MAPPING MARINE BENTHIC BIODIVERSITY IN WALES

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CRYNODEB GWEITHREDOL

Mae'r Deyrnas Unedig wedi ymrwymo trwy gytundebau rhyngwladol a rhwymedigaethau Ewropeaidd i sefydlu rhwydwaith ecolegol gydlynol o Ardaloedd Gwarchodedig Morol i ddiogelu ecosystemau a bioamrywiaeth forol. Mae Llywodraeth Cynulliad Cymru wedi ymrwymo i ddefnyddio'r dynodiad newydd Parth Cadwraeth Morol a ddarperir yn Neddf y Môr a Mynediad i'r Arfordir i greu safleoedd y rhoddir lefel uchel o warchodaeth iddynt. Hefyd mae Deddf y Môr a Mynediad i'r Arfordir yn caniatáu ar gyfer sefydlu system o Gynllunio Gofodol Morol yn nyfroedd Cymru. Gallai adnabod mannau â llawer o fioamrywiaeth fod o gymorth ar gyfer cynllunio Ardaloedd Gwarchodedig Morol ac ar gyfer Cynllunio Gofodol Morol.

Gall cymunedau amrywiol ddarparu'r gallu i wrthsefyll tarfu amgylcheddol (Petchey & Gaston 2009); gall adnabod a gwarchod mannau lle mae llawer o fioamrywiaeth forol gyfrannu at ddull o reoli ein moroedd sy'n seiliedig ar ecosystemau. Hefyd, mae canfod pa ardaloedd sydd bwysicaf ar gyfer bioamrywiaeth nid yn unig yn creu buddion o ran cynnal strwythur a gweithrediad ecosystemau, gall hefyd ei gwneud yn bosibl blaenoriaethu ardaloedd ar gyfer gwarchodaeth forol mewn ffordd gost effeithiol. Mae'r astudiaeth gyfredol yn adeiladu ar waith astudiaethau blaenorol ar lefel y Deyrnas Unedig ac ar lefel ranbarthol (Hiscock & Breckels 2007, Langmead et al. 2008) i ddatblygu dull o adnabod mannau lle mae llawer o fioamrywiaeth forol a'i ddefnyddio ym moroedd Cymru.

Gellir mesur bioamrywiaeth mewn llawer o wahanol ffyrdd ac mae gan bob metrig ei dybiaethau, ei fanteision a'i gyfyngiadau. Mae dulliau a ddefnyddiwyd yn y gorffennol i asesu mannau lle mae llawer o fioamrywiaeth yn cael eu hadolygu er mwyn rhoi dealltwriaeth glir o'u perthnasedd i ddyfroedd Cymru a'r setiau data sy'n bodoli eisoes. Bu'n rhaid datrys nifer o gwestiynau wrth ddatblygu'r dull methodolegol gan gynnwys:

- Pa lefel o fioamrywiaeth i'w mesur (genetig, rhywogaethau, lefelau tacsonomig uwch, amrywiaeth o ran cynefinoedd)?
- Pa un a ddylid canolbwyntio ar grwpiau penodol fel dangosyddion neu brocsïaid (e.e. endemig, rhywogaethau neu gynefinoedd blaenoriaethol, setiau data wedi'u modelu) neu ddefnyddio rhestrau llawn o rywogaethau a chynefinoedd?
- Pa fetrigau i'w defnyddio gyda'r data sydd ar gael i gynrychioli amrywiaeth orau?
- Pa un a ddylid cyfuno mesurau ynteu eu cadw ar wahân?
- Pa raddfa ofodol i'w defnyddio ar gyfer yr uned cymhariaeth?
- Pa feini prawf ansawdd i'w cymhwyso i'r setiau data a ddefnyddir yn yr asesiad?
- Pa ddulliau i'w defnyddio i sicrhau'r duedd samplu leiaf posibl?

Arweiniodd hyn at ddatblygu dull i'w ddefnyddio'n benodol yn nyfroedd tiriogaethol Cymru. Roedd iddo bedwar cam allweddol: 1) casglu data ac asesu ansawdd; 2) asesu graddfa briodol i gelloedd y grid; 3) dadansoddi a chynhyrchu mesurau bioamrywiaeth; a 4) mesurau dilysu ac asesu hyder.

Casglwyd data ar rywogaethau a chynefinoedd rhynglanwol ac islanwol oddi wrth Gyngor Cefn Gwlad Cymru a Phorth y Rhwydwaith Bioamrywiaeth Cenedlaethol (Marine Recorder Snapshot), y cronfeydd data MarLIN a'r Data Archive for Seabed Species and Habitats data (DASSH). Hefyd darparodd Cyngor Cefn Gwlad Cymru fapiau bïotopau Cam 1 a data pwynt rhywogaethau rhynglanwol, a data arolwg SeaSearch. Cafodd data arolygon gwahanol eu mewnforio i gronfa ddata ddaearyddol. Cafodd y rhestr rhywogaethau lawn ei chymharu â Chofrestr Rhywogaethau Morol y Byd (WoRMS) a chafodd unrhyw rywogaethau nas adnabuwyd eu cywiro. Cafodd y rhestr derfynol ei chymharu â rhestr wedi'i golygu o ymgeiswyr Nodweddion Morol o Bwysigrwydd Cenedlaethol er mwyn canfod y rhai sydd wedi'u cofnodi yng Nghymru, a chafodd y codau bïotopau eu cymharu â chodau EUNIS. Gwnaethpwyd asesiad o addasrwydd y data hwn ar gyfer asesu bioamrywiaeth, gan ystyried ffynhonnell y data, ei oed, cywirdeb ac ansawdd gofodol, tacsonomig a methodolegol gan ddefnyddio'r meini prawf a nodir yn safon ISO 19115 ar gyfer metadata geo-ofodol.

Defnyddiwyd grid hecsagonal oherwydd y rhain sy'n cynnig y ffordd orau o alinio i nodweddion cymhleth, megis morlin Cymru. Aseswyd y raddfa briodol ar gyfer celloedd y grid trwy greu gridiau hecsagonal o wahanol feintiau ac wedyn ymholi am nifer y samplau ym mhob hecsagon ar bob graddfa. Y rheswm am hyn yw nad oes digon o samplau mewn gridiau bach i gael eu dadansoddi'n effeithiol, ac y collir manylion nodweddion mewn gridiau mawr, ac felly rhywle rhwng y ddau yw'r maint mwyaf priodol, ar sail cwmpas y data. Penderfynwyd mai'r maint optimaidd oedd 1km^2 yn y rhynglanwol ac 20km^2 yn yr islanwol, ond crëwyd grid ychwanegol o hecsagonau 10km^2 i gwmpasu'r ddwy ardal.

Y metrigau a gynigiwyd i gynrychioli bioamrywiaeth forol yng Nghymru oedd toreithrwydd rhywogaethau, toreithrwydd bïotopau, gwahanrwydd tacsonomig cyfartalog, gwahanrwydd bïotopau , a nifer y nodweddion blaenoriaethol. Cafodd pob mesur ei gyfrifo ar gyfer pob math o ddull samplu bras, ei ail-gyfuno yn ôl yr hecsagon, a'i gyflwyno fel haen wahanol ar raddfa barhaus. Yn ogystal cyflawnwyd y broses hon ddwywaith ar gyfer pob metrig; ymholwyd am y data a chawsant eu dadansoddi gan ddefnyddio grid hecsagonal arferol ac yna cafodd y broses hon ei hail-wneud gan ddefnyddio dull cymdogaethol (dadansoddi data o'r chwe hecsagon cyfagos ynghyd â'r un canolog) er mwyn canfod gwahaniaethau a all fod oherwydd nodweddion lleol iawn neu aliniad y grid ei hun.

Yn ogystal â'r meini prawf ansawdd a gymhwyswyd i setiau data, cafodd graddfeydd hyder wedi'u seilio ar ansawdd a maint y data a ddefnyddiwyd yn y dadansoddiad terfynol eu cyfrifo ar gyfer pob uned hecsagonal er mwyn rhoi golwg ar y data sylfaenol i'r defnyddwyr wrth ymchwilio i bresenoldeb mannau lle mae llawer o fioamrywiaeth. Roedd yr haen hyder hefyd yn nodi ble roedd rhywogaethau goresgynnol yn cyfrannu at y fan lle'r oedd llawer o fioamrywiaeth, trwy gymharu'r rhestr rhywogaethau ar gyfer dyfroedd Cymru â rhestr DAISIE o rywogaethau morol anfrodorol Ewropeaidd. Yn ogystal, cyfrifwyd yr amcangyfrifyn Chao2 ar gyfer pob hecsagon. Techneg yw Chao2 i allosod toreithrwydd rhywogaethau o nifer gyfyngedig o samplau ar sail y cysyniad mai rhywogaethau prin sy'n cario'r wybodaeth fwyaf am nifer y rhywogaethau coll; defnyddiwyd hyn i wirio am artiffeithiau mewn dadansoddiadau. Yn olaf defnyddiwyd dadansoddiad o gytundeb (gan ddefnyddio ystadegyn cydberthyniad Pearson's Product Moment) i feintioli annibyniaeth gwahanol fesurau.

