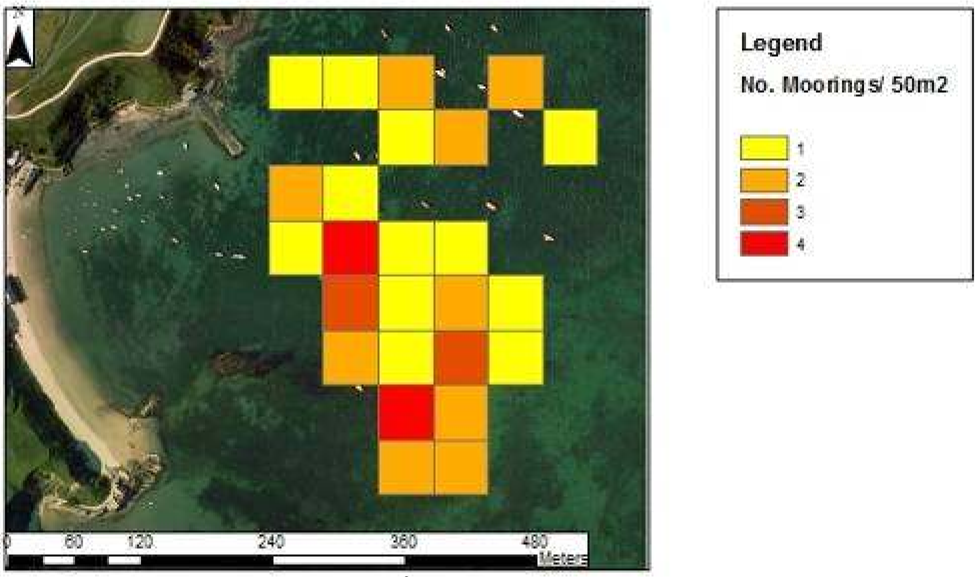


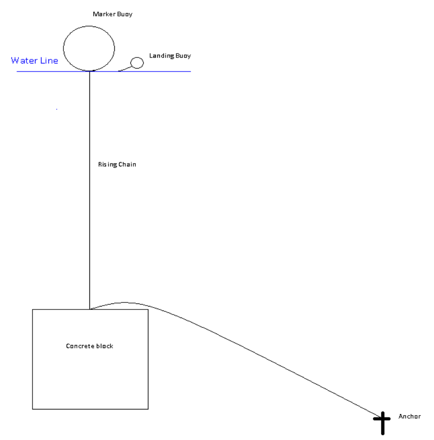
Figure 11: Mooring density (number of moorings / 50m^2) within Porthdinllaen Outer Harbour. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

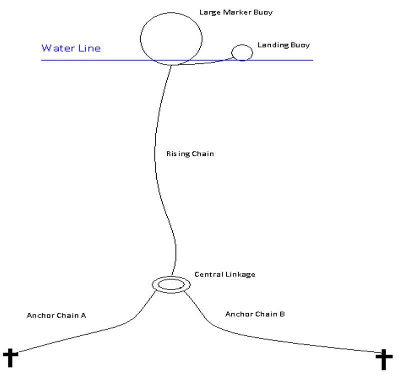
Using the mooring count data from 26/08/2012, the survey where the highest number of moorings was recorded, the mooring density was not found to be even across the outer harbour. The majority of the harbour had a mooring density of between 1-2 moorings per 50m^2. However within the south west of the outer harbour mooring density was found to be higher at 3-4 moorings per 50m^2. Due to the ephemeral movements of the keep pot buoys, as shown within Figure 9 & 10, they were not included within the data presented in Figure 11.

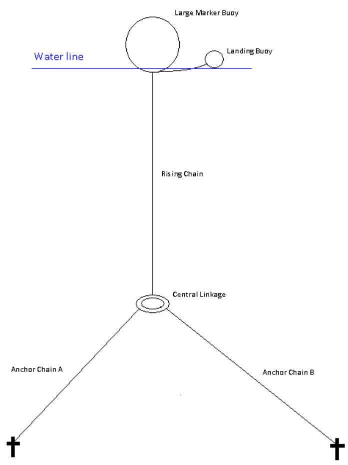
Mooring Designs and Distribution within Porthdinllaen Outer Harbour

Discussions with a local fisherman indicated that there may be a combination of three mooring designs deployed within Porthdinllaen outer harbour, For the purpose of this report they were given the following designations: 1) Concrete block mooring, 2) Two-Anchor mooring, 3) Three-anchor mooring. Details of their design is in Table 2.

Table 2: A list of suspected mooring designs used within Porthdinllaen outer harbour.

<table>
<tr><td rowspan="2">Concrete Block Mooring</td><td colspan="2">A large concrete block at the base of a rising chain. At the connection point between the rising chain and concrete block a long, thicker/heavier anchor chain is attached. The anchor chain lead to an anchor embedded within the sediment. At the top of the rising chain a larger marker and smaller landing buoy were attached.</td></tr>
<tr><td colspan="2">


</td></tr>
<tr><td rowspan="2">Two Anchor Mooring</td><td colspan="2">2 large anchors separated by approximately 25m. Each anchor is attached to 2 independent thick/heavy anchor chains which are linked at a central large linkage. At this linkage a lighter rising chain is attached. At the top of this rising chain a large marker buoy is always attached. A smaller landing buoy is attached at the base of the marker buoy by a length of rope approximately 1m long. This mooring design is laid with slack in the anchor chains. This slack allows the mooring to absorb tidal energy within periods of harsh weather conditions or extreme tides (refer to images below)</td></tr>
<tr><td>Low water/normal tidal or weather conditions


</td><td>Extreme tidal/weather conditions


</td></tr>
<tr><td>Three Anchor Mooring</td><td colspan="2">Three anchor moorings had a design similar to that of the two anchor moorings with an additional anchor chain attached at the central linkage.</td></tr>
</table>

A total of 31 moorings in the outer harbour were surveyed as part of the current project. Two of these were identified as the concrete block design and 29 were identified as the two anchor mooring design, no three anchor moorings were encountered during surveys. Refer to Figure 12 for the spatial distribution of the mooring designs observed at Porthdinllaen.

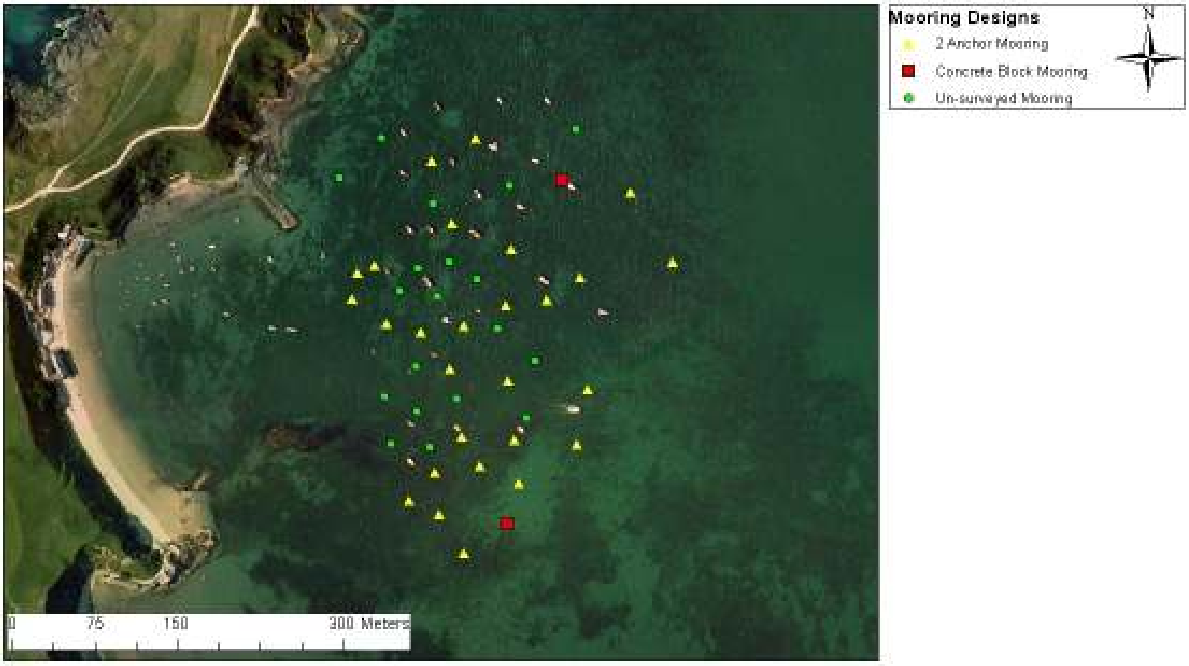


Figure 12: An aerial image of Porthdinllaen outer harbour which displays the spatial distribution of the concrete block and two anchor mooring designs as noted by divers during surveys in 2012. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

Two-Anchor Designs

Table 3: Table showing the range and average values for mooring depth together with the range and average values for the length of anchor chains, rising chains and total chain length of all two-anchor moorings observed by divers within Porthdinllaen outer harbour during surveys in August and October 2012 for the Porthdinllaen Seagrass project.

Depth at which moorings were encountered. (m BCD)		Anchor chain A length (m)		Anchor Chain B, Length (m)		Rising Chain Length (m)		Total Chain Length (Anchor chains A+B & Rising Chain) (m)	
Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
0.27 – 4.37	1.75	4 – 20.5	9.20	4.6 - 20.7	13.74	9 – 22.5	14.7	24.5 - 54	37.7

The 29 two-anchor moorings were widely distributed throughout the outer harbour in depths between 0.27m-4.37m BCD, and were found to have a wide range of rising and anchor chain lengths (Table 3). Details of the depth and mooring chain data for each mooring surveyed is provided in the full data set that has been made available to Gwynedd Council and CCW – see Appendix 3. A regression analysis was undertaken to see if there was any relationship between the length of the mooring chains and depth of water. No relationship could be found between the lengths of either the rising or anchor chains alone to the water depth at which the moorings were deployed. However, a positive relationship was found when the total chain length (i.e. Rising chain length + Anchor chain length A + Anchor chain length B) of each mooring was calculated and plotted against the depth in which the

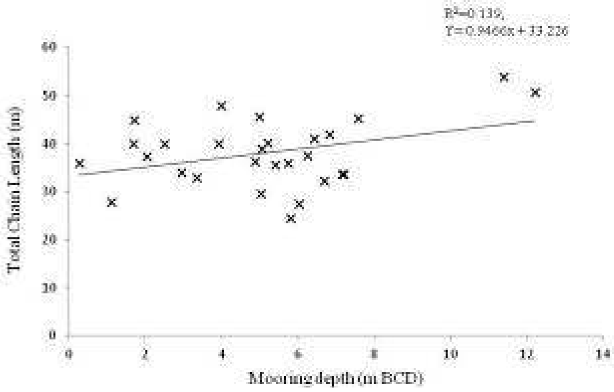


Figure 13: Increasing total chain length (TCL) of two anchor moorings with increasing water depth. Regression analysis of total chain length of surveyed two anchor moorings and depth BCD of moorings (ANOVA,df=1,27,F=4.202,P=0.051).

mooring was encountered i.e. moorings in deeper water have a greater total chain length (Figure 13). The fact that the strength of this relationship was weak however, may indicate that the overall size of the moorings in terms of total chain length is related to the depth in which it is deployed, but the individual lengths of the rising or anchor chains are not.

Concrete Block Mooring Design

Based on qualitative evidence a similar relationship was observed with the concrete-block mooring designs, to that of the two-anchor mooring design. Due to the fact that only 2 concrete block mooring was encountered no statistical verification could of the chain length to dept could be conducted. Mooring 271, the larger of the 2 concrete block moorings was located in 4.41m BCD where as mooring 362 was at a shallower depth, at 3.78 m BCD (Table 4).

Table 4: Mooring depth together with a the rising, anchor and total chain lengths of all surveyed concrete block moorings designs observed by divers within Porthdinllaen outer harbour for the Porthdinllaen Seagrass project 2012.

Mooring ID	Depth (m BCD)	Rising Chain Length (m)	Anchor Chain Length (m)	Total Chain Length (m)
271	4.41	6.2	12	18.2
362	3.78	6	6	12

Seagrass Data

Table 5: Average data for *Z. marina* shoot density, canopy height and wasting presence for sample stations away from suspected influence of moorings within Porthdinllaen outer harbour for 2008, 2009 and 2012 surveys. As per the methodology within Morris *et al.*, 2009, all *Z.marina* shoot density data from the 2012 surveys excludes those from the sampling stations within 10m of a mooring (because of the influence the mooring within this zone). 2008 was sourced from Morris *et al.* 2008.The raw data for all the sampling points for each mooring is provided in Appendix 3.

Site	Year	Location (where n = number of 5m survey stations)	Density (no. Live shoots/m^2)		Canopy Height ($cm/0.25m^2$)		Wasting presence (no. cell/$0.25m^2$ quadrat)		Depth (m BCD)	
			Max	Ave	Max	Ave	Max	Ave	Max	Ave
Porthdinllaen (subtidal)	2012	Porthdinllaen (n = 507) *all data including control sites*	464	115	92	27.5	3.66	0.93	4.57	1.7
		North Outer Harbour (n = 234)	426	127.64	74.6	15.7	3.58	1.31	4.57	2.3
		South Outer Harbour (n = 252)	464	83	92.2	19.3	3.66	1.28	2.14	1.45
	2009	Porthdinllaen *from various locations across the bay, excluding any moorings* (n = 145)	503	115	n/a	n/a	n/a	n/a	6.25	n/a
	2008	Porthdinllaen *measurements >10m from central moorings* (n = 109)	452	184 (outside area of moorings) 107 (inside moorings excl, <10m from moorings)	n/a	n/a	n/a	n/a	5.6	n/a

In 2012 the average *Z. marina* density recorded during the surveys within Porthdinllaen outer harbour was the same as that recorded in 2009, but lower than the density recorded in 2008 (Table 5). The maximum *Z. marina* density was of a similar order of magnitude across the three years. Canopy height of the *Z. marina* and presence of wasting were not recorded in 2008 or 2009 and therefore cannot be compared between the 3 years.

If the outer harbour is divided into northern and southern parts as show in Figure 14, the 2012 data indicates some differences in the characteristics of the *Z. marina* in the two sections. The average density of *Z.marina* was found to 55% times greater than that in the south of the harbour. In contrast, the average seagrass canopy height was found to be 18.65% greater within the southern part of the outer harbour than in the north. *Z. marina* wasting did not appear to differ dramatically between the north and the south of the harbour.

Figure 14: Distinction between the north and south of Porthdinllaen outer harbour. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

Control Sites

When volunteer divers surveyed control site 288, it was discovered the site was a rocky reef and no seagrass shoots were found on any of the surveyed cardinal transects. Due to the lack of suitable habitat and the lack of seagrass at control site 288, this was discounted as a valid control site and from here on reference to the data from control sites only refers to control sites 279, 320 & 321. The values for *Z.marina* density, canopy height and wasting presence were distinctly different at each of these 3 remaining control sites. Due to this difference the sites were not directly comparable to each other and did not serve as a good comparison to the data from the *Z.marina* growth within the moorings.

Control site 279, within the north of the bay (Figure 14), was found to have the highest *Z.marina* growth (227.56 shoots per m^2), whilst the lowest was recorded within control site 321 (118.22 shoots per m^2). The average canopy height was highest within control site 320 (31.66 cm) and the smallest was found at control site 321 (16.13 cm). Control site 321 was the deepest of the control sites (2.92m BCD), the shallowest was control site 320 (1.17m BCD). When looking at Figure 14 (summarised in Table 6) a pattern is observed where the deepest control site has both the lowest seagrass density and canopy height, but due to the limited number of control sites no statistical tests were undertaken as part of this report to examine this trend.

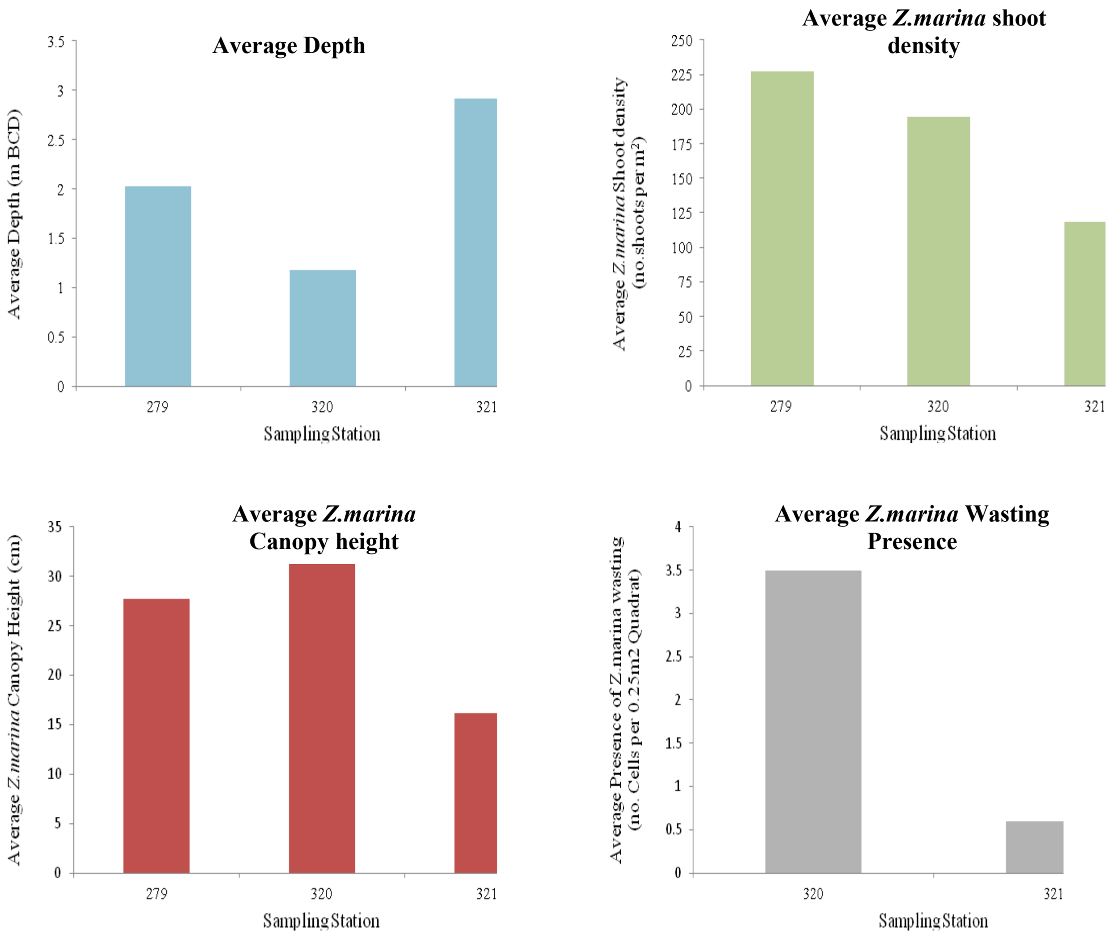


Figure 15: Average depth, *Z.marina* density, canopy height and wating presence within three control sites at Porthdinllaen Outer Harbour.

Table 6: Average depth, *Z.marina* density, canopy height and wating presence within three control sites at Porthdinllaen Outer Harbour.

Control Site ID	Average Depth (m BCD)	Average *Z.marina* density (no. of shoots per m²)	Average *Z.marina* Canopy Height (cm)	Average *Z.marina* wasting presence (no. of cells per 0.25m²)
279	2.03	227.56	27.72	N/A
320	1.17	194.67	31.66	3.5
321	2.92	118.22	16.13	0.59

Concrete Block Mooring Design Impacts on Adjacent Z. marina.

As only two concrete block moorings were surveyed (moorings 271 and 362) it is difficult to identify any particular trends in possible impacts of these moorings on adjacent *Z. marina*. Both moorings were surveyed on north, south and east bearings, but neither were sampled on a west transect.

The overall *Z. marina* density and canopy height was found to be greater around mooring 271 (the deeper mooring) than that of mooring 362. Mooring 271 had an overall average *Z. marina* density of 100.7 shoots/m^2 and canopy height of 24.13 cm/0.25m^2, whilst mooring 362 had an overall average density of 54.2shoots/m ^{2} and average canopy height of 19.8cm/0.25m^2, presented in Figures 16-19. South of mooring 271 there was a clear pattern of increasing *Z. marina* density (Figure 16) and canopy height (Figure 17) up to 20m from the central datum. At distances greater than 20m the seagrass density and canopy height decreased. On all other transects from both mooring 271 and 362 *Z. marina* density and canopy height were found highly variable and there was no obvious pattern between distance from the moorings and *Z. marina* density or canopy height.

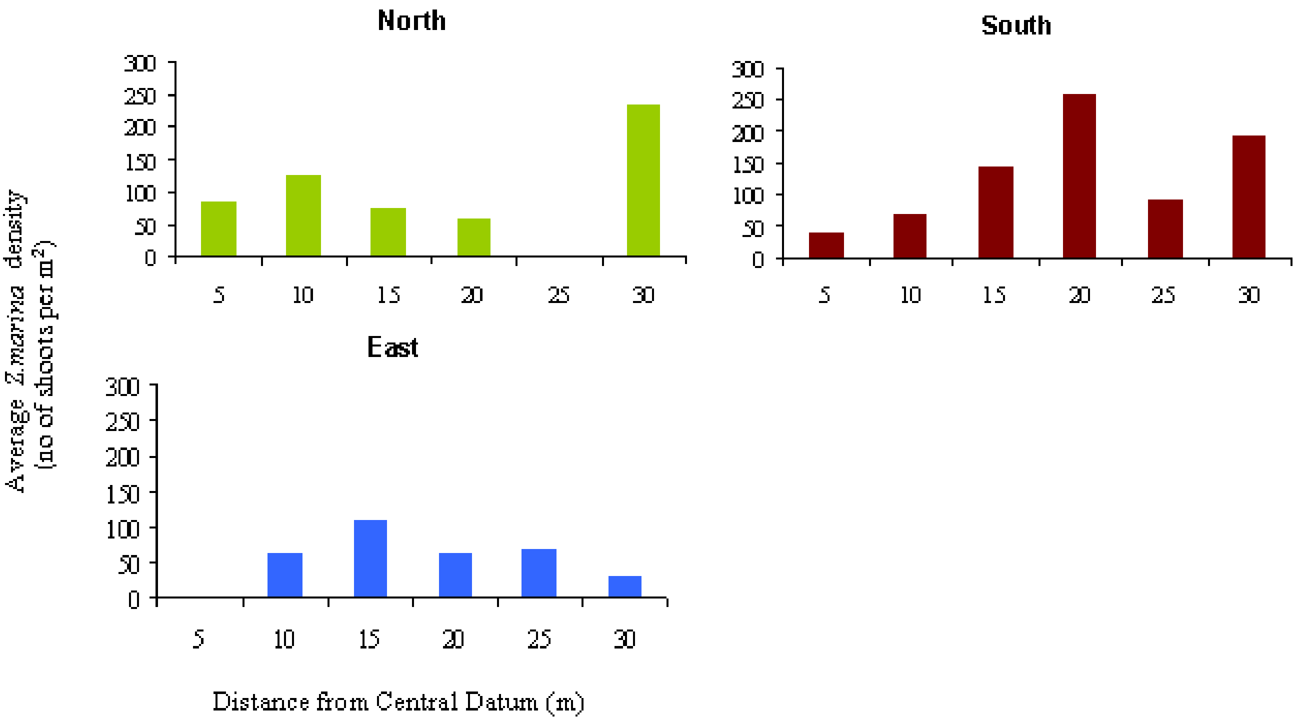


Figure 16: Average *Z. marina* shoot density with distance away from the central datum of concrete block mooring 271 within Porthdinllaen outer harbour.

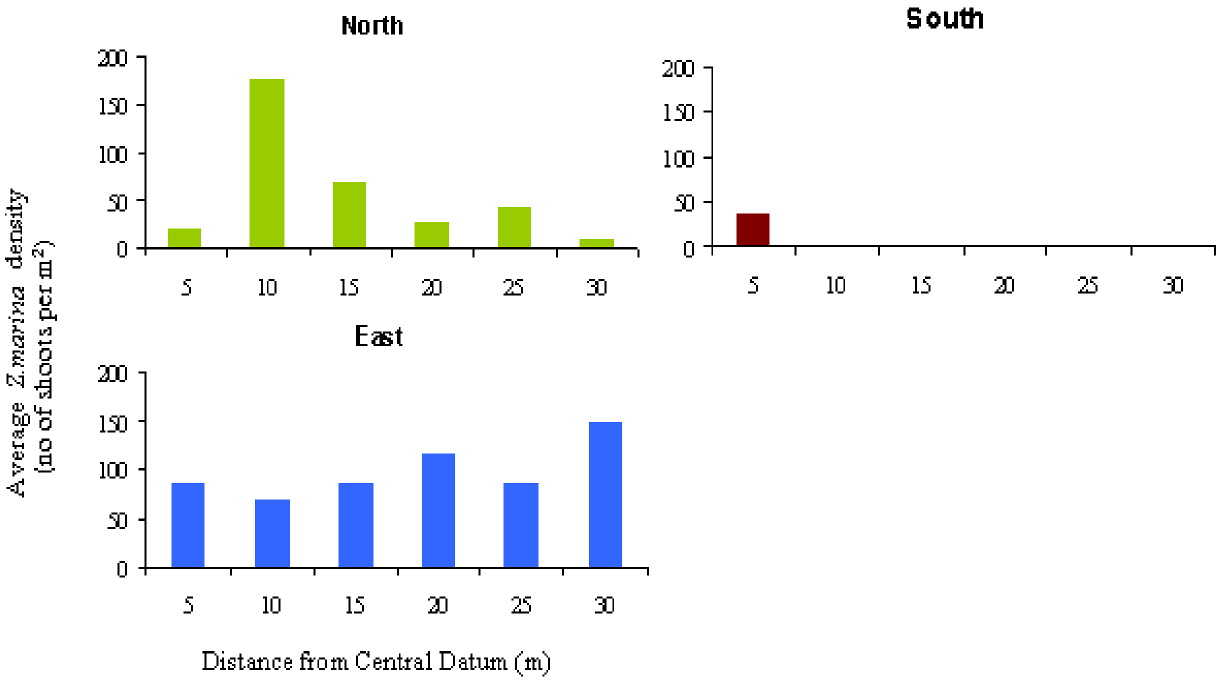


Figure 17: Average *Z. marina* shoot density with distance away from the central datum of concrete block mooring 362 within Porthdinllaen outer harbour.

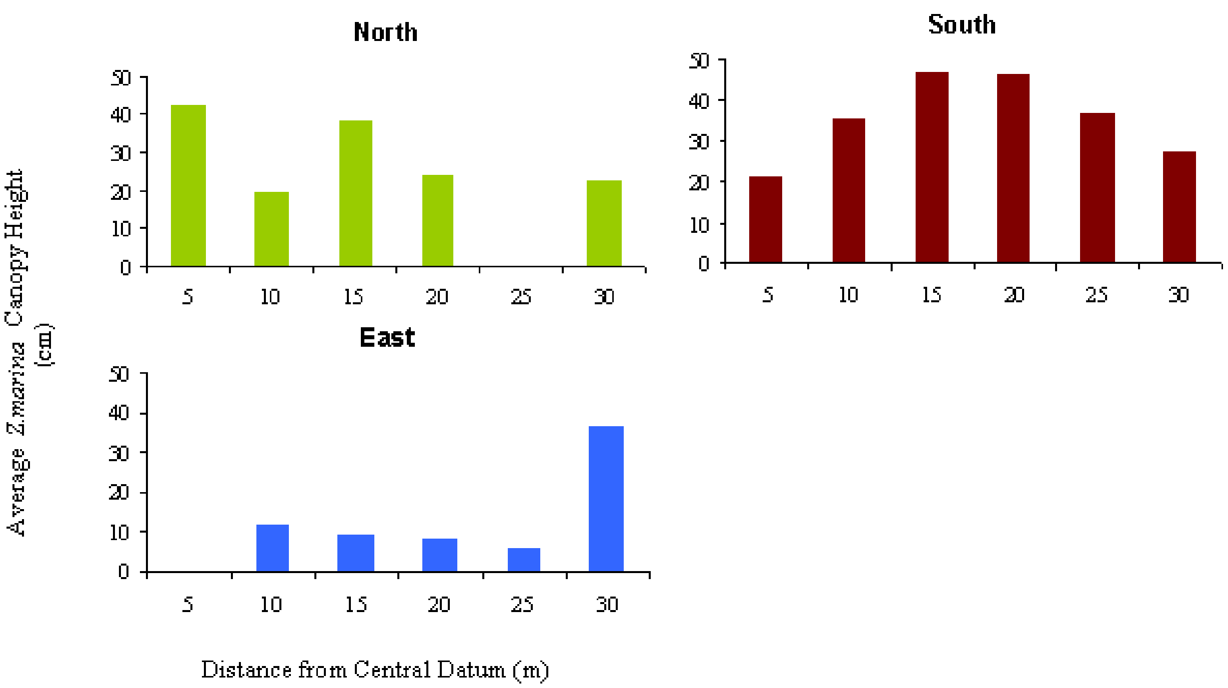


Figure 18: Average *Z. marina* canopy height with distance away from the central datum of concrete block mooring 271 within Porthdinllaen outer harbour

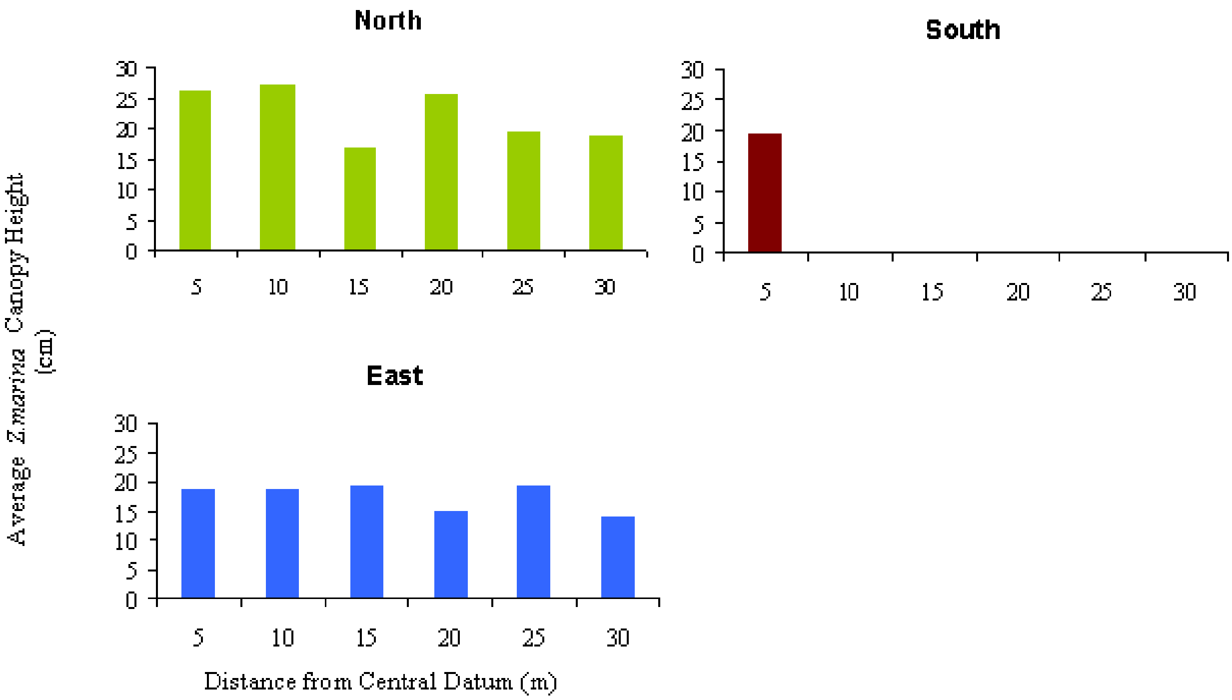


Figure 19: Average *Z. marina* canopy height with distance away from the central datum of concrete block mooring 362 within Porthdinllaen outer harbour.

Evidence of *Z. marina* wasting was only encountered at three sampling stations surrounding moorings 271 and 362 (Table 7), The highest average number of cells wasting was recorded within was 1.3 cells/0.25m^2 quadrat, south of mooring 271 (where the presence of wasting was averaged across the two sub-samples at each sampling station). The low presence of wasting symptoms surrounding mooring 271 and 362 would appear to indicate that these moorings had little impact upon the degree of *Z. marina* wasting, however due to the low sampling effort little comment can be made about the overall effect the concrete block mooring design have on *Z. marina* wasting.

Table 7: The average presence of wasting symptoms on *Z. marina* shoots surrounding concrete block mooring 271 and 362 at 5m distances from the central datum of each mooring. The data represents the average number of cells per quadrat (of a maximum of four) across three sub-samples at each 5m sampling station.

Mooring ID	Transect	Distance from Central Datum (m)					
		5	10	15	20	25	30
271	North	0.333333	0	0	0	0	0
271	South	0	0	0	1.333333	0	0
271	East	0	0	0	0	0	0
362	North	0	0	0	0	0	0
362	South	0	0	0	0	0	0
362	East	0	0	0	0	0	0.333333

Two-Anchored Mooring Design Impacts on adjacent Z. marina.

Of the 29 two-anchor moorings that were surveyed in August and October 2012, the north transect was surveyed on all 29 moorings, whilst the south transect was surveyed on 27 moorings, the east transect on 17 and the west transect on 15.

The average *Z marina* shoot density for the sampling stations along each cardinal transect are shown in Figure 20. A pattern of increasing *Z.marina* shoot density with increasing distance from the mooring can be seen for the north transect (an increasing density up to 20m from the mooring), the south and east transects (an increasing density up to 15m from the mooring). Across all north, south and east transects there is 25% difference in the average *Z marina* density between sampling stations 5m and 10m from the central datum. 30m from the central datum on the north and south transects there was a decline in the average density of *Z.marina* which may reflect the close proximity to other moorings and mooring 'scars'. The data for the west transects shows no clear pattern with increasing distance from the mooring; this may be due to the comparatively low sampling effort or may reflect the pattern of scour around the moorings which has less influence in a westerly direction, possibly due to the net overall combined influence of water flow, wind and wave action in Porthdinllaen outer harbour.

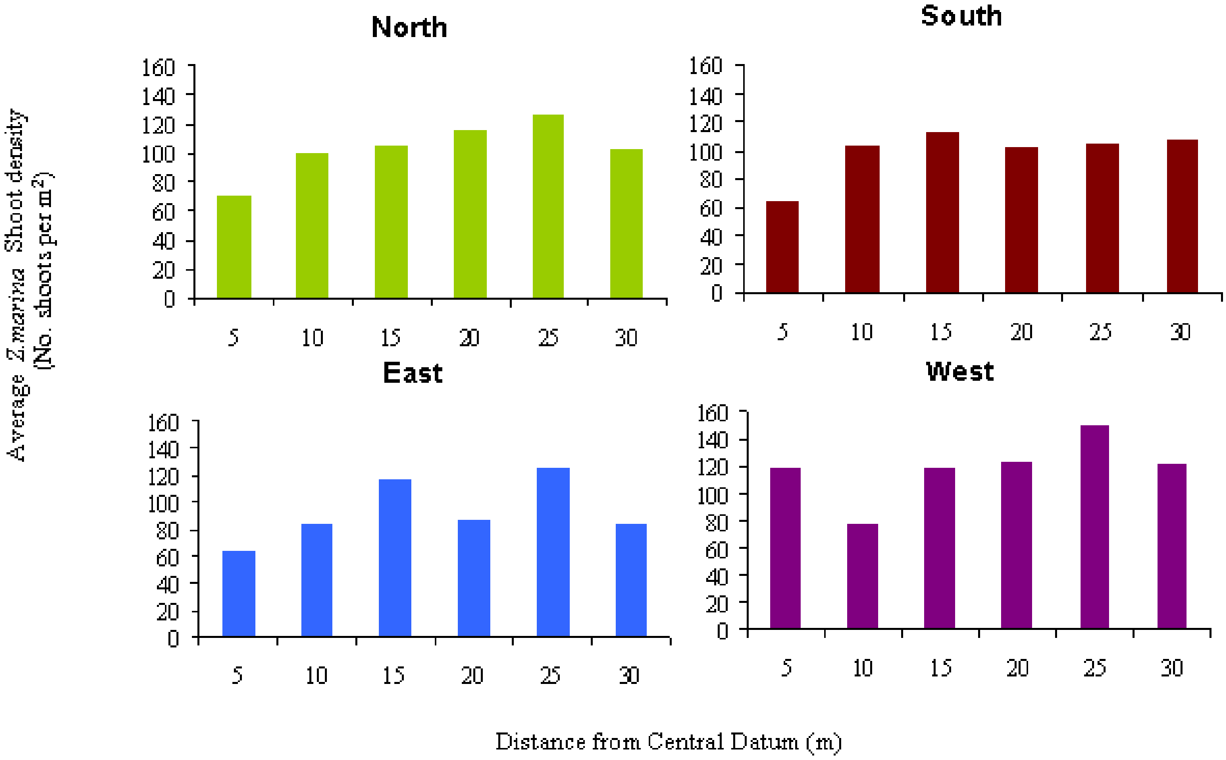


Figure 20: Average *Z. marina* shoot density with distance away from the central datum of surveyed two-anchor moorings within Porthdinllaen outer harbour.