Ceir llawer o amrywiaeth mewn nifer fawr o safleoedd rhynglanwol gan gynnwys Freshwater East (Sir Benfro), Bae Penrhyn (ger Llandudno), Porth Ruffydd (i'r gorllewin o Fae Trearddur), Ravens Point, Porth Llechog a dwyrain Bae Cemaes (Ynys Môn), Whiteshall Point (Bro Gŵyr) a Bae Langland (Gorllewin Morgannwg). Mesurwyd toreithrwydd isel rhywogaethau rhynglanwol ar gyfer llawer o'r ardaloedd rhynglanwol aberol (e.e. Hafren, Dyfrdwy, Mawddach a Glaslyn). Canfu'r ffwythiant llyfnu cymdogaethol wahanol ardaloedd toreithiog iawn o rywogaethau rhynglanwol gan gynnwys Ynys Skokholm, Penrhyn Mawr ar arfordir gorllewinol Ynys Môn, Frenchman's Bay ger St Ann's Head, arfordir deheuol Bro Gŵyr ger Overton ac Aberdinas yng ngogledd Sir Benfro. Cadarnhaodd yr amcangyfrifyn Chao2 hefyd statws amrywiaeth uchel safle Porth Ceris (Porthaethwy) ac mae yna hyder mawr yn y data ar gyfer y safle hwn. Mae'r amcangyfrifyn Chao 2 a'r haen hyder ill dau'n cefnogi'r mesur o amrywiaeth gymharol isel yn yr ardaloedd aberol.

Mewn cyferbyniad â thoreithrwydd rhywogaethau, canfuwyd y gwahanrwydd tacsonomig rhynglanwol uchaf yn yr aberoedd yn bennaf. Efallai bod hyn oherwydd, er eu bod yn brin o rywogaethau, ceir yn yr aberoedd rywogaethau o ffylogeneddau amrywiol, er y gallai hefyd fod oherwydd bod nifer y rhywogaethau yn y sampl yn cael dylanwad cryf ar y mesur. Mae gwahanrwydd tacsonomig uchel lle mae toreithrwydd rhywogaethau hefyd yn uchel yn ddangosydd da o ardaloedd amrywiol iawn. Mae ardaloedd o'r fath yn cynnwys Great Castle Head (Sir Benfro) ac ochr ddwyreiniol gwastadeddau Pwllcrochan (Aberdaugleddau). Roedd gan Ynys Sgomer un o'r crynodiadau uchaf o rywogaethau blaenoriaethol rhynglanwol; dim ond y rhai a gofnodwyd ar gyfer Pwll Ceris yn afon Menai oedd yn uwch. Hefyd roedd gan Ynys Sgomer gyfanswm toreithrwydd rhywogaethau amcangyfrifol uchel, Chao2, er na chafodd sgôr uchel yn nhermau toreithrwydd rhywogaethau na gwahanrwydd tacsonomig.

Ceir toreithrwydd rhywogaethau islanwol cymharol uchel o gwmpas y rhan fwyaf o arfordir Cymru, er bod ardaloedd aberol ar gyfer yr islanwol, fel y rhynglanwol, yn ymddangos yn brin o rywogaethau. Mae ardaloedd sy'n doreithiog iawn o rywogaethau yn cynnwys ardal i'r gogledd o Ynys Dewi ac un ger cornel ogledd orllewinol Ynys Môn (y ddwy â hyder uchel), ym Mae Caerfyrddin (hyder isel i ganolig) a rhannau o Fae Tremadog (hyder isel). Mae'n bosibl, hyd yn oed o fewn y dosbarthiad math dull arolwg bras, fod yna wahaniaethau mawr yn ansawdd yr arolygon ac mae'n bosibl bod hyn wedi arwain at ganfyddiadau annisgwyl megis ardaloedd ym Mae Caerfyrddin yn doreithiog iawn o rywogaethau, a Sgomer heb fod yn uchel yn nhermau toreithrwydd rhywogaethau.

Roedd y toreithrwydd tacsonomig ar gyfer yr islanwol yn adlewyrchu toreithrwydd tacsonomig y rhynglanwol ac yn dangos gwerthoedd uchel ar gyfer Aber Hafren, a hefyd Bae Caerfyrddin, gan ddangos na ellir defnyddio'r mesur hwn ar ei ben ei hun fel dangosydd amrywiaeth rhywogaethau. Y safleoedd mwyaf toreithiog ar gyfer rhywogaethau blaenoriaethol islanwol oedd Ynys Sgomer a rhannau o Aberdaugleddau. Ardaloedd pwysig eraill oedd dau safle ar benrhyn Llŷn (o gwmpas Ynys Enlli a ger Abersoch, gan gynnwys Ynysoedd Sant Tudwal).

Roedd toreithrwydd bïotopau'n arbennig o uchel yn yr ardaloedd rhynglanwol o gwmpas arfordir Ynys Môn (Moelfre, Bae Trearddur a Phwll Ceris yn afon Menai) a Sir Benfro (rhwng Traeth Trefdraeth ac Ynys Dinas, i'r de orllewin o Ynys Dinas a Phentir Sant Gofan). Mae'r holl ardaloedd ac eithrio rhai De Sir Benfro yn parhau i ymddangos fel y safleoedd mwyaf toreithiog pan ddefnyddiwyd llyfnu cymdogaethol, a ganfu safle arall ger Trwyn y Mwmbwls yn agos i Abertawe. Yn yr un modd â thoreithrwydd rhywogaethau, ymddangosai fod toreithrwydd bïotopau'n isel yn yr ardaloedd aberol.

Defnyddiwyd gwahanrwydd bïotopau rhynglanwol ar y cyd gyda thoreithrwydd bïotopau, ac mae'n dangos bod gan ardaloedd megis Aber Hafren amrywiaeth bïotopau is nag, er enghraifft, Sgomer ac Aberdaugleddau. Mae mapiau ar gyfer cynefinoedd blaenoriaethol rhynglanwol yn dangos bod yna o leiaf un cynefin blaenoriaethol ar arfordir Cymru bron i gyd. Mae'r ardaloedd â lefelau arbennig o uchel o gynefinoedd blaenoriaethol yn cynnwys Afon Menai (Pwll Ceris) Bae'r Foryd (ger Caernarfon) a rhannau o Aberdaugleddau a'r ddwy afon Cleddau.

Mae toreithrwydd bïotopau islanwol uchel yn amlwg yn rhannau uchaf aber Hafren i'r gogledd o'r bont ffordd, genau Aberdaugleddau, ac ardal ger Aberporth ym Mae Ceredigion, i'r de o Benrhyn Llŷn a nifer fawr o safleoedd o gwmpas arfordir Ynys Môn. Mae Bae Caerfyrddin, y rhan fwyaf o Aber Hafren a Bae Tremadog i gyd yn cael eu categoreiddio fel ardaloedd â thoreithrwydd bïotopau isel. Roedd y nifer isel o fïotopau wedi dylanwadu ar y gwahanrwydd bïotopau islanwol, fel ar gyfer y rhynglanwol, gan arwain at ymddangosiad lefelau uchel o wahanrwydd bïotopau mewn ardaloedd megis Aber Hafren a Bae Caerfyrddin. Defnyddiwyd mesur cyfun yn dangos yr ardaloedd lle mae toreithrwydd bïotopau uchel a gwahanrwydd bïotopau uchel yn digwydd gyda'i gilydd ac arweiniodd hynny at yr ardaloedd canlynol yn cael eu categoreiddio fel rhai ag amrywiaeth bïotopau islanwol uchel: yr ardal islanwol o gwmpas Ynys Môn, y dyfroedd ger Porth Neigwl ar Benrhyn Llŷn, y dyfroedd ger Aberystwyth, ger Aberporth ym Mae Ceredigion a Bae Abergwaun a Threfdraeth.

Mae'r ardaloedd pwysicaf ar gyfer cynefinoedd blaenoriaethol yn cynnwys pen gorllewinol Ynys Môn (Penmon, Ynys Seiriol), arfordir gogleddol Penrhyn Llŷn ac ardal i'r de o Benrhyn Llŷn sy'n cynnwys y môr ger Abersoch a Phorth Ceiriad, yn y môr ger Aberystwyth, rhannau o Aberdaugleddau a'r ddwy afon Cleddau a Sgomer. Mae toreithrwydd uchel cynefinoedd blaenoriaethol yn bennaf mewn ardaloedd agos at yr arfordir oherwydd y mathau o gynefinoedd sydd wedi'u cynnwys yn y rhestr hon.