The average *Z marina* canopy height for the sampling stations along each cardinal transect are shown in Figure 21. A pattern of increasing canopy height with increasing distance from the mooring can be seen for the north transect (an increasing canopy height up to 20m from the mooring), the south transect (an increasing canopy height up to 15m from the mooring) and east transect (an increasing canopy height up to 10m from the mooring, although the canopy height at subsequent sampling stations is variable). For the north, south and east transects there is a 36% difference in the canopy height between the 5m and 10m sampling stations. For these three transects there was a decline in the average canopy height at 30m from the central datum which, as with the shoot density, may reflect the close proximity to other moorings and mooring 'scars'. Along the western transects there does not appear to be any particular pattern in average canopy height related to distance from the mooring, although the data indicates increasing values from 10-30m distance from the mooring.

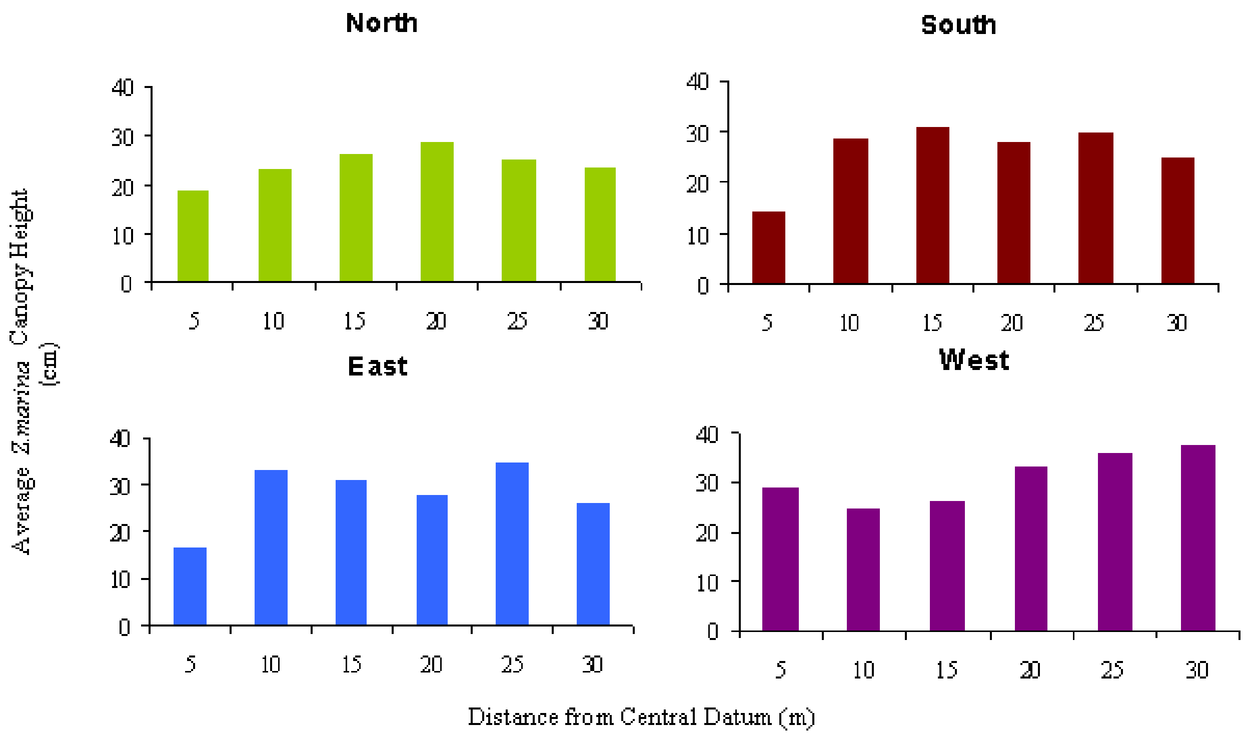


Figure 21: Average *Z. marina* canopy height with distance away from the central datum of surveyed two-anchor moorings within Porthdinllaen outer harbour.

Z. marina wasting was encountered on average within ≤1 cell/0.25m^2 quadrat for every survey transect on the two-anchor moorings. As such the presence of wasting was relatively homogenous across all the survey transects and no pattern was observed between the occurrence and prevalence of *Z.marina* wasting and distance from the mooring (Table 8).

Table 8: Average *Z. marina* wasting (no. cells/ 0.25m^2 quadrat) with distance from the two-anchor moorings within Porthdinllaen outer harbour.

	Distance from Central Datum (m)					
Transect	5	10	15	20	25	30
North	0.597701	0.712644	0.758621	1	0.678161	0.678161
South	0.481481	0.851852	0.901235	0.790123	1.049383	0.91358
East	0.764706	1	1.137255	0.882353	1.176471	0.980392
West	1.022222	0.547619	1	0.880952	1.128205	1.025641

Mapping Porthdinllaen Seagrass Data

The *Z. marina* density within Porthdinllaen outer harbour is patchy, with numerous sampling stations recording low density in close proximity to those with relatively dense *Z.marina* growth (see Figure 22). The data indicates that in 2012 the densest of the *Z.marina* growth appears to be localized to areas within the western part of the outer harbour, or those areas that were sheltered by the headland to the north of the harbour. The data indicate patchy and decreased growth with an increase in distance from the shore. As already noted above the data from sampling stations within the south of Porthdinllaen outer harbour appear to have lower average density to those within the north (see Figure 14 and accompanying text).

A similar pattern is observed in the *Z.marina* canopy height (Figure 23) and wasting presence (Figure 24). Areas within the western part of the outer harbour were found to have an increased average canopy height and wasting presence. Similarly with increasing distance from the shore *Z.marina* canopy height and wasting presence decreased. The increase in *Z.marina* canopy height and wasting presence may simply be factor of increased *Z.marina* density however this could not be verified within the current report.

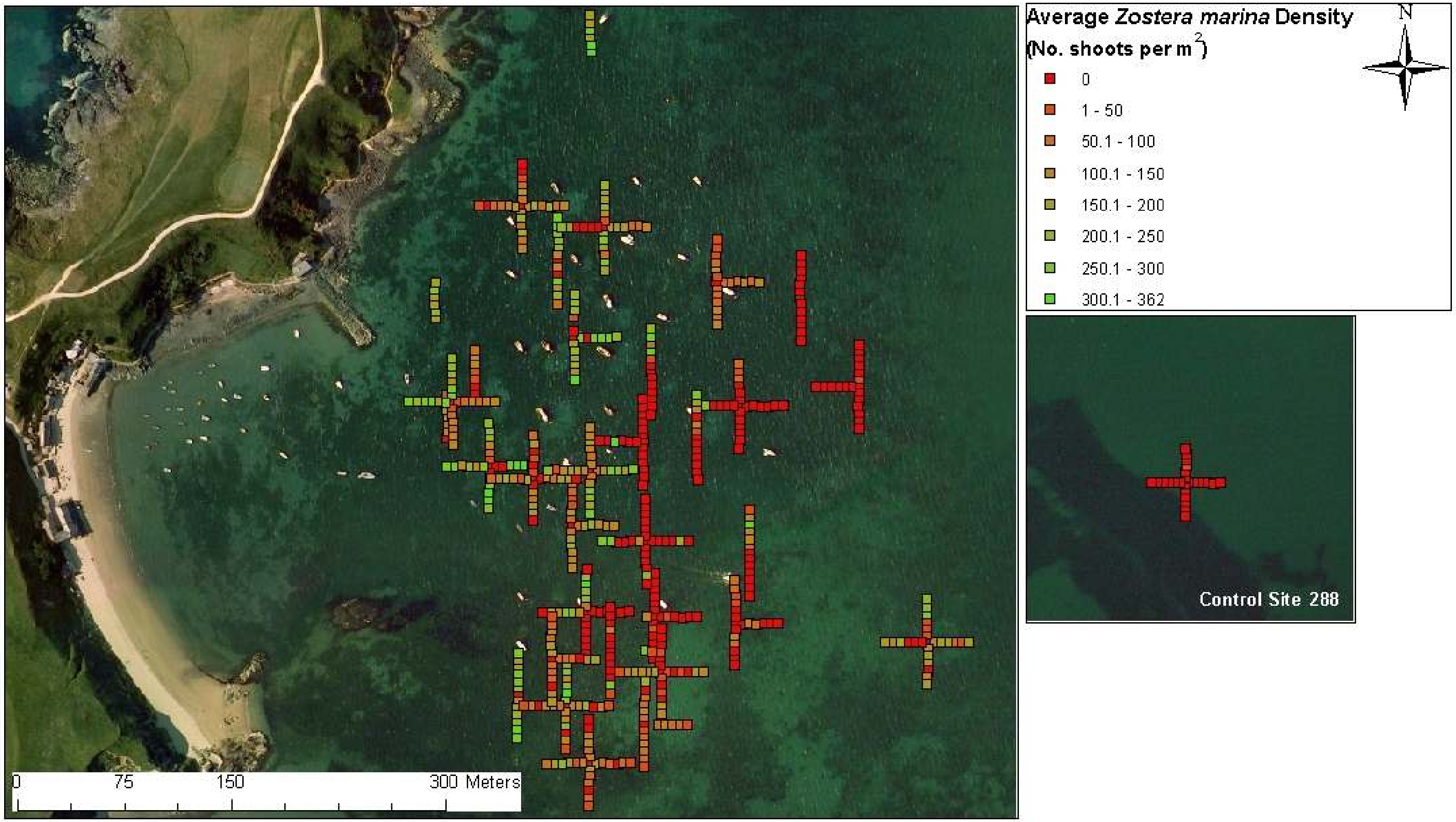


Figure 22: Average *Z.marina* shoot density (number of shoots per m^2) at each sampling station surveyed within the Porthdinllaen Seagrass monitoring project 2012. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

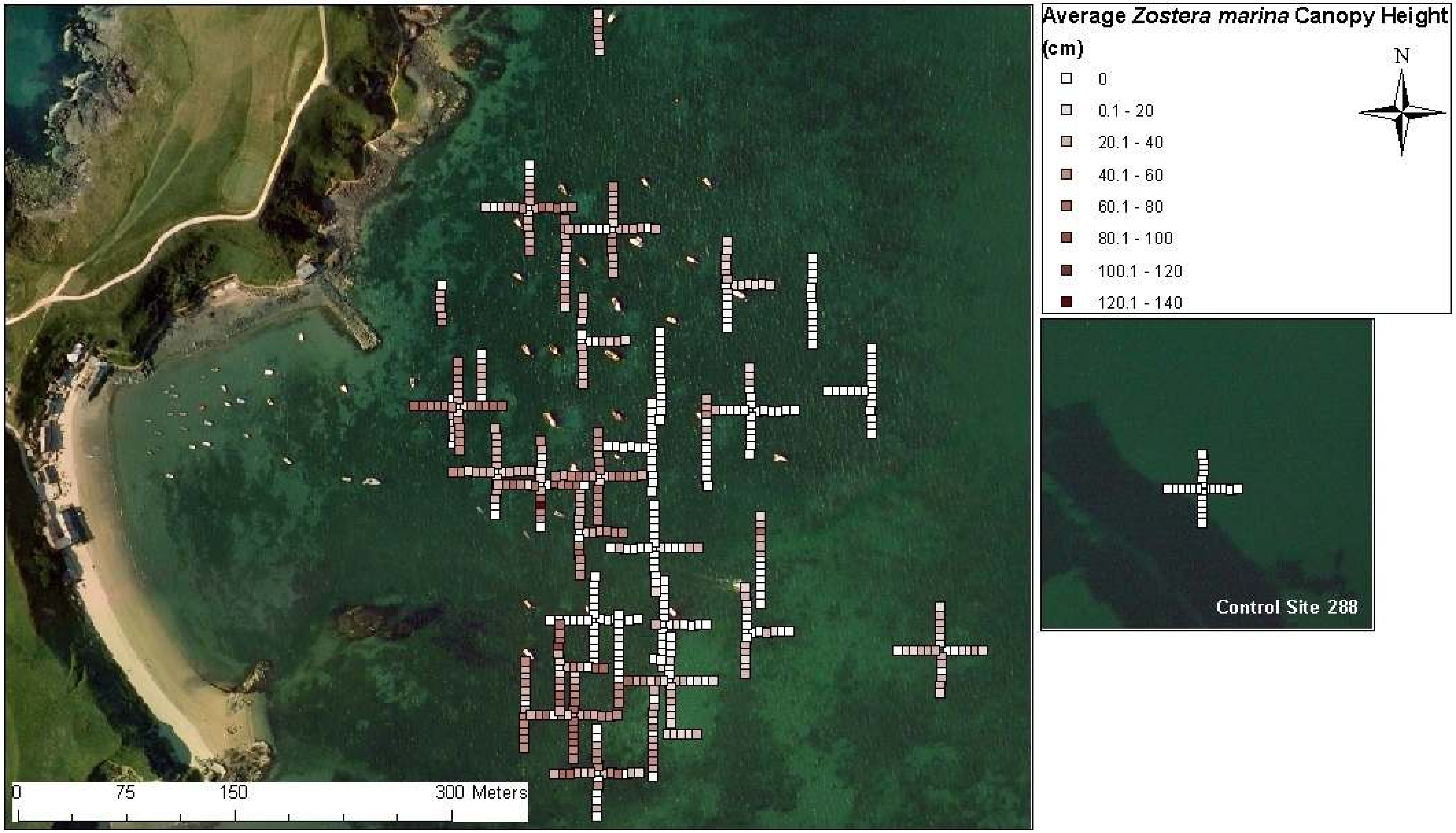


Figure 23: Average *Z.marina* canopy height (cm) at each sampling station surveyed within the Porthdinllaen Seagrass monitoring project 2012. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

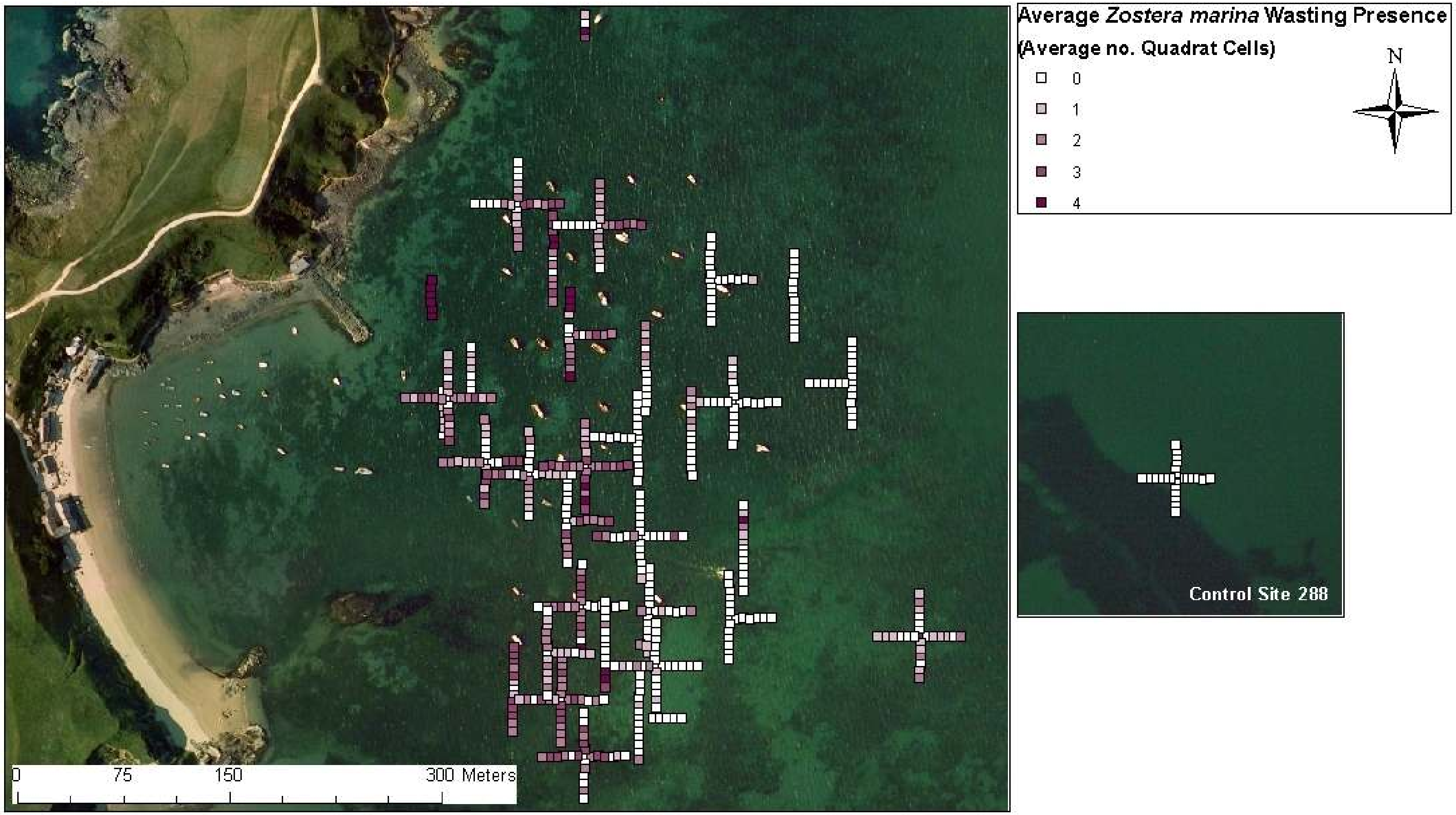


Figure 24: Average *Z.marina* wasting presence (number of quadrat cells that have signs of wasting disease/0.25m^2 quadratt) at each sampling station surveyed within the Porthdinllaen Seagrass monitoring project 2012. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

Other Notable Epifauna and Species of Conservation Interest

Divers recorded the presence of 14 species that were either present in notable abundance along the survey transects, are species of biodiversity importance or are species that have the potential to indicate change or impact native species and communities (Table 9). Please note this is not a comprehensive species list for the Porthdinllaen outer harbour, rather it is the volunteer diver observations of the dominant or easily identifiable epifauna and the presence of species of conservation interest that divers were specifically instructed to record if observed.

Table 9: List of species that were recorded by divers in August and October 2012 whilst undertaking surveys of the outer harbour moorings for the Porthdinllaen Seagrass Project. This species list is not exhaustive. * Indicates species of conservation interest that divers were specifically told to note if observed.

Fauna		Flora	
Common Name	Latin name	Common Name	Latin name
Common Shore Crab	*Carcinus maenas*	Red Seaweeds	Rhodophycota
Dahlia Anemone	*Urticina felina*	Bootlace weed	*Chorda filum*
Daisy Anemone	*Ceres pedunculatus*	Sea Oak / Podweed	*Halidrys siliquosa*
Pollock	*Pollachius spp (Juvenile)*	Eel grass*	*Zostera marina*
Sand Mason Worm	*Lanice conchilega*	Wire Weed*	*Sargassum muticum*
Snake Pipefish*	*Entelurus aequoreus*		
Snakelocks Anemone	*Anemonia viridis*		
Spiny Spider Crab	*Maja squinado (Juvenile)*		
Stalked Jellyfish*	Stauromedusae spp.		

Of the 14 species noted the Biodiversity Action Species (BAP) stalked jellyfish (Stauromedusae spp.) and the invasive non-native species wire weed (*Sargassum muticum)* were observed on 42 out of a total of 106 transects. The distribution of *S.muticum* across the outer harbour was not centralised within any particular region, however was much more widely distributed throughout the outer harbour (Figure 25). One diver observation noted 4 transects where *S.muticum* was super abundant (i.e. >80% cover, or more than 10 plants per m^2).

Stalked jellyfish, Stauromedusae spp. were observed on a total of 6 (of 106) transects. The distribution of the transects where Stauromedusae spp. was recorded do not appear to be grouped to any particular area within Porthdinllaen outer harbour (Figure 26).

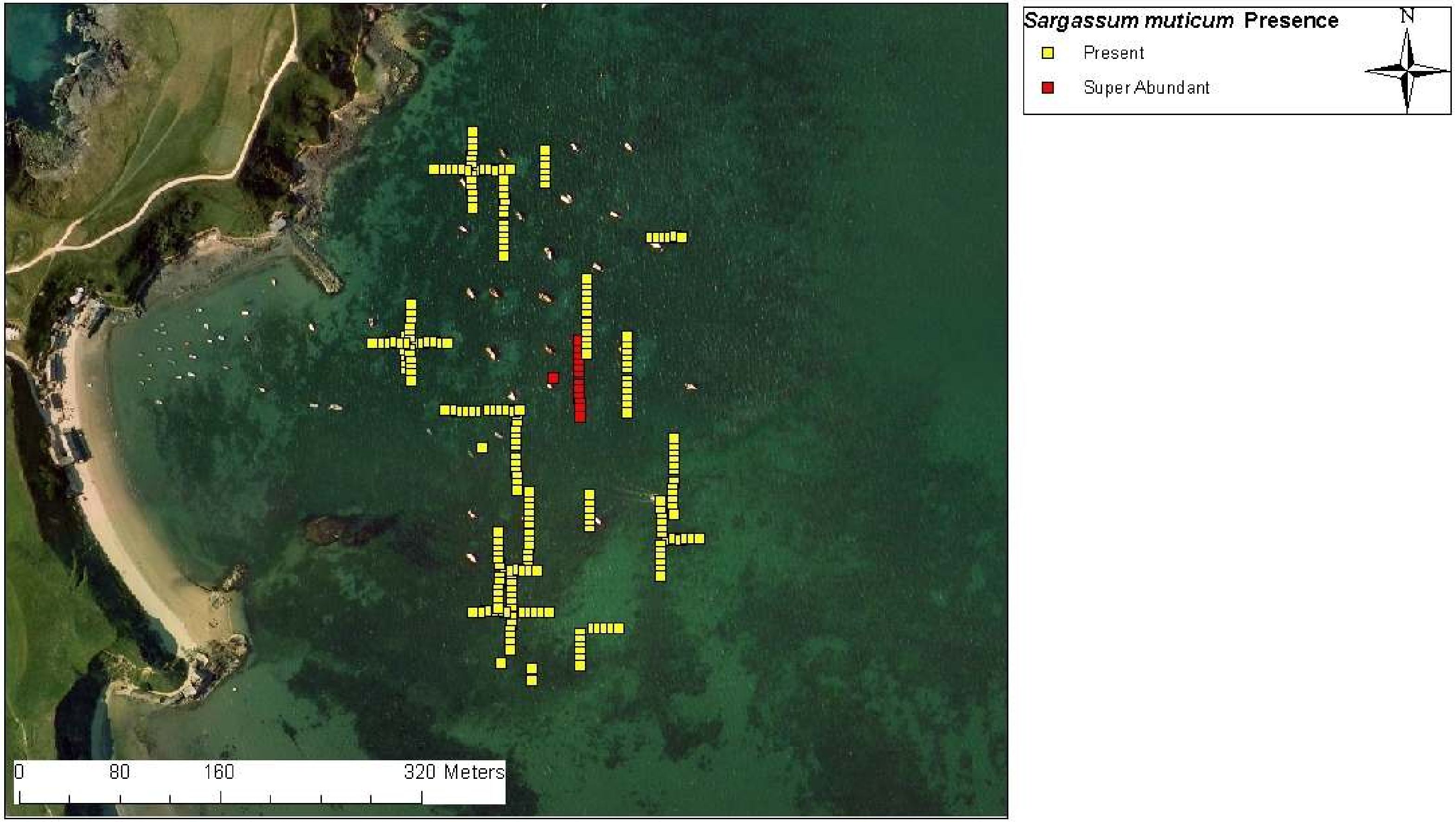


Figure 25: Presence/absence map highlighting areas were *Sargassum muticum* (wire weed) was encountered within Porthdinllaen outer harbour by volunteer divers during the Porthdinllaen Seagrass monitoring project 2012. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

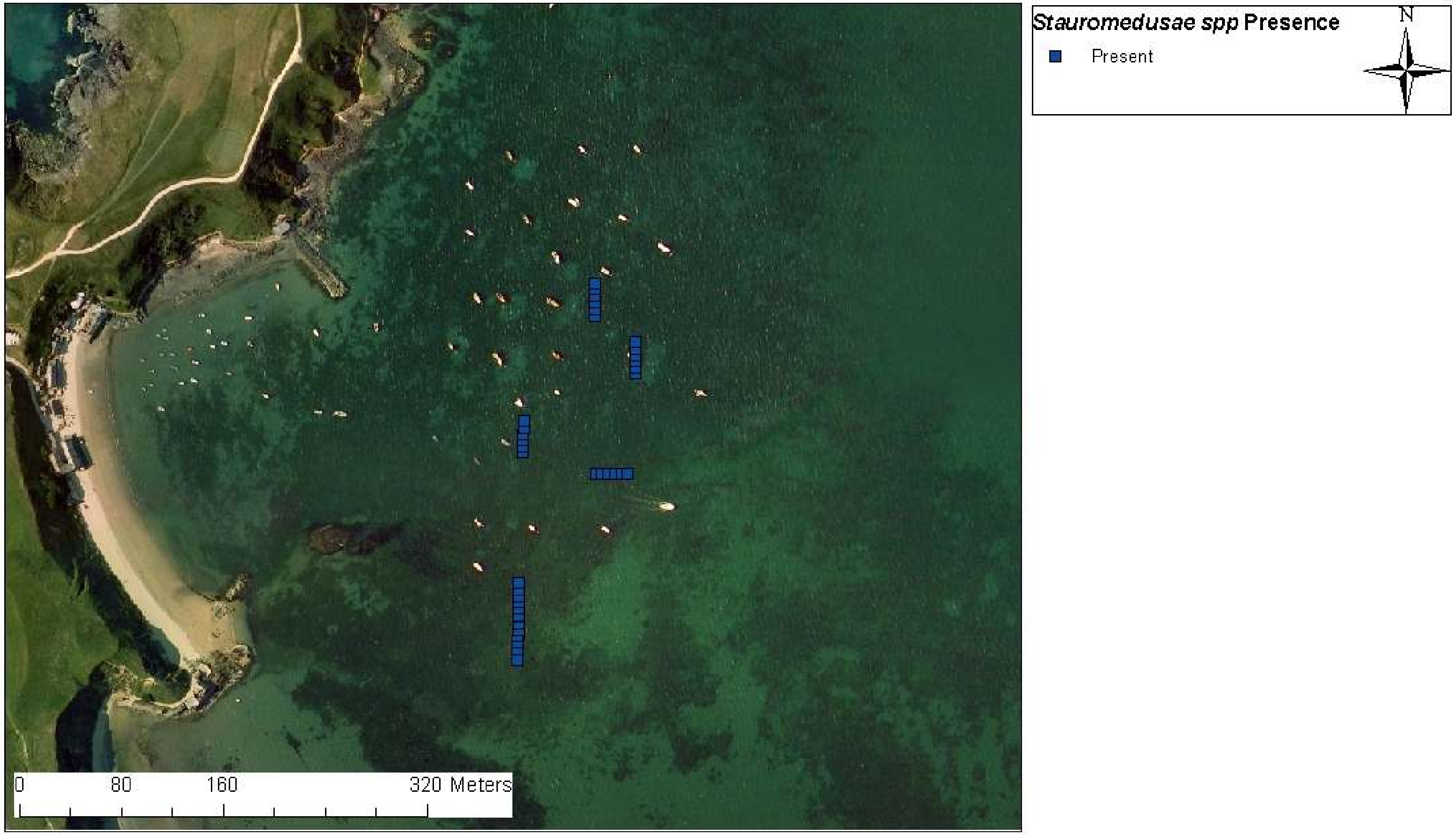


Figure 26: Presence/absence map highlighting areas were *Staruomedusae* (stalked jellyfish) was encountered within Porthdinllaen outer harbour by volunteer divers during the Porthdinllaen Seagrass monitoring project 2012. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

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Observations of *Z.marina* seeding and flowering: Divers were instructed to record if they saw *Z. marina* shoots that exhibited signs of seeding or flowering behaviour and the recorded observations are shown in Figure 27. Flowering behaviour was observed at only one transect within the north of the harbour, whilst seeding was noted at 13 transects. There was no observable pattern in the distribution of *Z. marina* shoots that exhibited seeding or flowering behaviour.

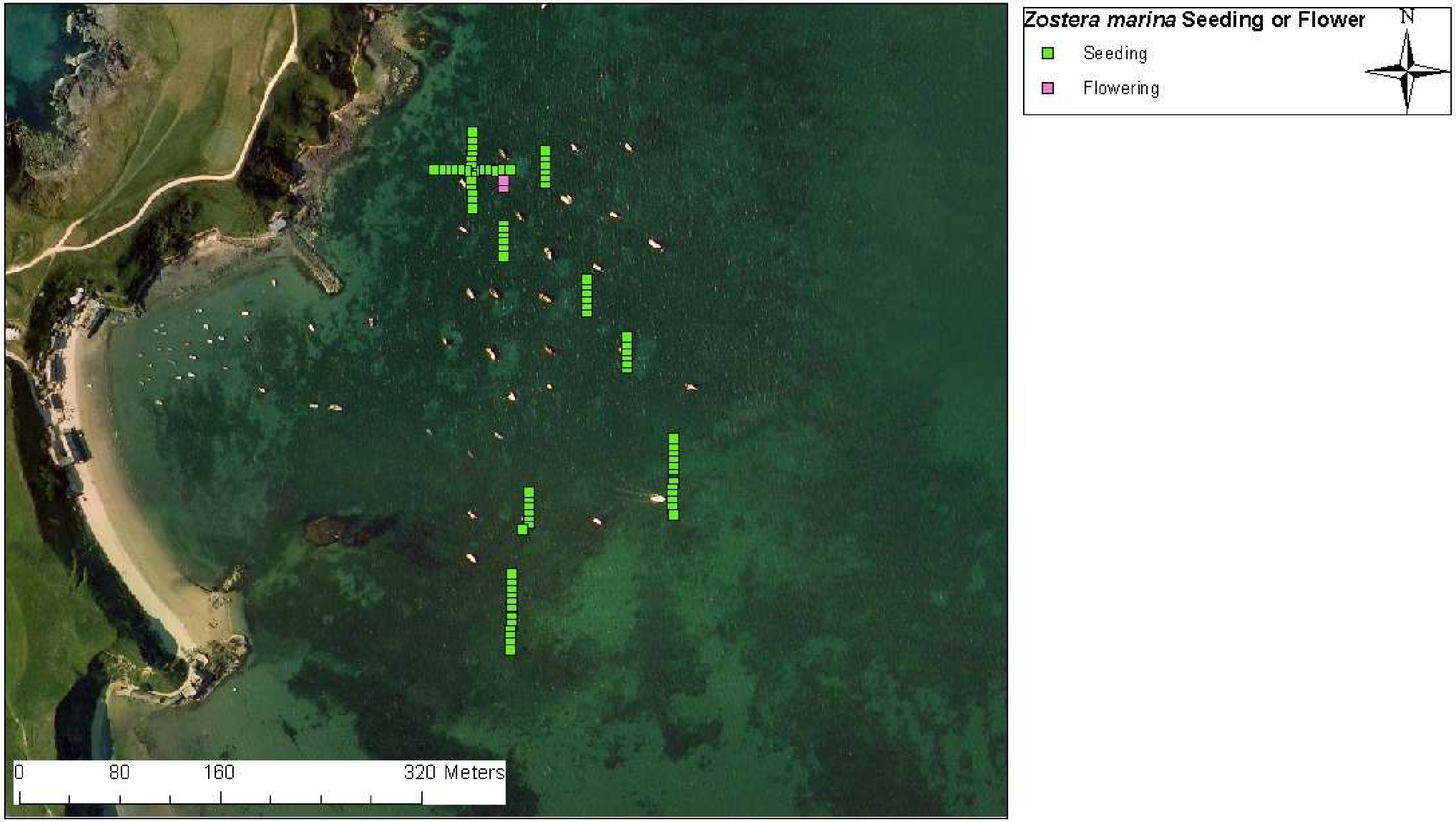


Figure 27: Presence/absence map highlighting areas were *Zostera marina* seeding or flowering behaviour was encountered within Porthdinllaen outer harbour by volunteer divers during the Porthdinllaen Seagrass monitoring project 2012. © This orthophotography has been produced by COWI A/S from digital photography captured by them in 2006. Licensed by the Welsh Government's Department for Environment to the Countryside Council for Wales.

DISCUSSION

Mooring Survey

A maximum of 45 mooring buoys and 34 keep pots were encountered during the survey work for this project in 2012. Comparisons between the SEACAMS survey data and that collected by Marine EcoSol for the current report, show there are seasonal changes in the number of moorings within Porthdinllaen outer harbour. Comments made by local fishermen support this finding, reporting that the moorings are seasonally removed for annual maintenance works. It is unclear from this data is whether all the moorings are removed throughout each winter or only a proportion of them. To clarify exactly how often and where moorings are moved to, a longer monitoring study would need to be conducted or interviews would need to be conducted with the local boat owners whose vessels are resident to Porthdinllaen outer harbour. The maximum number of moorings in the outer harbour at Porthdinllaen is not known for certain. Egerton (2011) reported a maximum of 40 moorings present in the outer harbour in 2011 however this was based on an estimate from Gwynedd Council so it is not known whether the number recorded in 2012 represents a small increase or not. Despite this, historical evidence does indicate the number of moorings within the outer harbour has been increasing since 1946 (Egerton 2011).

Of the 45 moorings present at the time of Marine EcoSol's survey 31 were surveyed using volunteer SCUBA divers. These surveys identified two mooring designs within the outer harbour that were termed "concrete block" and "two-anchor" moorings. The two-anchor mooring design appeared to be more common (29 out of the 31 surveyed) whereas only 2 concrete block moorings were recorded. The size and dimensions of the two-anchor moorings were found to be highly varied, however their overall size (in terms of total chain length) was correlated to the depth within which they were deployed. The 2012 data shows that the distribution of moorings is not even across the outer harbour, with a higher density of moorings per $50m^2$ in the south and west of the outer harbour than the north. It is likely that this is linked to increased exposure in the north and east of the bay and possibly depth although it has not been confirmed with the people who lay the moorings. A third design, "three anchor moorings" was described by a local fisherman as being used by some of the larger boats however this was not encountered within the surveys.

Influence of moorings on *Z.marina* shoot density and canopy height at Porthdinllaen - 2012 data

The shoot density and canopy height of *Z. marina* recorded at the sampling stations in the Porthdinllaen outer harbour were found to be highly variable. The maximum recorded density within the north of the outer harbour was similar to that of the south part, however a greater average density was recorded in the north. Comparing data from previous surveys in 2008 and 2009 the maximum and average *Z. marina* shoot density at Porthdinllaen appears to have remained at a similar level. The variability in the shoot density and canopy height and overall patchy nature of the Porthdinllaen *Z. marina* bed may be due to the majority of surveying occurring late within the year, predominantly in October following lots of wind and rain in September, and a generally wet and windy summer period. *Z. marina* shoots have been found to be annual, removed within the winter by storm erosion or natural die off and reaching their peak densities and biomass (i.e. canopy height) within June & July (Philips *et al.* 1983). *Z.marina* rhizomes persist under the sediment year-round. As such the sporadic patches of high density/canopy height, surrounded by low density may be related to the time of year the survey was conducted within. However, water temperature is still relatively warm in October. Also as the patchiness of the bed was also identified in 2008 and 2009 transects (Morris *et al.* 2008 & 2009) it suggests that there are other factors other than time of year that are causing the variability and patchiness.