Roedd y dadansoddiad o'r cytundeb yn dangos bod y rhan fwyaf o'r mesurau'n weddol annibynnol ar ei gilydd. Diddorol yw nodi bod yr amcangyfrifyn Chao 2 yn dangos rhywfaint o gydberthyniad cadarnhaol gyda thoreithrwydd bïotopau a thoreithrwydd rhywogaethau a rhywogaethau blaenoriaethol (er nad yw'n arwyddocaol) gan awgrymu y gall yr amcangyfrif hwn o gyfanswm toreithrwydd rhywogaethau fod yn offeryn defnyddiol wrth ganfod amrywiaeth gyffredinol. Mae hefyd yn ddiddorol nodi bod yr ardaloedd â nifer fawr o gynefinoedd blaenoriaethol â rhywfaint o gydberthyniad â'r rhai sy'n doreithiog iawn o rywogaethau blaenoriaethol. Ychydig o'r mesurau oedd yn cytuno â'r mesur gwahanrwydd bïotopau.

Mae'r adroddiad hwn yn dangos y nifer fawr o ddulliau sydd ar gael i adnabod ardaloedd â bioamrywiaeth uchel, yn nhermau'r mesurau a ddefnyddir, y raddfa yr edrychir arni a'r ffordd y gellir cyfuno neu holi'r haenau. Mae'r dadansoddiad o'r cytundeb yn dangos nad yw unrhyw fesur yn cipio pob agwedd ar fioamrywiaeth forol; yn wir, mae pob mesur yn cipio agweddau ychydig yn wahanol ar amrywiaeth. Felly, yng nghyd-destun defnyddio'r mapiau hyn i gynorthwyo ag adnabod safleoedd i leoli Ardaloedd Morol Gwarchodedig, dylid defnyddio mesurau lluosog, gan ddibynnu ar beth mae'r gwaith yn canolbwyntio. Er enghraifft, efallai y byddai mapiau rhywogaethau blaenoriaethol a thoreithrwydd cynefinoedd yn tynnu sylw at ardaloedd penodol lle byddai gwarchodaeth yn rhoi'r "gwerth gorau am arian". Yn yr un modd wrth sicrhau bod rhwydwaith o Ardaloedd Morol Gwarchodedig yn gynrychioliadol o'r holl gynefinoedd yn y rhanbarth, gellid defnyddio mapiau o doreithrwydd bïotopau i helpu i flaenoriaethu ardaloedd o restr o ddewisiadau posibl.

Os mai'r nod yw sicrhau bod lleoedd gyda chymunedau amrywiol yn cael eu hadnabod a'u gwarchod, mae'n bosibl y bydd yr amcangyfrifon Chao 2 sy'n mapio cyfanswm toreithrwydd rhywogaethau yn offeryn defnyddiol, gan yr ymddengys fod y dull dilysu hwn yn goresgyn rhai o broblemau ymdrech samplu a thuedd ansawdd nad yw dulliau eraill yn eu goresgyn. Nid oedd mesurau gwahanrwydd tacsonomig yn ystyrlon iawn o'u defnyddio ar eu pen eu hunain. Fodd bynnag, o'u defnyddio ar y cyd gyda thoreithrwydd rhywogaethau neu amcangyfrifon Chao 2 mae'n bosibl bod gwahanrwydd tacsonomig yn dangos ardaloedd lle mae cymunedau'n amrywiol yn ffylogenetig, rhywbeth a all fod yn gysylltiedig â swyddogaethau ecosystem.

Prif gyfyngiad y gwaith hwn yw, er gwaethaf y doreth o wybodaeth am rywogaethau a chynefinoedd sydd ar gael, nid yw'r data hyn yn cyfleu darlun llawn ac mae'n bosibl y bydd mwy o ardaloedd â bioamrywiaeth uchel yn cael eu datgelu wrth i arolygon gynnwys mwy o leoedd. Mae'r mapiau o ymdrech arolygu a hyder yn y data sylfaenol a gyflwynir yn yr adroddiad hwn yn offeryn defnyddiol ar gyfer adnabod ardaloedd sy'n cael blaenoriaeth ar gyfer ymdrech arolygu yn y dyfodol. Yn ogystal, mae'n bosibl y bydd angen ail-arolygu'r ardaloedd y nodir eu bod yn ardaloedd amrywiol iawn ond sydd wedi'u seilio ar ddata â hyder isel. Hefyd, mae'r amrywiaeth fawr o dechnegau arolygu a'r amrywioldeb wrth ddefnyddio'r technegau hyn yn arwain at broblemau wrth gyflawni asesiadau o fioamrywiaeth. Yn olaf, mae'r broses o adeiladu'r haenau hyn a thrafodaethau ar gynnyrch mapiau wedi tynnu sylw at bwysigrwydd safoni ar gyfer ymdrech wrth geisio mesur amrywiaeth gymharol, a all arwain at ganfyddiadau sy'n gwrthdaro â dirnadaethau cyffredin o batrymau amrywiaeth.

EXECUTIVE SUMMARY

The UK is committed through international agreements and European obligations to the establishment of an ecologically coherent network of Marine Protected Areas (MPAs) to conserve marine ecosystems and biodiversity. The Welsh Assembly Government has committed to using the new Marine Conservation Zone (MCZ) designation provided in the Marine and Coastal Access Act to create sites afforded a high level of protection. In addition the Marine and Coastal Access Act allows for the establishment of a system of Marine Spatial Planning in Welsh waters. The identification of areas of high biodiversity could be helpful for planning both Marine Protected Areas and for Marine Spatial Planning.

Diverse communities can provide resilience to environmental perturbations (Petchey & Gaston 2009); the identification and protection of areas of high marine biodiversity can contribute to an ecosystem-based approach to the management of our seas. Furthermore, identifying which areas are most important for biodiversity not only yields benefits for the maintenance of ecosystem structure and functioning but can also enable cost effective prioritisation of areas for marine protection. The current study builds on work from previous studies at a UK-wide and regional level (Hiscock & Breckels 2007, Langmead et al. 2008) to develop an approach for mapping marine benthic biodiversity and apply it to Wales' sea area.

Biodiversity can be measured many different ways and each metric has its own assumptions, advantages and limitations. Past approaches to biodiversity hotspot assessment are reviewed to give a clear understanding of their application to Welsh waters and the existing datasets. A number of questions had to be resolved in developing the methodological approach including:

- What level of biodiversity to measure (genetic, species, higher taxonomic levels, habitat diversity)?
- Whether to focus on specific groups as indicators or proxies (e.g. endemic, priority species or habitats, modelled datasets) or use full species and habitats lists?
- What metrics to employ with the available data to best represent diversity?
- Whether to combine measures or keep them separate?
- What spatial scale to use for the unit of comparison?
- What quality criteria to employ to the data sets used in the assessment?
- What methods to employ to minimise sampling bias?

This led to the development of a method specifically for application to the territorial waters of Wales. This comprised four key stages: 1) data collation and quality assessment; 2) assessment of appropriate scale of grid cells; 3) analysis and generation of biodiversity measures; and 4) validation measures and confidence assessment.

Data on intertidal and subtidal species and habitats were collated from the Countryside Council for Wales (CCW) and the National Biodiversity Network (NBN) Gateway (Marine Recorder Snapshot), the MarLIN databases and the Data Archive for Seabed Species and Habitats data (DASSH). CCW also provided intertidal Phase 1 biotope maps and species point data, and SeaSearch survey data. Distinct survey data were imported into a geodatabase. The full species list was matched against the World Register of Marine Species (WoRMS) and any unrecognised species corrected. The final list was matched against an edited list of candidate Nationally Important Marine Features (NIMF) to identify those recorded in Wales, while biotope codes were matched against EUNIS codes. An assessment of the suitability of these data for biodiversity assessment was carried out taking into account the source of the data, its age, spatial, taxonomic and methodological accuracy and quality using criteria set out in the ISO 19115 standard for geospatial metadata.

A hexagonal grid was used because they offer the best alignment to complex features, such as the Welsh coastline. The appropriate scale for grid cells was assessed by creating different sized hexagonal grids and then querying the number of samples in each hexagon at each scale. The

rationale for this is that small sized grids contain too few samples to be effectively analysed, while large sized grids lose the detail of features, and somewhere between the two is the most appropriate, based on the data coverage. The optimal size was determined as $1km^2$ in the intertidal and $20km^2$ for the subtidal, but an additional grid of $10km^2$ hexagons was created to encompass both regions.

The proposed metrics to represent marine biodiversity in Wales were species richness, biotope richness, average taxonomic distinctness, biotope distinctness and the number of priority features. Each measure was calculated for each broad sampling method type, re-combined by hexagon, and presented as a separate layer on a continuous scale. In addition this process was carried out twice for each metric; data were queried and analysed using a normal hexagonal grid and then this process was repeated using a neighbourhood approach (analyzing data from the adjacent six hexagons together with the central one) to identify differences that may be due to very localized features or the alignment of the grid itself.