Following discussions with local fishermen, and confirmed by observations by surveyors in the field, it is now known that many moorings in the outer harbour at Porthdinllaen are removed each winter and are not replaced in exactly the same location the following spring. The removal and replacement of the anchors and moorings within seagrass beds is known to increase the degree of fragmentation within a bed (Hastings *et al.* 1995, Francour *et al.* 1999, Montefalcone *et al.* 2008, Collins *et al.* 2010). The repeated removal and replacement of anchors/moorings has also been shown to have long term impacts upon the annual growth and recovery of sea grasses (Francour *et al.* 1999, Montefalcone *et al.* 2008). Although no research has been done into the recovery rate of the seagrass at Porthdinllaen that has been impacted by moorings, it is know that the main growth of seagrass rhizomes is in spring (Philips 1983), and therefore it is possible that the Porthdinllaen seagrass bed is patchy due to the annual placement and removal of moorings leading to scarring in slightly different places each year, resulting in patchiness as a result of both current and removed (recovering) mooring scars.

A further environmental factor that may be contributing to the *Z. marina* patchiness is weather exposure. Measuring the fetch from Porthdinllaen to the nearest land (Anglesey) there is a potential fetch of 25-33 km from the north and north-east and, as such, north/north-easterly winds could influence those moorings at relatively exposed locations in the Harbour i.e. the south and east of the harbour. Research assessing shading impacts upon *Z.marina* (Dennison 1987, Dennison & Alberte 1985) have found the concentration of light available can limit both the total leaf surface area (leaf length + width) and the total biomass of the plants. Local weather conditions and potential for re-suspension of sediments through mooring movements and the time of year could combine to cumulatively limit the growth of the *Z.marina* within Porthdinllaen.

Maximum depth of *Z.marina*

The maximum depth of seagrass is thought of as a natural indicator of water health, clarity and turbidity (Abal & Dennison 1996; Dennison 1987; Foden & Brazier 2007). In clearer and cleaner waters seagrass will grow faster and denser than in more turbid waters. Of the sites sampled, one point to note which has been verified from original data, is that the maximum depth of observed *Zostera marina* in Porthdinllaen seems to be 1.6m shallower in 2012 when compared to 2008 near control site 321. However the maximum depth surveyed near control site 321 was 3.6m BCD in 2012 so the results are not directly comparable. In 2012 however, depths of over 6m BCD were surveyed near control site 288 where no seagrass was observed. As there is no long term monitoring station at Porthdinllaen for natural or artificial turbidity, we can not make a judgement on whether this decrease in *Z. marina* depth is due to sampling effort, the natural rainy and windy short summers of recent years since 2008 and 2009, a factor of the relatively late surveys of 2012, or if there is any artificial influence at work in the bay, although it is suspected the former is the primary cause.

Control Sites

There was difficulty in locating good control sites for the study, as an area of good, undisturbed seagrass could not be identified away from the sheltered confines of the moorings. The control site locations were selected on the basis of data from the 2008 and 2009 surveys which indicated areas with high shoot density outside of the mooring area. Out of the four locations, one had to be discounted as no *Z.marina* was present. The maximum shoot density for the control sites was much lower than that for the moorings area (261 shoots/m^2 compared to 464 shoots/m^2, respectively), Maximum canopy height in the control sites was also much lower than for the moorings areas (44.2/m2 compared to 92 per m/2, respectively). There is less variation between the maximum and average shoot density and canopy height in the control sites compared with the moorings areas which implies less variability in the range of values recorded for these two parameters at each of the control site sampling stations It is not clear why the maximum shoot density and canopy height at the control sites should be so much lower than the moorings area, but it throws doubt on the validity of using the control sites as a true reflection of the state of the *Z.marina* without the impact of moorings. The overall patchiness of the Porthdinllaen seagrass bed as discussed above makes it difficult to locate good control sites.

Presence of the invasive non-native species wireweed *Sargassum muticum*

The surveys in Porthdinllaen in 2012 highlighted that the invasive brown macro alga wire weed (*Sargassum muticum*) was widely distributed throughout the harbour, present in 39.6% of transects in 2012 compared to 20% of quadrats surveyed in 2009 (Morris *et al.* 2009) indicating almost a 100% increase in abundance of *S. muticum* between 2009 and 2012. *Z. marina* and *S. muticum* are two species that are usually spatially distinct; *Z. marina* typically growing in sandy/muddy sediments whereas *S. muticum* typically grows on hard substrata such as shells and pebbles. When the substrate becomes a mixed substrate with cobbles & pebbles, as it is within Porthdinllaen, *S. muticum* can colonise and encroach into *Z. marina* habitats (Hartog 1997). Diver observations recorded a greater proportion of mixed substrate with cobbles and pebbles in areas scoured by the effect of moorings. Hartog (1997) reported within Brittany, France that *S. muticum* once established could inhibit the continued growth of *Z. marina* and, within time, even replace *Z. marina*. Tweedly *et al.* (2008) found that broken fragments from established *S. muticum* in areas adjacent to *Z. marina* beds can be "caught" within the *Z. marina* shoots and continue to grow and settle within the soft sediments that typify established *Z. marina* beds. Both authors cited that with increasing anthropogenic impacts upon *Z. marina,* it is likely *S. muticum* represents a great threat to the continued health of *Z. marina* beds within Europe.

The sediments within Porthdinllaen were found to be a mixture of sand-coarse sediments; this sediment profile is a potentially good vector for *S. muticum* to colonise the area. The findings of the Hartog and Tweedly studies indicate that the increase in presence of *Sargassum muticum* in Porthdinllaen is something that may have a seriously detrimental impact on the *Z,marina* bed in the future. Combined with the patchy nature and variable density of *Z. marina* within Porthdinllaen there is opportunity for *S. muticum* to spread and expand within the seagrass bed and potentially out compete the seagrass. There may be a further potential impact of *S.muticum* become much more abundant in that it can grow to considerable lengths which, in shallow water, can stretch out on the surface of the water. If it was to become extremely abundant as it has in other locations in the UK, it is possible that it may become a nuisance to boats operating in the bay (Josefsson & Jansson 2011). The presence of *S. muticum* within the harbour and potential for eradication or control warrants further work to ensure that *S.muticum* does not overwhelm the seagrass bed.

Flowering and Seeding of *Z.marina* at Porthdinllaen

The observations by divers during the 2012 surveys in August and October indicate that at least a proportion of the *Z.marina* at Porthdinllaen is reproducing sexually. Although it is not known whether the seeds produced by the plants at this location contribute to maintenance and possible expansion of the Porthdinllaen bed, it is encouraging the *Z.marina* within Porthdinllaen is reproducing at a typical time of year to that of the rest of the UK (Olsen 1999).

Presence of wasting in *Z.marina* at Porthdinllaen

The presence of wasting of *Z.marina* was recorded during the surveys in August and October 2012 but only at low level of occurrence across all surveyed moorings and as such it highly unlikely that the moorings are currently having any significant influence on the degree of wasting within *Z. marina* at Porthdinllaen

It is not possible to confirm whether the wasting observed is related to annual die-back of the *Z. marina* or is caused by the fungus *Labyrinthrula* spp. and this can only be confirmed by laboratory examination of material which was not possible to do in the current study. The low level of occurrence in the survey indicates that wasting does not appear to be particularly prevalent currently in the seagrass bed, but it is something that would be useful to continue to monitor as an indicator of the health of the seagrass at Porthdinllaen

Influence of concrete block and two-anchor moorings on *Z.marina* at Porthdinllaen

The data for average *Z.marina* shoot density and canopy height for both the two-anchor and concrete block moorings indicates a pattern of increasing shoot density and canopy height with increasing distance from the mooring up to as much as 25m from the mooring, although it is variable in different directions from the mooring.

In general, the data for the west direction transects (only completed for the two-anchor moorings) did not show any clear trends with increasing distance from the mooring. It may be that the environmental factors such as tidal current flow (predominantly towards the north for most of the tidal cycle in Porthdinllaen bay due to eddy currents on flood and ebb tides) and wind combine such that the direction of pull of a boat on a mooring is predominantly in an arc from north to south. It may however also be due to a lack of sampling effort on the western transects and just a reflection of the variability in the *Z. marina* at the moorings that were surveyed with a west transect.

The low sample size for the concrete block moorings (only 2 moorings out of 31) means that it is difficult to determine a clear picture of how this mooring design interacts with the surrounding *Z. marina*, although there is some evidence to suggest the mooring does cause a decrease in both the *Z. marina* density and canopy height.

For the two-anchor moorings, the data for the north, south and east transects (Figures 20 and 21) indicates lower *Z. marina* shoot density and canopy height closer to the mooring (in an area 5-10m away from the mooring), and then a pattern of increasing shoot density and canopy height between 10-25m from the mooring. Although the data for some of the transect directions (particularly the east transects) indicates a subsequent decrease in both shoot density and canopy height with increasing distance from the mooring. This is opposite to what might be expected (i.e. increasing distance from a mooring should mean reduced influence of the mooring and therefore increased shoot density and canopy height).

The transect data for concrete block mooring 271 (Figures 16 and 18) illustrates well the issue of variability in shoot density and canopy height with increasing distance from the mooring. South of this mooring a relationship was found that indicated an increase in distance from the mooring was related to an increase in *Z. marina* density and canopy height until a distance of 20m, at which point both density and canopy height decreased. The reason for this may be due to the close proximity to other mooring scars: mooring 271 was found within an area of high mooring density, and was surrounded by 4 other surveyed two-anchor moorings (Figure 28). Due to the close proximity of these moorings it is possible that the scour of these moorings (Walker *et al.* 1989), or possible secondary impacts of adjacent scour e.g. decreased in rhizome biomass in areas of high mooring density (Milazzo *et al.* 2004, Montefalcone *et al.* 2008), could influence the *Z. marina* density and canopy height 30m from mooring 271. Concrete block mooring 360 was also found surrounded by three other moorings, and a similar process could be occurring causing the variable *Z. marina* density and canopy height values.

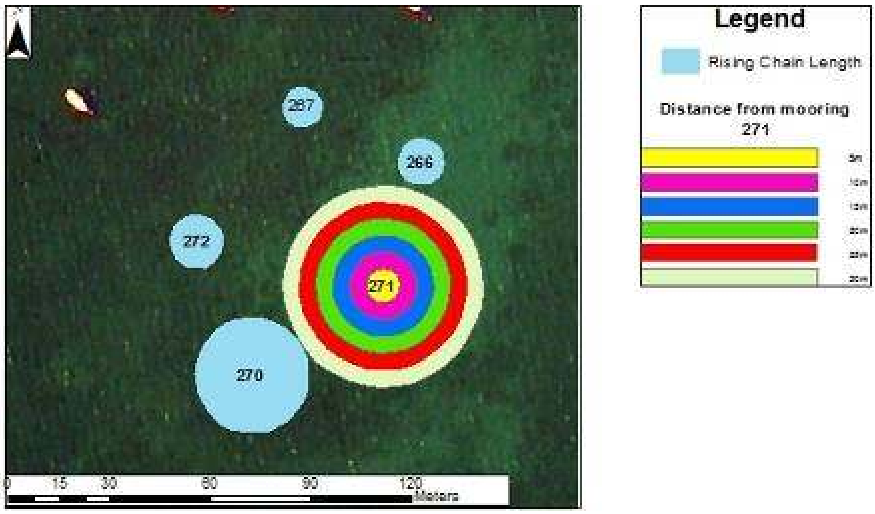


Figure 28: The length of two anchor moorings chain lengths that surround concrete block mooring 271, within Porthdinllaen outer harbour.

Previous reports have recorded that the rising chain is the principle cause of the scars surrounding moorings (Egerton 2011, Morris *et al.* 2008). As reflected within Table 2 and discussed in the results section the anchor chains of the two-anchor design moorings are laid with a degree of slack, when the moorings experience a high tide or wave surge the anchor chains can be lifted from the seabed to allow the mooring to absorb the tidal energy and not become submerged. It may therefore be possible the anchor chains are having a scouring impact upon the *Z.marina* as well as the rising chain. The slack which is laid within the mooring chains also explains why it is total chain length, and not just riser chain length, that correlates with water depth. It seems likely therefore that it is a combination of movement within both the anchor and rising chains that create the scar radius surrounding the moorings. Beyond 5m it may be that the rise chains have a greater effect when they are slack and sag at lower tide levels. However, manipulation of the two-anchor moorings design to limit damage to adjacent seagrass would have to be focused on the rising chain because any effort to manipulate the anchor chains could destabilise the anchors which hold the mooring in position, and may interfere with the moorings capabilities to withstand harsh weather conditions.

Conclusion

In conclusion, the 2012 surveys of the outer harbour moorings, *Z. marina* shoot density, canopy height, wasting and presence of notable species have found the following:

Number of moorings and their design & deployment

1. Many of the moorings are laid and removed on an annual basis resulting in a pattern of increasing mooring numbers from spring (April/May) through to late summer (August/September) and then a reduction when they are removed for the winter. A maximum of 45 moorings were recorded in the outer harbour in 2012; this may be a slight increase on the number of moorings in previous years. There is evidence that mooring numbers in the outer harbour have increased since 1946, but there are no specific records of mooring numbers each year so it is difficult to understand the absolute trend and variability. Observations by local residents and boat users are important to help inform understanding about the scale of use of the outer harbour.
2. Areas within the Porthdinllaen outer harbour are used for anchoring keep pots, the number of which was variable through the year. These were not considered in any detail in the current study.
3. There are reportedly three mooring designs used at Porthdinllaen. The one encountered most commonly in the current study was the two-anchor mooring (29 out of 31 moorings surveyed).
4. There is considerable variation in the lengths of anchor chains and riser chains used for the two-anchor moorings. The data recorded shows a correlation between total chain length (i.e. anchor chains + riser chain lengths) and water depth (corrected to below chart datum, BCD).
5. The anchor chains are generally set with some slack in them so that at high tides or in swell conditions both the anchor chains and the riser chain rise and fall, such that it is movement of both sets of chains that impact the seabed and seagrass. It is considered that manipulation of the two-anchor moorings design to limit damage to adjacent seagrass would have to be focused on the rising chain because any effort to manipulate the anchor chains could destabilise the anchors which hold the mooring in position, and may interfere with the moorings capabilities to withstand harsh weather conditions.

The seagrass bed and the influence of moorings

6. The maximum and average shoot density and canopy height of *Z. marina* in the Porthdinllaen outer harbour was of the same order of magnitude as that recorded in 2008 (canopy height not recorded) and 2009.
7. The data collected in 2012 shows a pattern of influence of the moorings on shoot density and canopy height similar to that recorded in 2008 & 2009. In general these are lower closer to the moorings with a pattern of increasing density and canopy height with increasing distance from the moorings, although there is considerable variation in terms of rate of increase and how far from any one mooring this trend reaches. On average between 5-10m of the 2 anchor mooring there was 25% less seagrass shoot density/m^2 and 36% lower in canopy height/0.25m^2 across the outer harbour. Further away from the moorings there tends to be some reduction density and canopy height reduce which is likely as a result of the influence of nearby moorings and past impact of moorings on the seagrass. Whilst the process of laying and removal of each mooring will have a direct impact on the seagrass on its own, it is considered that the predominant scour effect is from the operation of the mooring whilst it is *in situ*.
8. Quadrats of seagrass density and height should be taken as close to moorings as possible (distance 0m). Although in 2012 it was noted that no stations had seagrass directly around the moorings this should be properly recorded.
9. The direction of scour appears to be variable with patterns of scour showing in north, south and east direction from each mooring but not in a westerly direction from the mooring. It is considered that this is likely to be linked to the prevailing environmental conditions (tidal flow, wind and wave action).
10. There is considerable variation in shoot density and canopy height across the seagrass bed in the outer harbour and patchiness in the seagrass bed overall. It is highly likely that this is due to the current management of the moorings where the majority are laid and lifted annually, with moorings being placed in slightly different locations each time, resulting in a widespread effect across the bed and continuing influences from one year to the next as moorings impact slightly different locations each year. Some moorings are laid in close proximity

to each other and it is possible that there are over-lapping influences from adjacent moorings on the same areas of seagrass.

11. The rate of recovery of seagrass from one year of mooring impact is not known, neither are the cumulative effects of partial recovery of areas that may have been impacted previously and then subsequently impacted in following years when the moorings are moved again. It is not known to what degree the impact of a mooring in any one year affects the underlying rhizomes within the seabed substrate, or whether it primarily impacts the seagrass shoots leaving the rhizomes intact to re-shoot the following year. Improving understanding about this is necessary to understand the potential for recovery of impacted parts of the seagrass bed.
12. The control sites were selected as sites with high shoot density based on data from the 2008 & 2009 surveys but they have clearly changed as they had a noticeably lower maximum shoot density and canopy height than the mooring sampling sites which is opposite to what might be expected. There appears to have been considerable change in the condition of the control site locations between 2008/09 and 2012 but the reasons for this are not clear. There may be some influence from use of these areas in the intervening years or it may be part of changes due to wider environmental factors. The control sites highlight the problems associated with establishing truly representative control sites against which to monitor change in the seagrass bed over time. There is a need to establish control sites but more consideration needs to be given as to where these could be located.
13. The data from the current survey together with that from the 2008 and 2009, surveys should inform any future surveys within area, forming a baseline for future comparison.

Presence of wasting

14. There is no evidence from the 2012 data that wasting of *Z.marina* was prevalent in the seagrass bed at Porthdinllaen nor that the moorings are contributing to the presence of wasting.

Presence of the invasive non native brown seaweed *Sargassum muticum* (wireweed)

15. The 2012 data shows an almost 100% increase in recorded abundance of the invasive non native species *Sargassum muticum* (wireweed) in the seagrass bed in the outer harbour at Porthdinllaen. *S. muticum* is known to be able to establish itself on small stones within a mixed seabed substrate such as is present in parts of the outer harbour. The increase in abundance of *S. muticum* is of concern because in other locations where it has become established it has been shown to be able to out-compete seagrass. Invasive non-native species can be present in low numbers for a number of years before conditions favour a rapid expansion within a particular locality. It is not know whether the mooring impact on the seabed has an influence on the establishment of *S. muticum* by creating bare patches which it can more readily colonise.