In addition to the quality criteria applied to data sets, confidence ratings based on the quality and quantity of data used in the final analysis were calculated for each hexagonal unit to provide users with a view of the underlying data when examining hotspot occurrence. The confidence layer also flagged where invasive species contributed to the hotspot, by matching the species list for Welsh waters to the DAISIE list of European non-native marine species. In addition, the Chao2 estimator was calculated for each hexagon. Chao2 is a technique for extrapolating species richness from limited numbers of samples based on the concept that rare species carry most information about the number of missing species; this was employed to check for artifacts in analyses. Finally an analysis of concordance (using Pearson's Product Moment correlation statistic) was used to quantify the independence of different measures.

Results of the analyses are presented separately for the intertidal and subtidal and discussed for each measure. Intertidal species richness was highest at Freshwater East (Pembrokeshire), Penrhyn Bay (near Llandudno) and Ravens Point (Anglesey). Low intertidal species richness was measured for many of the estuarine intertidal areas (e.g. Severn, Dee, Mawddach and Glaslyn). The neighbourhood smoothing function identified different regions of high intertidal species richness including Skokholm Island, Penrhyn Mawr on the west coast of Anglesey, Frenchman's Bay near St Ann's Head, South coast of the Gower near Oveton and Aberdinas in North Pembrokeshire. The Chao2 estimator identified high diversity status of the Swellies (Menai Bridge) and there is high confidence in the data for this site. Both the Chao 2 estimator and the confidence layer support the measure of relatively low diversity in estuarine regions.

Contrasting species richness, highest intertidal taxonomic distinctness was found predominantly within estuaries. This may be because although species poor, estuaries contain species from diverse phylogenies, although it could also be due to the measure being strongly influenced by the number of species in the sample. High taxonomic distinctness where species richness is also high is a good indicator of highly diverse areas. Such areas include Great Castle head (Pembrokeshire) and the east side of Pwllcrochan flats (Milford Haven). Skomer Island had one of the highest concentrations of intertidal priority species, second only to those recorded for the Swellies in the Menai Strait. Skomer also had high estimated total species richness, Chao2, although it did not score highly in terms of species richness or taxonomic distinctness.

Relatively high subtidal species richness is found around most of the Welsh coast although, estuarine regions for the subtidal, like the intertidal, appear species poor. High species richness areas include an area north of Ramsey island and off the north western corner of Anglesey (both high confidence), in Carmarthen Bay (low to medium confidence) and parts of Tremadog Bay (low confidence). It is possible that even within the broad survey method type classification there were large differences in the quality of the surveys and this may have led to unexpected findings such as areas of Carmarthen Bay being highly species rich, and Skomer not featuring highly in terms of species richness.

Taxonomic richness for the subtidal resonated that of the intertidal and showed high values for the Severn Estuary, and also Carmarthen Bay, illustrating that this measure cannot be used in isolation as an indicator of species diversity. The most rich sites for subtidal priority species were Skomer Island and parts of Milford Haven. Other important areas were two sites on the Lleyn peninsula (around Bardsey Island and off Abersoch, including St Tudwal's islands).

Biotope richness was particularly high on intertidal regions around the coasts of Anglesey (Moelfre, Trearddur Bay and the Swellies in the Menai Strait) and Pembrokeshire (between Newport Sands and Dinas Island, south-west of Dinas Island and St Govan's Head). All but the southern Pembrokeshire areas continue to appear as the richest sites when neighbourhood smoothing was applied, which identified a further site at Mumbles Head near Swansea. Similar to species richness, biotope richness appeared low in the estuarine regions.

Intertidal biotope distinctness was used in combination with biotope richness, and shows areas such as the Severn Estuary as having lower biotope diversity in terms than for example Skomer and Milford Haven. Maps for intertidal priority habitats show there is at least one priority habitat on almost all the Welsh coast. Areas with particularly high levels of priority habitats include the Menai Strait (the Swellies), Foryd Bay (near Caernarfon) and parts of Milford Haven and the Daugleddau.

High subtidal biotope richness is evident in the upper reaches of the Severn estuary north of the road bridge, the mouth of Milford Haven, and area off Aberporth in Cardigan Bay, south of the Lleyn Peninsula and numerous sites around the coast of Anglesey. Carmarthen Bay, the majority of the Severn Estuary and Tremadog Bay are all categorized as having low biotope richness. Subtidal biotope distinctness, like that for the intertidal, was influenced by low numbers of biotopes, resulting in the appearance of high levels of biotope distinctness in areas such as the Severn Estuary and Carmarthen Bay. A combined measure showing the areas where high biotope richness and high biotope distinctness occur together was used and resulted in the following areas being categorized with high subtidal biotope diversity: the subtidal region around Anglesey, the waters off Hell's Mouth on the Lleyn Peninsula, the waters off Aberystwyth, off Aberporth in Cardigan Bay, and Fishguard and Newport Bay.

The most important areas for priority habitats include the western tip of Anglesey (Penmon, Puffin Island), the north coast of the Lleyn Peninsula and an area to the south of the Lleyn Peninsula encompassing the sea off Abersoch and Porth Ceiriad, offshore from Aberystwyth, parts of Milford Haven and the Daugleddau and Skomer. High richness of priority habitats are predominantly in near inshore areas due to the types of habitats included in this list.

The analysis of concordance showed that most of the measures were fairly independent of each other. Interestingly the Chao 2 estimator shows some positive correlation with both biotope and species richness and priority species (although not significant) suggesting that this estimate of total species richness may be a useful tool in identifying overall diversity. Also of interest is that areas with high numbers of priority habitats show some correlation with those of high priority species richness. Few of the measures showed any agreement with the biotope distinctness measure.

This report illustrates the large number of methods available for identifying areas of high biodiversity, both in terms of the measures used, the scale examined and the way in which the layers can be combined or interrogated. The analysis of concordance shows that no one measure captures all aspects of marine biodiversity; in fact each measure captures slightly different aspects of diversity. Therefore, in the context of using these maps to aid in the identification of sites for locating MPAs, multiple measures should be used, depending on the focus. For example, priority species and habitats richness maps might highlight specific areas where protection would give the most "value for money". Similarly when ensuring that a network of MPAs is representative of all habitats within the region, maps of biotope richness could be used to help prioritise areas from possible options.

If the aim is to make sure that locations with diverse communities are identified and protected, the Chao 2 estimates map of total species richness may be a useful tool as this validation method appears to overcome some of the issues of sample effort and quality bias that other methods do not. Taxonomic distinctness measures were not very meaningful when used in isolation. However, when used in combination with species richness or Chao 2 estimates taxonomic distinctness may indicate areas where communities are phylogenetically diverse which may be linked to ecosystem functions.

The primary limitation of this work is that despite the wealth of species and habitats information available, these data do not present a full picture and further areas of high biodiversity may be revealed with increasing survey coverage. The maps of survey effort and confidence in the underlying data presented in this report are a useful tool for identifying areas which are priority for future survey effort. In addition, areas which are identified has highly diverse areas but are based on low confidence data may need to be resurveyed. Also, the wide range of survey techniques and variability in applying these techniques leads to problems in carrying out assessments of biodiversity and may have incorrectly influenced the results in some places. The results of this work need to be interpreted with caution and with a full understanding of the limitations. Finally, the process of building these layers and discussions of the map outputs has highlighted the importance of standardising for effort when trying to measure relative diversity, which may lead to findings that conflict with common perceptions of diversity patterns.

1 INTRODUCTION

The UK is committed through international agreements and European obligations to the establishment of an ecologically coherent network of Marine Protected Areas (MPAs) to conserve marine ecosystems and marine biodiversity. The UK Government has also made a commitment under the Marine and Coastal Access Act to take forward a network of Marine Conservation Zones (MCZs) to conserve and promote the recovery of a wide range of habitats and species.

The Welsh Assembly Government has committed to using the new Marine Conservation Zone (MCZ) designation provided in the Marine and Coastal Access Act to create sites afforded a high level of protection. In addition, the Marine and Coastal Access Act allows for the establishment of a system of Marine Spatial Planning in Welsh waters. The identification of areas of high biodiversity could be helpful for planning both Marine Protected Areas and for Marine Spatial Planning.

There is growing evidence that biological diversity contributes to ecosystem resilience (Petchy & Gaston 2009), therefore the identification and protection of areas of high marine biodiversity may potentially contribute to the ecosystem-based approach to the management of our seas.

Identifying which areas are the most valuable for biodiversity may not only yield benefits for the maintenance of ecosystem structure and functioning but may also enable cost effective prioritisation of areas for marine protection. However, it is important biodiversity measures are used in conjunction with other aspects of the ecosystem-based approach to inform nature conservation, especially the development of measures that take account of habitat representation, species biology and the maintenance of ecosystem structure and functioning.

The current study builds on work previously undertaken for a WWF-UK study that identified benthic biodiversity hotspots at distinct locations around the UK (Hiscock & Breckels 2007) and an assessment of the biodiversity of the Firth of Clyde for the Scottish Sustainable Marine Environment Initiative (SSMEI) which applied hotspot techniques using equal-sized grid cells to map biodiversity hotspots (Langmead et al., 2008). Based on the specific species and habitats data available for the Welsh marine environment the current report proposes appropriate methods for mapping marine benthic biodiversity in Wales' territorial seas.