The patchy nature of the *Z.marina* bed throughout Porthdinllaen outer harbour have made the establishment of valid control sites and the assessment of mooring impacts on the general condition of the bed difficult within this study. *Z.marina* has been found to grow in sheltered locations within other studies (Bockleman *et al.* 2012, Hartog 1997), and as such areas that facilitate optimal growing conditions for *Z.marina* within Porthdinllaen may be within the area directly impacted by the moorings of the harbour, as these are the most sheltered. Therefore it is inherently difficult to find adequate comparison sites between areas affected by the moorings and those that aren't. Additional confounding variables such as historic/previous or present multiple moorings having an impact upon the same area of seabed may also have affected the results of this report. Despite this it was demonstrated within this report that within close proximity to the moorings the *Z.marina* density and canopy height were reduced. It is also possible that for the general health of the seagrass bed at Porthdinllaen it may be worth considering possible options to reduce patchiness and trial some permanent moorings in areas of dense seagrass but away from existing moorings in the bed. The further recommendations below suggest ways in which to achieve this.

Future Recommendations

1. Regular assessment of the Porthdinllaen *Z. marina* bed

Due to the highly patchy nature of the seagrass bed and the increased presence of *S. muticum* dispersed widely throughout the harbour, it is the recommendation of this report that a programme of continued monitoring of Porthdinllaen outer harbour be established. The 2008, 2009 and 2012 surveys form an excellent baseline on which to form a knowledge base for future surveys. Such surveys could be focused in areas of concern/interest within the harbour, such as patchiness (following methods suggested in 2009) and *S. muticum*. The specific objectives of this potential monitoring programme would need to be established prior to any works. In order to maximise volunteer diver time it may be beneficial to collect data exclusively on 1 or few *Z.marina* growth parameters, such as density. *Z.marina* density showed the highest impact in relation to the moorings within the current study, furthermore the equipment requirements to assess the *Z.marina* density is a standardized quadrat (a quadrat of a pre-established size). However the requirements of any future survey within the area would need to be fully discussed with management officials.

2. Use of volunteer divers

Ongoing monitoring can be achieved with relative low expenses through the use of volunteer divers through a carefully planned and organised programme that is overseen and run by experienced project manager. The general interest by volunteers within this project highlights the genuine enthusiasm and the capabilities of volunteer scuba divers, and it would be strong recommendation within the future to utilise volunteers to reduce costs. However, it must be noted that often volunteers do lose interest in long term monitoring projects, the success of any volunteer programme is determined by the dedication of its coordinators to maintain momentum and as a result significant budget need be allocated to both coordination and reporting.

3. Controlled Seagrass recovery study

It is also possible but could not be proven by the data from this study, that moorings in deeper water have a bigger impact on seagrass density. The hypothesis here is that at depth the seagrass growth is slower than in the shallows, so multiple and repeated placement of moorings in a small area may hinder rhizome growth and recovery. However, in order to prove that a minimum of five moorings in shallow water and five in water deeper than 3m below chart datum need to remain unmoved and free from other moorings for several years, and their recovery annually monitored.

3. Investigating the impact of the mooring movement

As reported by local fishermen and concurred by the results within this report a number of the moorings within Porthdinllaen outer harbour are seasonally removed. It is possible the act of removing and replacing the moorings may cause serious detriment to the *Z.marina* in terms of:

- The potential intensive and localized removal of both the shoots and below sediment rhizomes,
- Re-suspension of sediments,

4. Mooring density impacts upon *Z. marina*

Due to the current unregulated control of moorings within the outer harbour (Egerton 2011), the total number of moorings and/or the mooring density impacts upon the *Z. marina* should be considered in the future management of the harbour. If the current trend of increasing the maximum number of moorings within outer harbour continues, a maximum number of moorings/mooring density for the Porthdinllaen harbour should be calculated in terms of tolerable damage to the *Z. marina.*

In future surveys in the area it is recommended the number of moorings per unit area is compared to the average *Z. marina* density and canopy height of the same area (Figure 28). If Porthdinllaen harbour were split into appropriately sized grid cells, with Figure 28 50m^2 cells have been used, by conducting a systematic survey within each cell and calculating the mooring and *Z. marina* density plus canopy height within each cell this could be achieved.

Results from such a study could potentially calculate the optimal mooring density/ unit area, and based on this figure the maximum mooring number of Porthdinllaen outer harbour. As a further point in terms of potential future management of moorings within the area this technique could be taken further and moorings could be preferentially placed in/ removed from cells where the *Z. marina* is either in poor or good condition.

It is also recommended that some cells, particularly in the dense northern extent of seagrass, should, in liaison with local boat operators, be put in place with no moorings to ensure some areas are left without any repeated mooring activity and therefore the seagrass bed can recover in parts to its ‘natural’ optimal state.

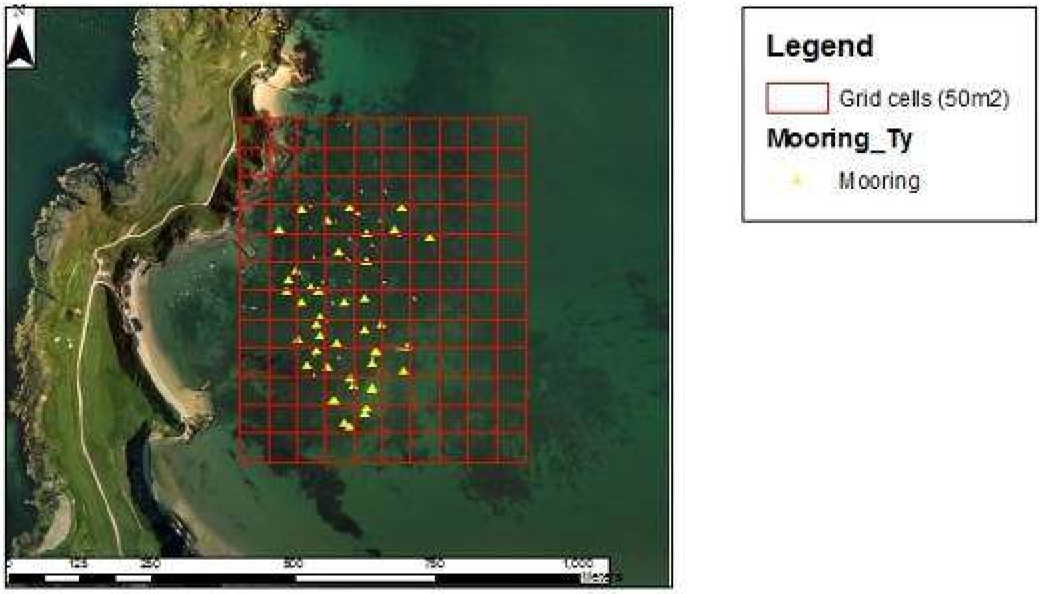


Figure 29: Porthdinllaen outer harbour split into 118 x 50m2 grid cells for the purposes of assess the impact of moorings/unit area on *Z. marina*.

5. Presence and possible management/eradication of *Sargassum muticum* (wireweed)

Given the potential for the invasive non-native brown seaweed species *Sargassum muticum* to out-compete seagrass it is recommended that consideration is given to a possible trial eradication programme, or as mentioned in recommendation 1 the potential spread of *S.muticum* be monitored within Porthdinllaen and any potential inter-specific competitions be noted.

REFERENCES

Peer Reviewed Journals and Reports

Abal, E.G. & Dennison, W.C. 1996. *Seagrass depth range and water quality in southern Moreton Bay, Queensland, Australia.* Marine and Freshwater Research 47(6): 763-771.

Beck, M.W., Heck, K.L., Able, K.W., Childers, D.L., Eggleston, D.B., Gillanders, B.M., Halpern, B., Hays, C.G., Hoshino, K., Minello, T.J., Orth, R.J., Sheridan, P.F., Weinstein, M.P. 2001. *The Identification, Conservation, and Management of Estuarine and Marine Nurseries for Fish and Invertebrates.* BioScience 51(8): 633-641.

Bockelmann, A.C., Beining, K. & Reusch, T.B.H. 2012. *Widespread occurrence of endophytic Labyrinthula spp. in northern European eelgrass Zostera marina beds.* Marine Ecology Progress Series 445: 109-116.

Boese, B.L., Kaldy, J.E., Clinton, P.J., Eldridge, P.M. & Folger, C. 2009. *Recolonisation of intertidal Zostera marina L. (eelgrass) following experimental shoot removal.* Journal of Experimental Marine Biology and Ecology 374(1): 69-77.

Bouma T.J., Olenin, S., Reise, K. & Ysebaert, T. 2009. *Ecosystem engineering and biodiversity in coastal sediments: posing hypotheses.* Helgoland Marine Research 63 (1):95-106.

Collins, K.J., Suonpää, A.M. & Mallinson, J.J. 2010. *The impacts of anchoring and mooring in seagrass, Studland Bay, Dorset, UK.* Underwater Technology: The International Journal of the Society for Underwater 29 (3): 117-123.

Constanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neil, R.V., Paruelo, J., Raskin, R.G., Sutton, P. & van den Belt, M. 1997. *The value of the world's ecosystem services and natural capital.* Nature 387: 253-260.

Countryside Council for Wales. 2009. Pen Llŷn 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.

Dennison, W.C. 1987. *Effects of light on seagrass photosynthesis, growth and depth distribution.* Aquatic Botany 27, 15-26

Dennison,W.C. Randall, A.S. 1985. Role of daily light period in the depth distribution of *Zostera marina* (eel grass). Marine Ecological Progress Series. 253 51-65

Duarte, C.M. 2002. *The future of seagrass meadows.* Environmental Conservation 29 (2): 192-206.

Egerton. J. 2011. Management of the seagrass bed at Porthdinllaen. Initial investigation into the use of alternative moorings systems. Report for Gwynedd council.

Foden, J and Brazier, D.P. (2007) Angiosperms (seagrass) within the EU water framework directive: A UK perspective. *Marine Pollution Bulletin* 55(1-6),181-196

Francour, P. Ganteaume,A. Poulain M. 1999. Effects of boat anchoring Posidonia oceanica seagrass beds in the Port-Cros National Park (Northern Mediterranean sea). Aquatic conservation: Marine and freshwater ecosystems. 9: 391-400.

Gladstone, B. 2011. *Monitoring of Seagrass Friendly Moorings in Shoal Bay.* OnWater Marine Services Pty Ltd. 29pp.

Golden, R/R/, Busch, K.R., Karrh, L.P., Parham, T.A., Lewandowski, M.J. & Naylor, M.D. 2010. *Large-Scale Zostera marina (eelgrass) Restoration in Chesapeake Bay, Maryland, USA. Part II: A Comparison of Restoration methods in the Patuxent and Potomac Rivers.* Restoration Ecology 18(4): 502-513.

Goudge, H. 2012. Marine Ecological Solutions Ltd. (Marine EcoSol) Diving Rules and Standard Operating Procedures. 38pp.

den Hartog, C. 1997. *Is Sargassum muticum a threat to eelgrass beds?* Aquatic botany 58: 37-41.

Heck, K.L. & Thoman, T.A. 1984. *The Nursery Role of Seagrass Meadows in the Upper and Lower Reaches of the Chesapeake Bay.* Estuaries 7 (1): 70-92.

Maccabes, A. 2008. Joint Nature Conservation Committee. Seagrass beds: a UK biodiversity action plan, prioirty habitat description.

Maddock, A. 2008. UK Biodiveristy Action Plan (BAP) priorty habitat descritpions: Seagrass beds. Joint Nature Conservation Comiittee.

Marba, N. & Duarte, C.M. 1998. *Rhizome elongation and seagrass clonal growth.* Marine Ecology Progress Series 174: 269-280.

Milazzo, M., Badalamenti, F., Ceccherelli, G., Chemello, R. 2004. *Boat anchoring on Posidonia oceanica beds in a marine protected area (Italy, western Mediterranean): effect of anchor types in different anchoring stages.* Journal of Experimental Marine Biology and Ecology 299, 51– 62.

Montefalcone, M., Chiantore, M., Lanzone, A., Morri, C., Albertelli, G., Bianchi, C.N. 2008. *BACI design reveals the decline of the seagrass Posidonia oceanica induced by anchoring.* Marine Pollution Bulletin 56,1637–1645.

Moore, K.A., Wetzel, R.L. & Orth, R.J. 1997. *Seasonal pulses of turbidity and their relations to eelgrass (Zostera marina L.) survival in an estuary*. Journal of Experimental Marine Biology and Ecology 215: 115-134.

Morris, E.S. & Goudge, H. 2008. *Piloting the Use of Volunteer Divers in Subtidal Marine Monitoring in Wales: Preliminary Seagrass Surveys in Porthdinllaen and Milford Haven.* CCW Marine Monitoring Interim Report.

Morris, E.S., Hirst, N., & Easter, J. 2009. *Summary of 2009 Seagrass Surveys in Porthdinllaen.* CCW Marine Monitoring Interim Report.

Nakamura, Y., Hirota, K., Shibuno, T. & Watanabe, Y. 2012. *Variability in nursery function of tropical seagrass beds during fish ontogeny: timing of ontogenetic habitat shift.* Marine Biology 159 (6): 1305.

Olësen, B. 1999.. *Reproduction in Danish eelgrass (Zostera marina L.) stands: size-dependence and biomass partitioning.* Aquatic Botany 65: 209–219.

Phillips, R.C., Grant, W.S. & McRoy, C.P. 1983. *Reproductive strategies of eelgrass (Zostera marina L.).* Aquatic Botany 16: 1-20.

Schwarz, AM., Matheson, F. & Mathieson, T. 2004. The role of sediment in keeping seagrass beds healthy. Water & Atmosphere 12(4): 18-19.

Tweedley, J.R., Jackson, E.L. & Attrill, M.J. 2008. *Zostera marina seagrass beds enhance the attachment of the invasive alga Sargassum muticum in soft sediments.* Marine Ecology Progress Series 354: 305-309.

Uhrin, A.V., Kenworthy, W.J. & Fonseca, M.S. 2011. Understanding uncertainty in seagrass injury recovery: an information-theoretic approach. Ecological Applications 21:1365–1379.

Walker, D.I., Lukatelich, R.J., Bastyan, G., McComb, A.J. 1989 *Effect of Boat Moorings on Seagrass Beds near Perth, Western Australia.* Aquatic Botany 36, 69-77

Michelle Waycotta,M. Duarteb, C,M. Carruthersc, T,J,B. Orthd, R,J. Dennisonc, W,C. Olyarnike, S. Calladinea, A. Fourqureanf, J, W. heck, K,L. Randall Hugese, Jr.g.h.A. Kendricki, G,A. Kenworthyj,W,J. Shotk,F,T. Williomse,S,L. 2009. Accelerating loos of seagrass across the globe threatens coastal ecosystems.PNAS. 106 (30) 12377-12381.

Webster, P.J., Rowden, A.A. & Attrill, M.J. 1998. *Effect of Shoot Density on the Infaunal Macro-invertebrate Community within a Zostera marina Seagrass Bed.* Estuarine, Coastal and Shelf Science 47 (3): 351-357.

Young, P.C. 1978. Moreton Bay, Queensland: A Nursery Area for Juvenile Penaeid Prawns. Australian Journal of Marine and Freshwater Research 29(1):55-75.

Websites

URL 1: World registry of Marine Species (WORMS). http://www.marinespecies.org/aphia.php?p=taxdetails&id=182740. Accessed January 2013, Re-checked February 2013

URL 2: Garmin. https://buy.garmin.com/shop/shop.do?pID=6446. Accessed January 2013, Re-checked February 2013

URL 3:Arc GIS resource centre. http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//003100000059000000.htm. Accessed January 2013, Re-checked February 2013.

Personal Communication

Jones, P. 2012. Llŷn Fishermen's Association. Pre survey meeting held at Porthdinllaen RNLI office,

Williams, I. 2012. Marine and General Engineering. General discussions throughout sampling

APPENDIX 1

List of the surveyed moorings, each moorings design and on which transect each mooring was surveyed.

Mooring Type	Mooring Number	Latittude (WGS 1984)	Longitude (WGS 1984)	Surveyed Transect			
				North	South	East	West
Control Site	279	N52 56.7606	W4 33.7428	Yes	No	No	No
	288	52 56.544	W4 32.9676	Yes	Yes	Yes	Yes
	320	N52 56.544	W4 32.968	Yes	No	No	No
	321	N52 56.618	W4 33.775	Yes	Yes	Yes	Yes
Total	4			4	2	2	2
Two anchor mooring	8	N52 56.605	W4 33.797	Yes	Yes	Yes	Yes
	11	N52 56.584	W4 33.744	Yes	Yes	Yes	No
	12	N52 56.601	W4 33.769	Yes	Yes	Yes	Yes
	13	N52 56.605	W4 33.734	Yes	Yes	Yes	Yes
	18	N52 56.550	W4 33.690	Yes	Yes	Yes	Yes
	19	N52 56.616	W4 33.701	Yes	Yes	No	Yes
	20	N52 56.643	W4 33.698	Yes	Yes	No	No
	25	N52 56.631	W4 33.642	Yes	Yes	Yes	Yes
	26	N52 56.673	W4 33.606	Yes	Yes	No	No
	233	N52 56.619	W4 33.668	Yes	Yes	No	No
	235	N52 56.640	W4 33.567	Yes	Yes	No	Yes
	249	N52 56.615	W4 33.825	Yes	Yes	No	No
	250	N52 56.629	W4 33.822	Yes	Yes	Yes	Yes
	251	N52 56.633	W4 33.808	Yes	No	No	No
	255	N52 56.57	W4 33.697	Yes	Yes	Yes	Yes
	256	N52 56.576	W4 33.632	Yes	Yes	No	No
	257	N52 56.549	W4 33.639	Yes	Yes	Yes	No
	265	W4 33.733	52.942517	Yes	Yes	Yes	Yes
	266	N52 56.529	W4 33.685	Yes	Yes	Yes	Yes
	267	N52 56.537	W4 33.717	Yes	Yes	No	No
	269	N52 56.519	W4 33.774	Yes	Yes	No	No
	270	N52 56.494	W4 33.728	Yes	Yes	Yes	Yes
	272	N52 56.515	W4 33.744	Yes	Yes	Yes	Yes
	273	N52 56.533	W4 33.754	Yes	Yes	Yes	No
	307	N52 56.7036	W4 33.783	Yes	Yes	Yes	Yes
	308	N52 56.684	W4 33.759	Yes	Yes	No	No
	358	N52 56.655	W4 33.747	Yes	Yes	Yes	No
	359	N52 56.685	W4 33.765	Yes	Yes	No	No
	360	N52 56.697	W4 33.730	Yes	Yes	Yes	Yes
Total	29			29	28	17	15
Concrete Block mooring	271	N52 56.515	W4 33.744	Yes	Yes	Yes	No
	362	N52 56.678	W4 33.659	Yes	Yes	Yes	No
Total	2			2	2	2	0

Raw Data matrix from volunteer diver surveys of Porthdinllaen Outer harbour. Table is sorted into mooring type, Mooring ID, then by the bearing and distance surveyed. The *Zostera marina* density, canopy height and wasting presence within each quadrat is then displayed.

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Control Site	279	0	5	309.3333333	17	7.333333333
			10	304	28	4.333333333
			15	176	28	3
			20	261.3333333	42	3.333333333
			25	160	35	0
			30	154.6666667	16.3	1
	320	0	5	176	44.22222222	3.666666667
			10	213.3333333	27.55555556	3.333333333
			15	192	35.44444444	3.333333333
			20	170.6666667	25.11111111	3.666666667
			25	261.3333333	26	3.666666667
			30	154.6666667		3.333333333
	321	0	5	32	6.666666667	0
			10	10.66666667	2.666666667	0
			15	26.66666667	7.666666667	0
			20	261.3333333	26.44444444	0.666666667
			25	240	24.66666667	1.333333333
			30	218.6666667	27.11111111	1
		90	5	112	4.222222222	0
			10	160	0	1
			15	170.6666667	0	0.666666667
			20	85.33333333	14.22222222	0.333333333
			25	32	18.66666667	0
			30	186.6666667	24.88888889	1.666666667
		180	5	122.6666667	13.33333333	0.333333333
			10	181.3333333	21.33333333	1
			15	160	31.55555556	1.333333333
			20	0	0	0
			25	128	25.66666667	1
			30	181.3333333	28.22222222	1.666666667
		270	5	0	13.55555556	0
			10	0	21.77777778	0
			15	0	26.22222222	0
			20	240	22.11111111	0.666666667
			25	128	6.666666667	0.666666667
			30	160	19.55555556	1

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	11	0	5	96	23.44444444	0
			10	154.6666667	32.77777778	0
			15	48	35.55555556	0
			20	26.66666667	34.66666667	0
			25	85.33333333	29.22222222	0
			30	80	20.66666667	0
		90	5	69.33333333	9.555555556	1
			10	176	38	2.333333333
			15	202.6666667	35.33333333	2
			20	122.6666667	43.11111111	1.333333333
			25	122.6666667	55.77777778	1.666666667
			30	112	59.22222222	2.333333333
		180	5	0	0	0
			10	229.3333333	45.55555556	2.666666667
			15	256	61.88888889	1.333333333
			20	288	48.77777778	1.333333333
			25	48	35.22222222	2
			30	133.3333333	44.44444444	0
	12	0	5	16	6.666666667	0
			10	0	0	0
			15	48	19.33333333	0
			20	0	0	0
			25	186.6666667	30	1.333333333
			30	90.66666667	52.77777778	0.333333333
		90	5	0	0	0
			10	138.6666667	68.66666667	1
			15	69.33333333	56.44444444	0.333333333
			20	154.6666667	74.66666667	0.666666667
			25	165.3333333	74	0.666666667
			30	0	0	0
		180	5	69.33333333	27.33333333	1.666666667
			10	218.6666667	66.66666667	1.333333333
			15	245.3333333	130.8888889	0.333333333
			20	154.6666667	51.66666667	1
			25	176	50.66666667	0.666666667
			30	0	0	0
		270	5	234.6666667	66.22222222	1.333333333
			10	10.66666667	4.666666667	0
			15	144	56.22222222	0.666666667
			20	234.6666667	61.44444444	2.333333333
			25	133.3333333	40.22222222	1.333333333
			30	96	39.77777778	2.666666667

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	13	0	5	117.3333333	42.44444444	2.333333333
			10	58.66666667	43.22222222	0.333333333
			15	112	37.55555556	1.666666667
			20	192	36.66666667	0.333333333
			25	122.6666667	52.66666667	0.333333333
			30	138.6666667	45.66666667	1.333333333
		90	5	69.33333333	19.55555556	1.333333333
			10	149.3333333	45.33333333	1.666666667
			15	282.6666667	61.33333333	2.333333333
			20	213.3333333	53.33333333	1.666666667
			25	170.6666667	44.88888889	2.666666667
			30	256	26	2.333333333
		180	5	186.6666667	14	2
			10	229.3333333	60.44444444	2.666666667
			15	256	50.44444444	3.333333333
			20	165.3333333	42.44444444	2
			25	245.3333333	48.44444444	3.666666667
			30	176	46.22222222	3
		270	5	128	30.44444444	1.333333333
			10	160	52.33333333	1.666666667
			15	197.3333333	64.22222222	2.333333333
			20	149.3333333	49.55555556	1.666666667
			25	42.66666667	31.55555556	2.666666667
			30	218.6666667	51.11111111	2.333333333
	18	0	5	0	0	0
			10	0	0	0
			15	0	0	0
			20	0	0	0
			25	0	0	0
			30	0	0	0
		90	5	0	0	0
			10	48	4	0.333333333
			15	0	0	0
			20	0	0	0
			25	0	0	0
			30	0	0	1.666666667
		180	5	0	0	0
			10	0	0	0
			15	0	0	0
			20	0	0	0
			25	96	16.44444444	1.666666667
			30	53.33333333	13	1
		270	5	101.3333333	0	1.666666667
			10		0	
			15		0	
			20		0	
			25		0	
			30		32.1111	

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	19	0	5	0		0
			10	0		0
			15	0		0
			20	0		0
			25	0		0
			30	0		0
		180	5	0		0
			10	0		0
			15	0		0
			20	0		0
			25	0		0
			30	0		0
		270	5	0		0
			10	0		0
			15	0		0
			20	362.6666667		0
			25			
			30			
	20	0	5	0		0.666666667
			10	5.333333333		1.333333333
			15	341.3333333		0
			20	74.66666667		1.666666667
			25	304		0.666666667
			30	202.6666667		1.333333333
		180	5	0		0
			10	0		0
			15	0		0
			20	0		0
			25	0		0
			30	0		0

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	25	0	5	0	0	0
			10	0	0	0
			15	0	0	0
			20	96	26.22222222	0.333333333
			25	26.66666667	10.66666667	0
			30	90.66666667	16	0.666666667
		90	5	0	0	0
			10	0	0	0
			15	0	0	0
			20	0	0	0
			25	0	0	0
			30	0	0	0
		180	5	0	0	0
			10	0	0	0
			15	0	0	0
			20	0	0	0
			25	0	0	0
			30	0	0	0
		270	5	0	0	0
			10	0	0	0
			15	0	0	0
			20	0	0	0
			25	256	37.77777778	0.333333333
			30	112	48.66666667	0.333333333
	26	0	5	0		0
			10	0		0
			15	0		0
			20	0		0
			25	0		0
			30	0		0
		180	5	0		0
			10	0		0
			15	0		0
			20	0		0
			25	0		0
			30	0		0
	233	0	5	16	8	0.666666667
			10	149.3333333	29	1.333333333
			15	0	0	0
			20	117.3333333	49	1.666666667
			25	197.3333333	31	0.666666667
			30	277.3333333	26	1.333333333
		180	5	0	0	0
			10	0	0	0
			15	0	0	0
			20	0	0	0
			25	0	0	0
			30	0	0	0

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	235	0	5	10.66666667		0
			10	0		0
			15	0		0
			20	0		0
			25	0		0
			30	0		0
		180	5	0		0
			10	0		0
			15	0		0
			20	0		0
			25	0		0
			30	0		0
		270	5	0		0
			10	0		0
			15	0		0
			20	0		0
			25	0		0
			30	0		0
	249	0	5	128	13	0.333333333
			10	96	21.33333333	0.666666667
			15	176	18.33333333	1
			20	176	24.11111111	0.666666667
			25	245.3333333		0.333333333
			30	10.66666667		0
	250	0	5	298.6666667	37.77777778	0.666666667
			10	272	38.22222222	1.666666667
			15	106.6666667	28	0
			20	218.6666667	53.55555556	2
			25	245.3333333	54.66666667	0.666666667
			30	202.6666667	46.88888889	0.666666667
		90	5	16	17.33333333	1.333333333
			10	96	48	1.666666667
			15	128	62	1.666666667
			20	64	52.66666667	2.666666667
			25	117.3333333	67.33333333	1
			30	133.3333333	70.66666667	1.666666667
		180	5	69.33333333	11.33333333	0
			10	272	50.88888889	1.666666667
			15	325.3333333	51.11111111	2.666666667
			20	426.6666667	54.55555556	0.666666667
			25	170.6666667	49.11111111	1.666666667
			30	133.3333333	57.88888889	2.666666667
		270	5	277.3333333	40.66666667	1.333333333
			10	186.6666667	45.33333333	1.666666667
			15	272	49.66666667	1.666666667
			20	293.3333333	50.33333333	2.666666667
			25	202.6666667	63.33333333	1
			30	250.6666667	62	1.666666667

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	255	0	5	0	0	0
			10	0	0	0
			15	0	0	0
			20	0	0	0
			25	0	0	0
			30	0	0	0
		90	5	0	15.22222222	0
			10	0	0	0
			15	0	0	0
			20	0	0	0
			25	224	38.88888889	2.333333333
			30	0	28	0
		180	5	0	0	0
			10	0	0	0
			15	0	0	0
			20	0	0	0
			25	0	0	0
			30	26.66666667	14.88888889	0.666666667
		270	5	138.6666667	0	1.666666667
			10	0	0	0
			15	0	0	0
			20	0	0	0
			25	261.3333333	40	1.333333333
			30	250.6666667	0	3
	256	0	5	58.66666667	29.33333333	0.333333333
			10	106.6666667	24	0.333333333
			15	112	22.44444444	2
			20	352	65.77777778	3.333333333
			25	112	28.22222222	0.333333333
			30	16	5.555555556	0
		180	5	0	0	0
			10	0	0	0
			15	0	0	0
			20	0	0	0
			25	0	0	0
			30	0	0	0

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	257	0	5	0	0	0
			10	0	0	0
			15	26.66666667	12.88888889	0
			20	42.66666667	12.22222222	0
			25	64	20.77777778	0
			30	80	13.33333333	0
		90	5	0	0	0
			10	117.3333333	0	0
			15	74.66666667	31.33333333	0
			20	0	18.88888889	0
			25	0	0	0
			30	0	0	0
		180	5	0	0	0
			10	133.3333333	29.33333333	0
			15	165.3333333	26	0
			20	42.66666667	8.555555556	0
			25	112	20	0
			30	117.3333333	20.33333333	0
	265	0	5	74.66666667		1.333333333
			10	240		2.333333333
			15	208		3
			20	304		2.333333333
			25	240		2
			30	0		0
		90	5	0		0
			10	0		0
			15	0		0
			20	0		0
			25	0		0
			30	0		0
		180	5	165.3333333		1.333333333
			10	170.6666667		1.666666667
			15	128		2.333333333
			20	186.6666667		1.666666667
			25	0		0
			30	464		3.333333333
		270	5	112		1.666666667
			10	224		1
			15	298.6666667		2.666666667
			20	106.6666667		2
			25	181.3333333		1.666666667
			30	0		0

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	266	0	5	0	0	0
			10	0	0	0
			15	16	7.555555556	0
			20	0	0	0
			25	0	0	0
			30	0	0	0
		90	5	37.33333333	22.88888889	0
			10	0	33.77777778	0
			15	37.33333333	0	0
			20	0	6.555555556	0
			25	165.3333333	0	0
			30	117.3333333	9.888888889	0
		180	5	74.66666667	13.77777778	0.333333333
			10	85.33333333	27.55555556	0
			15	42.66666667	23.33333333	0
			20	53.33333333	6	0
			25	5.333333333	2.222222222	0.333333333
			30	64	18	0
		270	5	170.6666667	15.11111111	1.333333333
			10	122.6666667	43.55555556	0
			15	144	17.55555556	1.666666667
			20	160	46.88888889	0
			25	117.3333333	36.44444444	1
			30	16	61	0
	267	0	5	0	0	0
			10	0	0	0
			15	101.3333333	12.22222222	1.333333333
			20	0	0	0
			25	0	0	0
			30	0		0
		90	5			
			10			
			15			
			20			
			25	272		2
			30	48	0	1
		180	5	0	0	0
			10	0	0	0
			15	0	0	0
			20	309.3333333	50.11111111	3.666666667
			25	192	44.11111111	3.333333333
			30	224	43.55555556	2.666666667

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	269	0	5	250.6666667	38.55555556	0.666666667
			10	224	24.22222222	2.333333333
			15	288	43.33333333	1.666666667
			20	181.3333333	34.66666667	2.333333333
			25	160	37.88888889	2.666666667
			30	256		2.666666667
		180	5	122.6666667	47.88888889	0.333333333
			10	165.3333333	22	2.333333333
			15	213.3333333	41.77777778	3
			20	229.3333333	51.33333333	3
			25	341.3333333	59.33333333	1.666666667
			30	266.6666667	43.88888889	1.333333333
		270	5		55.55555556	
	270	0	5	117.3333333	46.44444444	2.666666667
			10	90.66666667	56.22222222	2.333333333
			15	144	42.22222222	1.666666667
			20	122.6666667	34	2.333333333
			25	0	0	0
			30	0	0	0
		90	5	154.6666667	24.66666667	1.666666667
			10	90.66666667	60	2.333333333
			15	90.66666667	62.88888889	2.666666667
			20	0	0	0
			25	53.33333333	26.44444444	0.666666667
			30	10.66666667	3.444444444	0
		180	5	0	0	0
			10	80	60	1.666666667
			15	0	0	0
			20	0	0	0
			25	96	28.88888889	1.333333333
			30	0	0	0
		270	5	106.6666667	40	2.333333333
			10	16	5.555555556	0
			15	165.3333333	39.88888889	2
			20	234.6666667	62.44444444	3
			25	170.6666667	60.77777778	2.333333333
			30	85.33333333	32.44444444	1.666666667

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	272	0	5	298.6666667	70.55555556	2
			10	304	70.44444444	2
			15	208	59.77777778	1.666666667
			20	117.3333333	58	2.666666667
			25	288	33.77777778	1.333333333
			30	197.3333333	12.66666667	1.333333333
		90	5	112	32.22222222	1.333333333
			10	149.3333333	45.55555556	2.333333333
			15	213.3333333	23.11111111	1.666666667
			20	0	40.44444444	0
			25	122.6666667	42.22222222	2
			30	16	45.66666667	0
		180	5	101.3333333	70.22222222	2.333333333
			10	106.6666667	72.44444444	2.333333333
			15	138.6666667	67.11111111	2.666666667
			20	80	61.33333333	1.333333333
			25	234.6666667	53	1.666666667
			30	154.6666667	57.33333333	1.666666667
		270	5	69.33333333	6.111111111	0.333333333
			10	112	53.77777778	1.333333333
			15	149.3333333	0	2.333333333
			20	0	60.22222222	0
			25	117.3333333	56	1.666666667
			30	26.66666667	27.55555556	0.333333333
	273	0	5	154.6666667	8	1.333333333
			10	192	24.44444444	1.666666667
			15	85.33333333	92.22222222	1.333333333
			20	117.3333333	64.88888889	0.666666667
			25	69.33333333	56.88888889	0.333333333
			30	16	67.33333333	0
		90	5	90.66666667	35.55555556	0.666666667
			10	85.33333333	44.88888889	1
			15	90.66666667	35.11111111	1
			20	0	0	0
			25	106.6666667	72	0.666666667
			30	154.6666667	66.88888889	0.666666667
		180	5	144	7.111111111	1
			10	144	58.44444444	1.333333333
			15	133.3333333	29.22222222	1
			20	80	63.22222222	0.333333333
			25	117.3333333	63.33333333	1.333333333
			30	21.33333333	28.11111111	0

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	307	0	5	58.66666667	25.33333333	2
			10	176	45.11111111	0.666666667
			15	69.33333333	37.77777778	0.333333333
			20	5.333333333	10.22222222	0
			25	0	0	0
			30	0	0	0
		90	5	106.6666667	27.77777778	2.666666667
			10	218.6666667	63.11111111	2.333333333
			15	90.66666667	56.44444444	0.333333333
			20	218.6666667	68.88888889	1.666666667
			25	58.66666667	36.66666667	2.333333333
			30	101.3333333	55.33333333	2.333333333
		180	5	5.333333333	1.111111111	0
			10	101.3333333	25.33333333	1
			15	117.3333333	28.44444444	1
			20	64	28.33333333	1.333333333
			25	90.66666667	26	1.333333333
			30	176	51.33333333	2
		270	5	170.6666667	58.44444444	0.666666667
			10	101.3333333	27.33333333	1.333333333
			15	74.66666667	27.11111111	0
			20	64	16.44444444	0
			25	0	0	0
			30	10.66666667	5.333333333	0
	308	0	5	133.3333333	19.33333333	2
			10	245.3333333	36	3.333333333
			15	229.3333333	30.66666667	3.333333333
			20	240	29.33333333	3
			25	309.3333333	54.44444444	2.666666667
			30	272	56.66666667	2.333333333
		180	5	144	26.66666667	1.333333333
			10	0	0	0
			15	314.6666667	46	2
			20	117.3333333	38.88888889	1.666666667
			25	245.3333333	52.88888889	2.666666667
			30	90.66666667	9.555555556	1.333333333
	251	0	5	0		0
			10	26.66666667	15.55555556	0
			15	37.33333333	21.77777778	0.666666667
			20	133.3333333	28.77777778	0.666666667
			25	117.3333333	21.77777778	0.333333333
			30	58.66666667	10.88888889	0

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	8	0	5	37.33333333	24.77777778	0
			10	90.66666667	22	0
			15	117.3333333	21.33333333	0
			20	202.6666667	28.11111111	1
			25	208	25.88888889	1
			30	245.3333333	32.33333333	2
		90	5	0	13.88888889	0
			10	0	22.77777778	0
			15	288	21.55555556	2.333333333
			20	341.3333333	34.55555556	2.333333333
			25	352	37.88888889	2.333333333
			30	234.6666667	33	1.333333333
		180	5	208	14	0.666666667
			10	234.6666667	20.44444444	1
			15	378.6666667	25.77777778	2.333333333
			20	261.3333333	32.11111111	0.666666667
			25	304		3
			30	202.6666667		1.666666667
		270	5	277.3333333	38.77777778	1.666666667
			10	149.3333333	38.66666667	0.666666667
			15	213.3333333	35.66666667	0.666666667
			20	117.3333333	19	0.666666667
			25	272	46.22222222	1.333333333
			30	282.6666667	58.11111111	1.333333333
	359	0	5	133.3333333	6.5	0
			10	314.6666667	19.55555556	0
			15	357.3333333	29	0
			20	250.6666667	24	0
			25	272	25.88888889	0
			30	336	24.44444444	0
		180	5	37.33333333	11.5	0
			10	170.6666667	21.83333333	0
			15	0		0
			20	0		0
			25	0		0
			30	64	17.66666667	0