In general, most studies define areas of high biodiversity as areas with high levels of a single or combined measure representative of diversity. Whilst such simplistic approaches can synthesise lots of information into a less complicated form for management and planning, there is a risk that some of the finer detail is obscured. A clear understanding of the assumptions underlying the choice of measure and method are essential in identifying the limitations of the approach and the applicability of the hotspot layer. Therefore the following section reviews past methods and suggests methods applicable to the Welsh marine species and biotope data, based on preliminary assessments. Section 2 highlights the specific details of employing these methods to map Welsh marine benthic biodiversity.

2 SUMMARY REVIEW OF METHODS AND APPLICATION TO THE WELSH MARINE DATA

The main considerations when carrying out an assessment of benthic biodiversity follow.

- What level of biodiversity to measure (genetic, species, higher taxonomic levels, habitat diversity)?

- Whether to focus on specific groups as indicators or proxies (e.g. endemics[1], priority species or habitats, modelled datasets) or use full species and habitats lists?
- What metrics to employ with the available data to best represent diversity?
- Whether to combine measures or keep them separate?
- What spatial scale to use for the unit of comparison?
- What quality criteria to employ to the data sets used in the assessment?
- What methods to employ to minimise sampling bias?

In the following sections we review some of the past approaches to biodiversity hotspot assessments and examine their application to the available Welsh datasets. In Section 3 we outline the specific methodology employed for examining data quality and assessing spatial scale elements and also set out the proposed analyses (with examples where possible in order that some possible outputs can be assessed).

2.1.1 What to measure and what metrics to use?

Areas of high biodiversity defined using different metrics have shown a considerable lack of similarity (Orme et al. 2005), resulting in controversy over which to use. Biodiversity includes richness at all levels from landscapes to genes (Godfray & Lawton 2001, Gaston & Spicer 2004). An assessment of areas of high genetic diversity would be impractical at large geographical scales and the data do not exist. Within the range of ecological scale, species and habitats tend to be the most appropriate to identify areas of high biodiversity for conservation management (Ward et al. 1999), as they are familiar and need minimal interpretation or explanation when the information is shared with stakeholders. In addition species and habitats are the most commonly measured level and therefore there is greater data coverage

Species richness (the number of species at a given location) alone does not account for the spread in abundance of those species (a site with ten species but with one species dominating would be thought to be less diverse than one where all ten species were found in equal abundance but species richness alone will not identify this). However, measures of species richness or biotope richness have advantages over metrics that do account for spread such as *Pielou's evenness* index (Purvis & Hector 2000) or the Shannon Wiener (H') diversity index (which incorporates species richness and evenness) because they do not require abundance data. Although a large proportion of the datasets available for assessing marine benthic biodiversity in Wales have some measure of abundance, they vary significantly from simple counts, numbers per area (i.e. density) and semi quantitative abundance scales (e.g. SACFOR). Within each there will be differences, for example in methodology, which add a further level of variability and make standardisation very difficult. In addition, a significant proportion of the data only indicate presence/ absence of species. Species richness overcomes many of these issues although the influence of sampling effort must be considered (see section 2.1.3). *Sensu stricto* species richness should include all species occurring at a location, collated through exhaustive sampling, otherwise the measure is not representative and no comparison with another site (also exhaustively sampled) can be made. However due to the methods employed when surveying marine benthic habitats, many species groups are commonly misrepresented (e.g. meiofauna, microphytobenthos and fish). It is therefore necessary to apply criteria regarding which groups to include. The current study will examine the biodiversity of macrobenthic organisms excluding fish (due to the particularly patchy and inconsistent nature of the data for this group).

Legendre and Legendre (1998) make a case that "in principle, diversity should not be computed on taxonomic levels other than species". This is because the resources of an ecosystem are

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[1] Endemism (where a species is restricted to a particular area) is an important criterion to identify hotspots on land and in freshwater but is an unusual feature in the marine environment of the north-east Atlantic due to fewer and weaker barriers to dispersal, and there are no marine species believed endemic to anywhere in the UK.

apportioned among the local populations (demes) of the species present in the system, each species representing a separate genetic pool. Attempts at measuring diversity at supraspecific levels generally produce confusing or trivial results. However, diversity at high taxonomic levels is much greater in the sea where nearly all known phyla are represented and there are 14 phyla found only in marine ecosystems (Clarke & Warwick 2001). Comparing diversity measures between sites may therefore be facilitated by the higher-level diversity in marine ecosystems.

One way of overcoming the issues identified by Legendre and Legendre (1998) but still getting some idea of how diverse a system is at higher taxonomic levels is to employ measures based on Average Taxonomic Distinctness, which is based on species data, but captures the phylogenetic relatedness of the species in an assemblage (Clarke & Warwick 2001). It is calculated by summing the path lengths through a taxonomic tree connecting every pair of species in the list and dividing by the number of paths. Therefore a sample consisting of ten species from the same genus could be seen as much less biodiverse than another sample of ten species, all of which are from different taxonomic families. Unlike measures of species richness, the level of taxonomic relatedness is relatively robust to variations in sampling effort and funnel plots can be used to statistically assess departures from the expected. Phylogeny is highly related to the biological traits exhibited by species and taxonomic distinctness has been used as an indicator of the functional diversity structure of an assemblage and even related to ecosystem function (Graham et al. 2006, Cooper et al. 2008). Identifying high biodiversity areas using average taxonomic distinctness may also therefore be useful in indicating functional diversity.

It has been proposed that to be most effective for biodiversity conservation, measures should take account of the presence of rare or threatened species and habitats, although others may describe this as a target for fulfilling criteria of representativity under guidelines for designing networks of MPAs (Defra 2008). For example, Hiscock & Breckles (2007) used the following working definition:

> *"Marine biodiversity hotspots are areas of high species and habitat richness that include representative, rare and threatened features".*

The term 'hotspots' is also used for the occurrence of a single species, ecosystem services or productivity, but these types of hotspots are not hotspots of biodiversity. Similarly it can be argued that hotspots of the number of rare or declining species or habitats or other priority features are not hotspots of biodiversity. It is also assumed that by focusing on priority species there will be an effective umbrella for overall species richness of an area, which is not always the case (Bonn et al. 2002), although protecting structural or ecosystem engineer species may effectively protect other species. However, from a conservation management perspective, having priority features hotspot maps negate the need to visually process many separate maps of priority features (in Wales this would relate to 95 species and over 80 habitats, with the possibility of duplication due to different importance criteria used) when making decisions to cost effectively prioritise where, for example, MPAs should be located. Therefore in this study a separate assessment of priority species and habitat hotspots will be carried out, using a revised[2] list of Welsh Nationally Important Marine Features (see Appendix 3).

The variety of different habitats (often expressed as biotopes) in an area is another way of expressing biodiversity. The Britain and Ireland marine biotopes classification was developed by the Marine Nature Conservation Review of Great Britain (MNCR) as a contribution to the EU-funded BioMar programme. Biotopes are a pragmatic approach to identifying distinctive recurrent species assemblages in habitats with particular physico-chemical conditions (e.g. rocky

[2] The list of Nationally Important Marine Features (Hiscock et al 2006), was cross checked against species occurring in Wales, and reviewed by CCW project officers to remove irrelevant taxa.

vs. sedimentary substrata and different salinity and oxygenation regimes). However, assessing habitat diversity requires translation of all habitat data to a common classification schema. Standard translation tables have been set up for translating various classifications to the EUNIS[3] habitat-types classification scheme, making it the preferred choice.

OSPAR guidelines recommend classification of the marine environment to EUNIS level 3 where possible (which will be achievable with the predicted maps from MESH) “to reasonably reflect the variation in biological character of the habitats in the OSPAR area”. However, it is only at level 4 of the EUNIS classification that biological characteristics are considered. Depending on the level of classification for the data available (e.g. biotope to broad scale habitat) and the coverage of data (point records through to full coverage maps) different measures of biotope and habitat diversity may be appropriate.

It may be necessary to apply a common method across the area based on the lowest level of data quality, but apply more detailed measures for areas with higher quality data (e.g. full coverage biotope maps of the intertidal). For point data records of biotopes, a suitable diversity metric could be represented as the number of different biotopes per spatial unit standardised for sampling effort.

Full coverage biotope maps exist for the Welsh intertidal zone (Phase 1 intertidal maps), thus the number and area of each biotope or habitat within a spatial unit can be used to calculate a diversity index that accounts for the number and evenness of spread of biotopes within a unit. However, this would be highly influenced by the size and orientation of the area being examined and could give misleading results without employing roaming windows or neighbourhood statistics (see section 2.1.2). Habitat richness (the number of habitats) offers a standard measure that can be applied to all data sets, although sampling effort will need to be accounted for point data (see section 2.1.3).