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (2 anchor)	360	0	5	37.33333333	10.66666667	0.333333333
			10	138.6666667	22.66666667	0.333333333
			15	202.6666667	38.66666667	1.666666667
			20	170.6666667	31.11111111	0.666666667
			25	186.6666667	36.66666667	1.666666667
			30	218.6666667	44.33333333	2
		90	5	160	26.77777778	1.333333333
			10	165.3333333	26.22222222	2
			15	165.3333333	25.44444444	3
			20	74.66666667	34.44444444	2.333333333
			25	85.33333333		2
			30	112	26.66666667	2.333333333
		180	5	224	48.77777778	1
			10	256	41.66666667	1.333333333
			15	181.3333333	46.88888889	0.333333333
			20	96	28.55555556	0.333333333
			25	261.3333333	36.22222222	0.666666667
			30	186.6666667	31	0
		270	5	0		0
			10	0		0
			15	0		0
			20	0		0
			25	197.3333333	21	0
			30	234.6666667	32.55555556	0
	358	0	5	0		0
			10	0		0
			15	26.66666667	19.33333333	0.666666667
			20	213.3333333	35.88888889	3.333333333
			25	208	26.55555556	3.333333333
			30	208	22	3.666666667
		90	5	288	19.55555556	1.666666667
			10	0		0
			15	272	22.44444444	2
			20	293.3333333	17.11111111	2.333333333
			25	250.6666667	27.44444444	1.666666667
			30	213.3333333	19.11111111	2
		180	5	165.3333333	24.66666667	1
			10	202.6666667	29.22222222	2
			15	170.6666667	22.16666667	2
			20	213.3333333	26.33333333	2.333333333
			25	117.3333333	12	1.333333333
			30	352	26.66666667	3.333333333

Mooring Type	Mooring ID	Bearing	Distance from Mooring (m)	Average *Zostera marina* density (no. Shoots per m^2)	Average Canopy Height (cm)	Average Zostera marina wasting (no. Cells per $0.25m^2$ quadrat)
Mooring (Concrete Block)	271	0	5	85.33333333	42.22222222	0.333333333
			10	128	19.77777778	0
			15	74.66666667	38.33333333	0
			20	58.66666667	24.11111111	0
			25	0	0	0
			30	234.6666667	22.55555556	0
		90	5		0	0
			10	64	11.77777778	0
			15	112	9.333333333	0
			20	64	8.222222222	0
			25	69.33333333	6.111111111	0
			30	32	36.77777778	0
		180	5	37.33333333	21.66666667	0
			10	69.33333333	35.77777778	0
			15	144	46.77777778	0
			20	256	46.33333333	1.333333333
			25	90.66666667	36.88888889	0
			30	192	27.77777778	0
	362	0	5	21.33333333	26.44444444	0
			10	176	27	0
			15	69.33333333	16.88888889	0
			20	26.66666667	25.66666667	0
			25	42.66666667	19.55555556	0
			30	10.66666667	18.66666667	0
		90	5	85.33333333	18.66666667	0
			10	69.33333333	18.55555556	0
			15	85.33333333	19.44444444	0
			20	117.3333333	14.77777778	0
			25	85.33333333	19.33333333	0
			30	149.3333333	14.11111111	0.333333333
		180	5	37.33333333	19.33333333	0
			10	0		0
			15	0		0
			20	0		0
			25	0		0

Additional Arc GIS information

Calculating Sampling Station Coordinates

As mentioned within sthe methods section, all the surveyed moorings and control sites were marked using a Garmin GPSmap 60 handheld device. Due to practicality issues the GPS coordinates for all the sampling locations along each transect however could not be marked insitu and needed to be calculated after the survey. Using the GPS coordinates from the surveyed moorings and control sites, the GPS coordinates for all the sampling locations along the transects could be calculated based on a distance-bearing computation. Knowing the distance and bearing of each sampling station from the central datum each sampling station's coordinates could be calculated based on it's displacement from the central datum's. This was achieved by the following procedure; all coordinates of the surveyed moorings and control sites were converted from WGS 1984 format into the projected coordinate system OSGB 36. The following equation was then applied to the coordinates with the relevant bearing and distance figures input;

X displacement = distance (m) * SIN(Bearing) > New Latitude = Original Latitude + X displacement.
Y displacement = distance (m) * COS(Bearing) > New Longitude = Original Longitude + Y displacement.

Once all sampling positions were calculated they were converted back to WGS 1984. These data points were then populated in excel with all the survey data sourced from each sampling location, this attribute table was then input to Arc GIS v 9.2. This data then formed the basis for the data displayed within figures:6, 17-20, 21 & 22.

APPENDIX 2

Proforma recording sheet for volunteer divers – Sheet One: density and wasting

Proforma sheet for volunteer divers to record *Z. marina* density and wasting prevalence at each sampling station. Plus the depth, sediment type and any additional notes for each sampling station. This form was repeated 4 times on each recording sheet.

Name: **Date:** **Time:**
Mooring number:

Mooring Info
Include length of all chains plus direction labelled in diagram below

Distance from Datum	Direction from Datum	Depth (m)	*Z.marina* density per quadrat			*Z.marina* wasting per quadrat			Sediment type	Additional notes
			Q1	Q2	Q3	Q1	Q2	Q3		
5m										
10m										
15m										
20m										
25m										
30m										

Additional species observed along transect
Snake Pipefish, Wire Weed, Slipper limpets, Stalk jellyfish, Sea horses, Seeds or flowers

Any additional survey notes

Proforma recording sheet for volunteer divers – Sheet two: canopy height

Bearing	Distance	Q	Shoot Length		
0	5	1			
0	5	2			
0	5	3			
0	10	1			
0	10	2			
0	10	3			
0	15	1			
0	15	2			
0	15	3			
0	20	1			
0	20	2			
0	20	3			
0	25	1			
0	25	2			
0	25	3			
0	30	1			
0	30	2			
0	30	3			

Bearing	Distance	Q	Shoot Length		
270	5	1			
270	5	2			
270	5	3			
270	10	1			
270	10	2			
270	10	3			
270	15	1			
270	15	2			
270	15	3			
270	20	1			
270	20	2			
270	20	3			
270	25	1			
270	25	2			
270	25	3			
270	30	1			
270	30	2			
270	30	3			

Bearing	Distance	Q	Shoot Length		
180	5	1			
180	5	2			
180	5	3			
180	10	1			
180	10	2			
180	10	3			
180	15	1			
180	15	2			
180	15	3			
180	20	1			
180	20	2			
180	20	3			
180	25	1			
180	25	2			
180	25	3			
180	30	1			
180	30	2			
180	30	3			

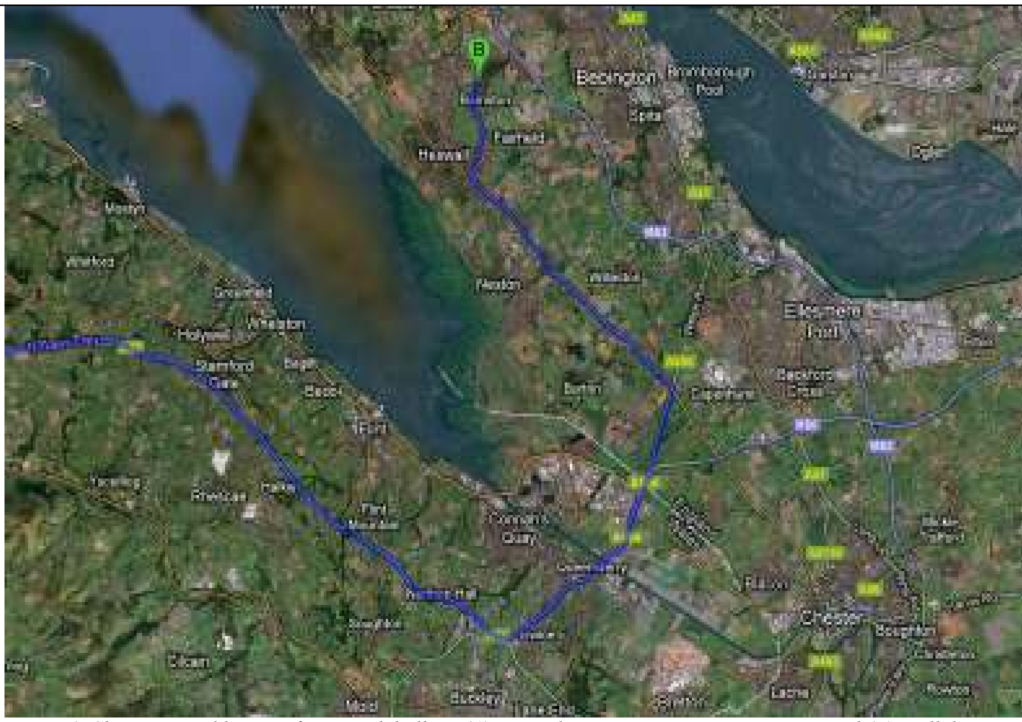
Bearing	Distance	Q	Shoot Length		
90	5	1			
90	5	2			
90	5	3			
90	10	1			
90	10	2			
90	10	3			
90	15	1			
90	15	2			
90	15	3			
90	20	1			
90	20	2			
90	20	3			
90	25	1			
90	25	2			
90	25	3			
90	30	1			
90	30	2			
90	30	3			

Table 2: Marine EcoSol's diving project plan for the Porthdinllaen seagrass monitoring project 2012

Decompression Sickness and Emergency Procedures

Survey Information		
Location	Porthdinllaen outer harbour, North Wales	
Proposed Dates	26th august, October 1st, 4th, 5th, 7th & 15th	
Location of Diving Operation	Porthdinllaen, Pen Llŷn a'r Sarnau SAC	
Purpose of Project	Surveying mooring size and type at Porthdinllaen, North Wales, and assess the impact of such moorings on eel grass, *Zostera marina*. Measuring *Z. marina* shoot density, Presence/absence of black spot disease and the abundance of Jap weed (*Sargassum muticum*) plus Snake pipefish (*Entelurus aequoreus*) with distance from the moorings.	
Name of Volunteer Co-ordinator	Thomas Stamp (Emergency First Response, 1st aid)	
Primary Contact and Contact Details	**Thomas Stamp**, Marine Ecological Solutions Ltd, 41 High Street, Menai Bridge, Anglesey, LL59 5EF Telephone: 01248 717437, Mobile: 07729060551 Email:Tom@marine-ecosol.com	
Volunteer Divers plus Qualifications:	Volunteer Name	Diving Qualification
	Antony Hughes	Padi: Dive Master
	Aribella Taylor	Padi: Rescue Diver
	Bernd Baufeld	CMAS ***
	Carol Horne	BSAC: Sports Diver
	Charles Ellis	Padi: Dive Master
	Chris Bridge	Padi: Dive Master
	Daniel Gill	Padi: Dive Master
	David Hartley	Padi: Assitant Instructor
	Dylan Jones	BSAC: Dive Leader
	Graham Cruikshank	Padi: Rescue Diver
	Jamie Mclean	Padi: Dive Master
	Jamie Ramday	Padi: Assistant instructor
	Jessica Lincoln	Padi: Rescue Diver
	Jonathon Easter	Padi: Dive Master
	Matthias Biber	Padi: Open Water Instructor
	Mathew Sargent	Padi: Rescue Diver
	Steven Barnard	Padi: Master instructor
	Robert Fairweather	Padi: Dive Master
	Victoria Greenhalgh	Padi: Open Water Instructor
Other Personnel and Duties	Paul Turkentine, Skipper of RIB Waterline	
Groups/persons to Contact Prior to Diving Operations Taking Place	**Prior to** **diving each day** call the following: RAF Valley: Ask for the main switchboard of "air traffic" and ask the following question exactly as written: "Do you know of any reason that your rescue helicopter can not take off today?" Telephone: 01407 762241. **Prior to and after diving each day** call Holyhead Coastguard to notify diving and ensure radio coverage is available (also mobile phone available from most coastal sites. Telephone: 01407 762 051. **Prior to and after each diving operation** notify Mike Davies (07766 880252) and if requested K. Fitzpatrick (07733 231008) that diving is taking place or has finished.	
Equipment Required:	Standard SCUBA + Surface Marker Buoy (SMB), Dive survey equipment: Tape measures, Quadrates, Compass, Recording sheets.	
Emergency Oxygen Equipment	All dive boats used by Marine EcoSol carry at least one emergency O_2 kit (e.g. 1 x D sized cylinder with a single demand-valve mask and constant-flow mask. Before leaving the port/launch site this should be checked to be present, full and working correctly, and that all personnel are familiar with its use. An additional 5 litre cylinder with 100% O_2 and a 12 litre cylinder with 80% O_2 will be taken onboard when operating further than 30 minutes from port / launch site, in case diver(s) need(s) emergency oxygen for an extended period beyond 30 minutes. When operating less than 30 minutes travelling distance from port/launch site, these additional oxygen cylinders are kept in a vehicle ready to be used during an evacuation nearest chamber using our own car.	
Special Competencies Required for Personnel	*All supervisors qualified as PADI Dive master/ CMAS level 3 or higher with first aid qualification. *All volunteers qualified as PADI rescue diver/ BSAC sports diver with a minimum of 60 logged UK dives, * All boatmen fully qualified and familiar with the boat, survey tasks and project sites in the area;	

DCS Symptoms	General Pain Skin Level of consciousness Hearing and vision Strength Co-ordination Bladder Pulmonary	Excessive fatigue, Joint, ear and chest pain, Itching, redness, marbling, Strange, speech and thoughts disorientated, difficulty speaking, Hearing loss, vertigo, tinnitus, visual impairment, Weakness in limbs, sensation, pins & needles, numbness, Poor balance, Incontinence, Cough, Shortness of breath, voice changes, Coughing up blood.
Casualty Evacuation Plan	In the event of any diving related injury, such as DCS, the following protocol will be followed; 1) Immediately contact emergency services on VHF channel **16** or **999** using a mobile phone, 2) Arrange the best place for the emergency services to pick the casualty up (helicopter lift from boat / shore / ambulance at shore), 3) Prepare casualty for pickup, have incident record information and diver emergency details (in emergency action plan written down to hand, and dive computers ready to be taken with casualty, 4) If the helicopter is unavailable and ambulance delayed the casualty may have to be driven from the nearest port or RIB launch site to meet the ambulance at an agreed half-way point between the dive site and the hospital. If the ambulance will be significantly delayed or is unavailable the casualty(s) should be driven directly to the recompression chamber. Maps of the fastest routes from each port/launch/dive site to the nearest recompression chamber are provided below, 5) Contact 0845 6026020 For Traffic Wales (instant traffic reports), In the event a helicopter is not available and an ambulance will be delayed there should be enough emergency oxygen to hand to allow the diver(s) to be transported by car to meet the ambulance at an agreed half-way point between the dive site and the hospital or recompression chamber. It is estimated that a 12 litre cylinder will last 2 divers 60 minutes breathing constantly.	
Emergency Services Contact	**999** or VHF channel **16**	
Recompression Chamber Details	HYPERBARIC MEDICINE, North West Emergency Recompression Unit, Murray field Hospital , Holmwood Drive, Hes CH61 1AU 24 hour telephone queries and emergencies **0151 648 8000**.	
Directions		

	 *Figure 1: Shortest possible route from Porthdinllaen (A) to North West Recompression Unit, Wirral (B). Full directions will be provided within emergency action plan. Google maps. 2012*
Shortest possible travel time from Porthdinllaen to North West Recompression Unit = **2 hours 16 minutes** (Google maps. 2012)	

APPENDIX 3: DATA ARCHIVE APPENDIX

Data outputs associated with this project are archived as Project No. [386] and Media No. [1475] on server–based storage at Natural Resources Wales.

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

- Stamp & Morris 2012 Porthdinllaen seagrass – survey of moorings in outer harbour Report.doc
- Stamp & Morris 2012. Porthdinllaen seagrass - survey of moorings in outer harbour Report.pdf

[B] A full set of maps produced in JPEG format.

- Figure 6. All survey locations.
- Figure 9. Moorings 26.08.2012,
- Figure 10. Moorings 01.10.2012,
- Figure 11. Mooring Density,
- Figure 12. MES surveyed moorings,
- Figure 14 NorthSouth divide Porthdinllaen Outer Harbour,
- Figure 22. Zostera marina density,
- Figure 23. Zostera marina canopy height,
- Figure 24. Zostera marina wasting,
- Figure 25. Sargassum muticum presence.absence,
- Figure 26. Staruromedusae presence absence,
- Figure 27. Zostera marina seeding.flowering

[C] A series of GIS layers on which the maps in the report are based with a series of word documents detailing the data processing and structure of the GIS layers

- All sampling points (shapefile includes all zostera marina density, canopy height and wasting data. Plus presence absence of species noted within the report),
- MES_Mooring_survey(26082012),
- MES_Mooring_survey(01102012),
- SEACAMS_Mooring_Survey,
- Unmapped area,
- Keep Pot Area Boundary.

[D] A full set of images produced in [*jpg*] format.

- Cover Image. Mooring Anchor Chain within Zostera marina (Barnard),
- Figure 1. Zostera marina wasting disease (Boese et al. 2008),
- Figure 4. 30m Tape Measure,
- Figure 4. Diver recording Slate,
- Figure 4. Quadrat,
- Figure 5. Diver methodology.

[E] Raw data as referenced in the report

- 20120605 Porthdinllaen Moorings
- 20120605 Porthdinllaen Seagrass data
- 20120605 Survey Coordinates

[F] Metadata

Metadata for this project is publicly accessible through Countryside Council for Wales' Library Catalogue http://www-library.ccw.gov.uk/olibcgi?infile=details.glu&loid=114836&rs=22986&hitno=1&straight_to_details=TRUE&tiarray=full. The metadata is held as record no [115560]