Finally, since the EUNIS classification scheme is hierarchical, locations with biotopes from completely different habitat types can be considered more diverse than locations with biotopes that are similar (i.e. from the same biotope complex). From this a measure of biotope distinctness can be calculated which is fundamentally similar to taxonomic distinctness (Hiscock & Breckels 2007, Langmead et al. 2008).

Many studies combine a number of different measures (Reid 1998, Hiscock & Breckels 2007), for example, the number of endemic species in combination with areas of threatened or declining habitats (Myers et al. 2000). Combined scoring hotspot approaches have the advantage of combining different measures representative of priority features and diversity of features into one measure (where data allow) presenting the information as one relative rank of biodiversity importance for marine spatial planners to view. Alternatively, current GIS technology means that different biodiversity metrics (e.g. species richness, biotope distinctness, seabed type diversity etc.) and the distribution of priority species in respect to the various criteria could be held separately within a decision support tool. In the proposed approach for the Welsh marine biodiversity mapping assessment the layers will be kept separate. In addition there are problems with setting criteria for scoring areas as ‘hotspots’. By presenting the biodiversity layers on continuous scales in the present work rather than categorical scores, the layers will give CCW the flexibility to choose relevant levels.

Despite their advantages over other metrics, species and habitat richness metrics are highly dependent on scale and sampling intensity. It is important that the correct spatial unit is chosen and that data is standardised for sampling effort so that locations of more than expected levels of

[3] The EUNIS Habitat types classification is a comprehensive pan-European system to facilitate the harmonised description and collection of data across Europe through the use of criteria for habitat identification; it covers all types of habitats from natural to artificial, from terrestrial to freshwater and marine.

species or habitat richness, relative to sampling effort, are identified, not just the most intensively sampled areas.

2.1.2 Spatial scale considerations

The number of species present in any given area will be a function of the size of that area (McGuinness 1984). Spatial considerations are therefore important in identifying areas of high biodiversity. The first consideration regarding spatial scale is the area of search as this can influence the relative diversity scale, the species pool and the size of grid cell appropriate. Often the area of search is primarily dictated by management requirements or by large scale ecosystems. Even global assessments are often separated by realms (marine, freshwater, terrestrial). The current study is restricted to Welsh territorial seas (see Figure 1), including the intertidal up to or slightly above the mean high water mark (matching the extent of the intertidal Phase 1 survey data) and the whole of the Severn and Dee Estuaries.

Figure 1 Area of study which includes Welsh territorial seas (including the intertidal and the Severn and Dee Estuaries).

The selection of suitable spatial units for mapping biodiversity is dictated by the survey data resolution and spatial coverage but there may also be management implications to consider. Hiscock and Breckels (2007) promoted the use of areas that could potentially become manageable ‘units’, for example physiographic features (islands, embayments, estuaries, linear coastlines and sealochs). Others have utilized predetermined equal-area grid cells (Worm et al. 2003, Orme et al. 2005, Langmead et al. 2008). The current work will use the latter, to compare areas of equal size.

Ideally a small grid is preferable for identifying potential Marine Protected Areas but it is unlikely that there will be sufficient data coverage to allow this in all areas. Within Wales there are huge differences in spatial resolution of the data between the intertidal and the subtidal; therefore consideration of different scales is appropriate. For the present study it was proposed that the analysis of biodiversity should be separated into the intertidal and subtidal zones to reflect spatial resolution of the data, and that a finer scale should be used for the intertidal. In addition, we proposed that a "one-size-fits-all" layer is also provided, encompassing both zones to give a comparable hotspot layer, which can be used to identify areas where areas of high biodiversity may extend above and below the low water mark.

The shape of the equal-area grid also needs to be taken into consideration. Hexagonal units are commonly used for spatial planning (Bassett & Edwards 2003, Worm et al. 2003, Oetting et al. 2006) because they offer the best alignment to complex features such as the UK coastline, ensuring a better level of coverage. But even at small scale and using hexagons, some grid cells will be dissected by the coastline, making them no longer of equal size. In the Welsh intertidal, cell sizes may vary based on the layout of the grid and the tidal boundaries, with some areas being very thin slither sections of cells and others entire cells.

Whilst this would, at first, suggest that some standardisation by area is required, because the size and shape of the cell actually reflects the profile of the intertidal region and the type of habitat, standardisation by area would give spurious outputs. For example, thin sections of intertidal tend to be rocky shores or cliffs where the numbers of biotopes are likely to be high whereas wider sections tend to be sedimentary shores with a lower number of biotopes per area.

Irrespective of the size and shape, using a grid cell approach can result in an output which contains bias and artefacts based on where the grid was placed. Using overlapping/roaming grid squares or neighbourhood statistics are methods developed to overcome this bias created by the location of the grid, and also scale dependent issues. Neighbourhood statistics involve combining data from surrounding cells into the central focal cell, thus the final value of each cell is influenced not only by the data underlying that cell but also by its direct neighbours.

2.1.3 Data quality and standardisation

Estimates of biodiversity are dependent on the state of current knowledge, and hence data coverage. Equally important is the fact that estimates of current distribution of species and biotopes are dependent on sampling or survey effort, and on the age of the dataset concerned. The basic approach to mapping biodiversity should therefore compensate for sample intensity to give an estimate of relative biodiversity in areas where the data meets set criteria in terms of quality and quantity for the analysis. Setting criteria for the inclusion and rejection of datasets is therefore crucial for carrying out an objective, defendable assessment upon which evidence-based decisions can be made. An assessment of the suitability of the data for biodiversity assessment and mapping of benthic biodiversity should take account of the source of the data, its age, spatial, taxonomic and methodological accuracy.

Other sources of variability, such as spatial patchiness, will be accounted for in the selection of the size of spatial units. For areas with extremely low numbers of surveys, it may be necessary to omit them altogether and set a lower limit to the number of surveys per spatial unit. For the current study we propose that a minimum of three samples should occur within a cell in order for it to be included in diversity analyses. In addition, it is important that individual sightings records should be left out of diversity analyses, particularly those analyses that incorporate statistical techniques for minimising sampling bias (see below) as these would distort results (one sample equating to only one record).

Various statistical techniques are available to minimise or remove sampling effort bias, for example rarefaction (Worm et al. 2003), regression (Hiscock & Breckels 2007, Langmead et al. 2008) and Monte Carlo analysis (Moulins et al. 2008). But prior to analyses some of the more inherent bias may come from the way samples were gathered (methods) or the fact that some physiographic features are intrinsically more biodiverse than others. Sub-setting data to allow like-with-like comparisons is one approach to standardization. Splitting analyses at large scales e.g. by realm (as proposed in the previous section) will help overcome these inherent biases. But even within these, data may be collected very differently. Samples collected using a benthic core and sieved using a 0.5 mm sieve are likely to have greater diversity than samples collected using a trawl. Sampling methods and effort will vary markedly depending on the physiographic feature surveyed, so by adopting the approach of Hiscock and Breckels (2007) this source of bias may be minimised, alternatively samples can be separated into broad method types. The latter approach has been adopted in this study (see Section 3.3).

We propose using a linear regression technique to standardize for sampling bias, with richness correlated with sampling intensity by grid cell (partly because rarefaction techniques require abundance data, not fully available in the current assessment). Regression plots can be generated for each broad sampling method type together with 95% confidence intervals to indicate where 95% of the data would fall if measurements were repeated. Each grid cell can then be scored based on the position relative to these confidence intervals. Using this method, proposed and employed by Hiscock and Breckels (2007), if a location fell within the confidence intervals, it would be assigned a score of 2, if it fell below the lower confidence limit, it would be considered to be poor for that richness measure and assigned a score of 1. Locations that fell above the 95 % confidence limits would be considered to have high values for the particular richness measure and assigned a score of 3. As an alternative to this, using the residuals from the regression analysis, the relative position for each cell (by sampling method), can be determined and translated to a value on a continuous scale based on where it lies in the regression (i.e. the confidence that that particular hexagon is part of the population). The measure of average taxonomic distinctness (and the adapted version for biotope distinctness) has the advantage that the funnel plots can be used to statistically assess departures from the expected. Rather than scoring, once again, the residuals and confidence limits of the funnel plot can be used to provide values indicating unusualness of any particular cell on a continuous scale.

3 METHODOLOGY

3.1 Data collation and quality assessment

Available species and biotope information was collated from CCW and the National Biodiversity Network Gateway (Marine Recorder Snapshot from the Joint Nature Conservation Committee, JNCC). Species and biotope information in the format of a Marine Recorder snapshot (September 2008) was provided by CCW and included data collected and collated by CCW and also data supplied to CCW by JNCC. The Marine Recorder database covers both subtidal and intertidal surveys. Approximately 365 surveys are held on the database. MarLIN databases and any additional data holdings within the Data Archive for Seabed Species and Habitats data[4] (DASSH) were also used.

CCW also provided intertidal Phase 1 biotope maps and species point data (Wyn et al. 2006, Hiscock & Breckels 2007), and five additional Seasearch surveys that had not, at that point in time, been incorporated into the main dataset. The Phase 1 biotope maps contain details of biotopes, life forms, specialised and nationally important biotopes, presence of artificial substrata and priority habitats. In addition, the intertidal Phase 1 survey derived species GIS layer contains details of the species recorded for a whole survey site, for specific biotopes and from target notes. The details contained are: species name and NBN code, site name, precision, OS grid reference and data source.

The CCW supplied data survey names and keys were queried against a snapshot of the JNCC marine recorder (10/12/2007), a MarLIN snapshot (13/03/2008) and surveys from DASSH. Surveys duplicated in either database were removed so that only distinct survey data were imported into a geodatabase. CCW, JNCC, MarLIN and DASSH sourced data were loaded into

[4] Includes data from the Coastal Surveillance Unit (CSU) database

an individual feature class in GIS. The final geodatabase contained 223,742 species records (12,270 samples from 320 surveys) and 8,641 biotope records (4,935 samples from 142 surveys).

MapInfo files were converted into ArcGIS shapefiles and the biotope polygon files were appended into one feature class of the whole region. The Phase 1 species data were imported into the point species layer[5]. Duplicate data were removed (e.g. *Sargassum* data and *Sabellaria* polygons). All data were clipped by the supplied boundary. Some of the biotopes in the intertidal polygon layer were tagged as 'Artificial' (i.e. sea walls, groynes, piers etc) and these polygons were removed from the layer. All the data were then cropped using this intertidal layer to delimit the landward extent of the study region. Once complete, the full species list was exported from the GIS. The species list was reviewed and any abbreviations removed (e.g. "sp.", "cf." or "indet.") to allow recognition by WoRMS (World Register of Marine Species, www.marinespecies.org). The whole list was matched against WoRMS and any species not recognised (due to spelling mistakes and synonym differences) were checked and matched manually. A definitive table of the original recorded species name and the matched WoRMS names and phylogeny was produced. Phyla not included in these analyses[6], records which were entered only to family level or higher, and invalid names which could not be matched to a valid name were omitted from the analysis. The final list was matched against an edited list of candidate Nationally Important Marine Features (NIMF) to identify those recorded in Wales.

Biotope codes were matched against EUNIS codes. Biotopes in 97.06 format were manually matched to 04.05 biotopes prior to EUNIS translation. In some instances the code could not be accurately matched to the same level, and a higher level code was assigned.

An assessment of the suitability of data for biodiversity assessment and mapping of biodiversity was carried out, taking into account the source of the data, its age, spatial, taxonomic and methodological accuracy. Data were also graded on survey quality using the following three categories with respect to field surveyors: professional and academic; volunteer with expert ID; and volunteer. Quality assurance of datasets used criteria set out in the ISO 19115 standard for geospatial metadata (ISO 2006) and using guidelines from Rackham and Walker (2006) (Table 1). Derived confidence ratings were recorded in the metadata and low quality data were flagged and removed from subsequent analyses.

Table 1 Quality assessment (QA) criteria.

Level	Spatial accuracy	Taxonomic accuracy	Methodological consistency	Temporal Accuracy	QA procedure	Overall QA
High	Accurate positioning system used, i.e. GPS, dGPS. Spatial reference system.	Surveyors with expert knowledge, surveyors accredited e.g. NHM trained, or record verified by taxonomic expert, few errors expected	Standard methodology used and documented in detail	Accurate dates and times available for all records.	Rigorous internal (and possibly external) QA procedures documented	Very high quality data, internally quality assessed, high confidence of accuracy of position and species identification of all records.
High-Medium	Positions estimated from charts or OS maps by surveyor but with reference	Trained surveyors with good natural history background, a small number of potential errors in	Standard methodology used and documented in detail, some minor details	Most records have accurate date (and time if appropriate),	Data Collection QA procedures In place, including training of data collectors and use of standardized	High quality data, Most data with high confidence of accuracy of position and species

[5] Phase 1 species data with source labelled 'Site' was removed from the analyses to avoid replication, because this data represents a collated species list from the other records for that site.

[6] Pelagic organisms (including planktonic), highly mobile species, meiofaunal groups where removed from the analysis due to the high variability in sampling effort and level of identification.

Level	Spatial accuracy	Taxonomic accuracy	Methodological consistency	Temporal Accuracy	QA procedure	Overall QA
	to easily identifiable features and detailed descriptions.	difficult to identify groups.	unclear.	but some records may be recorded to month only.	methodologies. Post processing QA of data on a more ad hoc basis not necessarily documented or standardized	identification.
Medium	Positions estimated from charts or OS maps by surveyor	Surveyors with good natural history background potential errors in difficult to identify groups.	Standard methodology used but not supported by full documentation	All records recorded to minimum of month and year but often not to day.	Some internal (or external) QA on a more ad hoc basis not necessarily documented or standardized	Good quality data, may lack internal QA, full documentation or may have some spatial/ taxonomic ambiguity
Medium-Low	Positions estimated by third party from map and descriptions from surveyor.	Volunteer, other non-expert surveyors errors possible for non-common and easy to identify species	Indications that a standard methodology was used but poorly documented.	Some dates recorded to month and year but many only recorded to month range e.g. summer 1984 or year only.	It is possible that some ad hoc internal (or external) QA has taken place during data collection, e.g. verification of species Identification but no documentation available and it is unlikely that post processing QA has occurred.	Some good quality data present but lacking internal QA, and/or full documentation Inaccuracies expected in a number of records.
Low	Description only. Positions estimated from charts or OS maps by third party[1]	Volunteer/ other non-expert surveyors errors possible for non-common and easy to identify species	No information on methodology or indications that no set methodology was used, this includes records from casual observations.	Only vague dates recorded. Large date ranges e.g. summer 1984, year only or year ranges e.g. 1977-1979.	No QA procedures documented, ad hoc QA unlikely.	Data with spatial/ taxonomic ambiguities and/or little documentation
Data deficient	Insufficient information available to make an assessment.	Insufficient information available to make an assessment.	Insufficient information available to make an assessment.	Insufficient information available to make an assessment.	Insufficient information available to make an assessment.	Insufficient information available to make an assessment.

[1] Data Archive for Seabed Species and Habitats (DASSH)

The spatial distribution of data by sample density across the study area can be seen for species in Figure 2. Surveys which scored an overall quality level of low/medium and above were included in the assessment (see Appendix 1). Appendix 2 gives a list of those surveys removed due to quality criteria not being met.

3.2 Assessing appropriate spatial scale of grid cells

Hexagonal units are proposed for the spatial grid because these are most commonly used for spatial planning (Bassett & Edwards 2003, Worm et al. 2003, Oetting et al. 2006), and because they offer the best alignment to complex features, such as the Welsh coastline, ensuring a better level of coverage.

The Welsh boundary layer provided by CCW was altered to remove most of the land to increase speed with which the hexagon layer was drawn. The intertidal, subtidal and land areas were identified and separated, using the relevant dissolved biotope polygon.

Then the hexagon grid layers were created at five spatial scales, 1, 5, 10, 15 and 20km^2, and the number of samples included in each hexagon at each scale was queried in GIS, in order to examine the most appropriate scale for the available data, as a minimum three samples were required per cell to include the cell in the analysis. Hexagons of 1, 5, 10 and 15km^2 hexagons were used in the intertidal, while 5, 10, 15 and 20km^2 hexagons were used for the subtidal and whole region (with land removed).

Table 2 Description of sample numbers, percentage inclusion and area covered at different cell sizes for the subtidal and the intertidal based on species data (values given for all data and for medium quality and above data). The maximum neighbourhood area accounts for the area of the focal cell and its neighbouring cells assuming all are intact.

Cell size km^2	**Total number of cells**	**Mean no. of samples per cell**	**s.d.**	**Number of blank cells**	**Area blank**	**Proportion of cells used in analysis (>3 samples)**	**Maximum neighbourhood area**
Intertidal							
All data							
1	2607	5.18	8.90	1099	1099	31.80	7
5	879	11.48	16.97	199	995	56.88	35
10	555	16.94	25.52	94	940	66.67	70
15	437	21.34	30.98	71	1065	71.62	105
Medium and high quality data only							
1	2607	4.77	8.62	1139	1139	29.73	7
5	879	10.46	15.95	209	1045	55.52	35
10	555	15.40	23.76	100	1000	65.77	70
15	437	19.25	29.14	73	1095	70.94	105
Subtidal							
All data							
5	4049	6.31	15.26	3057	15285	11.11	35
10	2146	8.58	20.34	1416	14160	18.22	70
15	1494	10.67	25.48	907	13605	23.96	105
20	1147	12.60	29.93	650	13000	27.11	140
Medium and high quality data only							
5	4049	5.77	13.34	3081	15405	10.40	35
10	2146	7.79	17.49	1430	14300	17.52	70
15	1494	9.66	21.55	916	13740	23.16	105
20	1147	11.34	24.77	655	13100	26.42	140

s.d. = standard deviation

The number of distinct species and biotope sample points were queried using models built in ArcMap™. Distinct samples were identified using latitude, longitude, date, replicate identification, method and survey key. Queries were carried out for all surveys then repeated for surveys categorised as medium quality and above, with the exception of subtidal biotope samples which were all high quality. Table 2 and Table 3 summarise the outputs of these queries for species and biotopes respectively, and Figures 2 to 5 illustrate the spread of samples within the different sized scales for the subtidal.

Since the width of the intertidal in many regions was less than 1km and there is a management preference for 1km^2 grids for the intertidal, we examined whether a 1km^2 grid (compared to the larger sized grids) would meet the criteria of including a minimum of three samples. A 1km^2 grid in the intertidal gives an average of 4.77 samples per cell (s.d. 8.62) with only 32% of the hexagons included in the analysis (although using neighbourhood statistics would increase this value to almost 60%). Figure 6 shows an example of 1km^2 scale for the intertidal. Due to the difficulties in viewing the 1km^2 scale within printed reports, the shore was sub-sectioned at appropriate scales based on the broad habitat type with the proviso that European Marine Sites and landscape features such as bays and estuaries will not be sub-sectioned.

For the subtidal, a combination of sparse data (particularly for biotope data, see Table 3) and greater homogeneity in habitats means that even at large scales (e.g. a 20km^2 grid) only 19% of cells can be used, although again this proportion would increase by employing neighbourhood statistics. However, to use even larger sized cells would only result in greater interpolation of sparse data, and ultimately reduce the overall confidence in identifying areas of high biodiversity. Since the underlying sample points are viewable within GIS, areas highlighted as potential areas of high biodiversity at this scale can be further examined to see the actual samples that underpin the interpolation.

Table 3 Description of sample numbers, percentage inclusion and area covered at different cell sizes for the subtidal based on available biotope data.

Cell size km^2	**Total number of cells**	**Mean no. samples per cell**	**s.d.**	**number of blank hexagons**	**Area blank**	**Proportion of cells used in analysis (>3 samples)**	**Maximum neighbourhood area**
5	4049	4.14	7.79	3374	16870	6.89	35
10	2146	5.55	10.15	1643	16430	11.93	70
15	1494	6.90	12.37	1089	16335	16.47	105
20	1147	8.31	14.02	811	16220	19.18	140

A 10km^2 “one-size-fits-all” hexagonal grid was also applied across the intertidal and subtidal. For the subtidal, this size was too small to meet the minimum three samples in more areas (resulting in more gaps than at the larger scale) and in the intertidal finer detail was lost at this scale (compared with the 1 km grid).

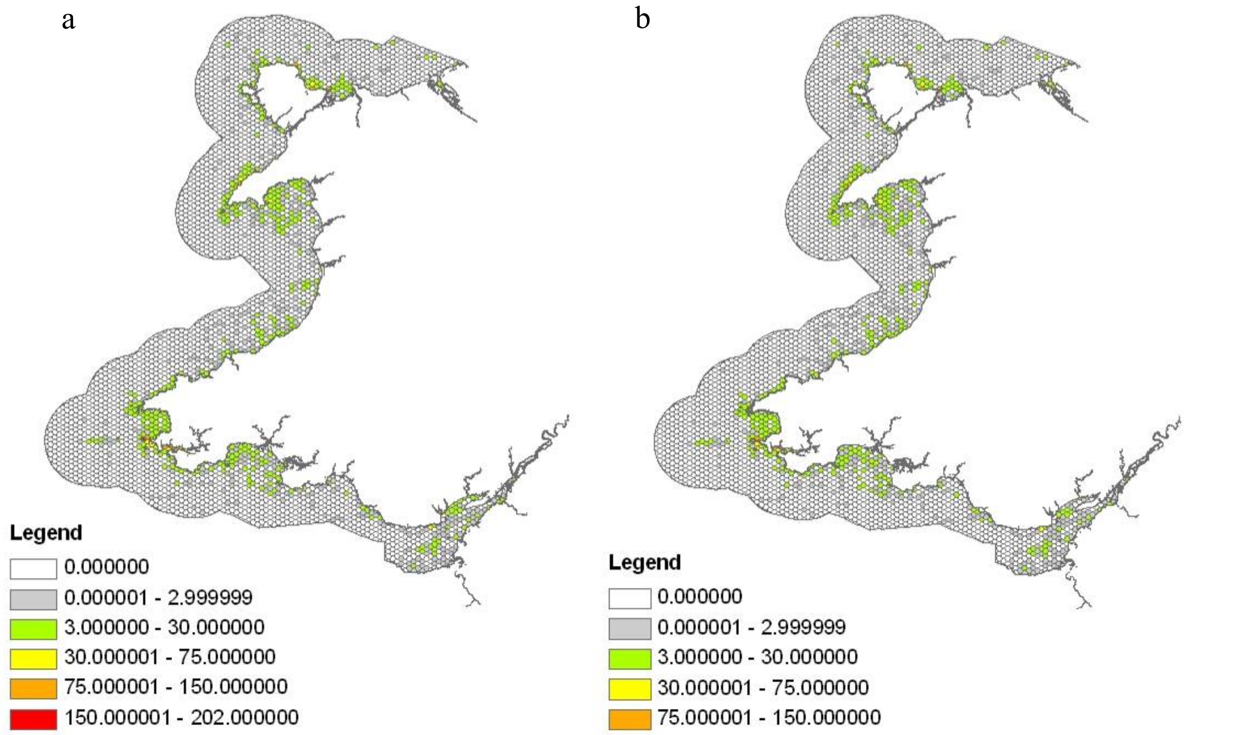


Figure 2 Number of unique species samples available within $5km^2$ hexagon grid for subtidal Welsh waters, using (a) all surveys and (b) surveys categorised as medium and above quality.

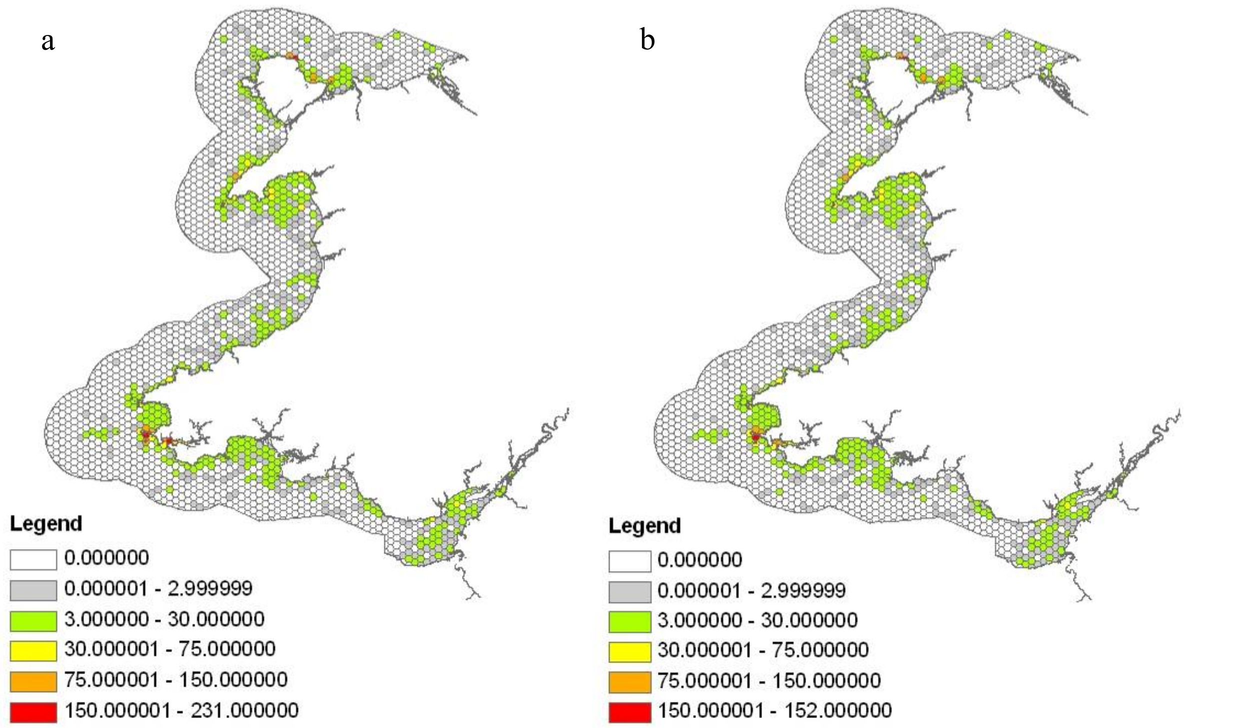


Figure 3 Number of unique species samples available within $10km^2$ hexagon grid for subtidal Welsh waters, using (a) all surveys and (b) surveys categorised as medium and above quality.

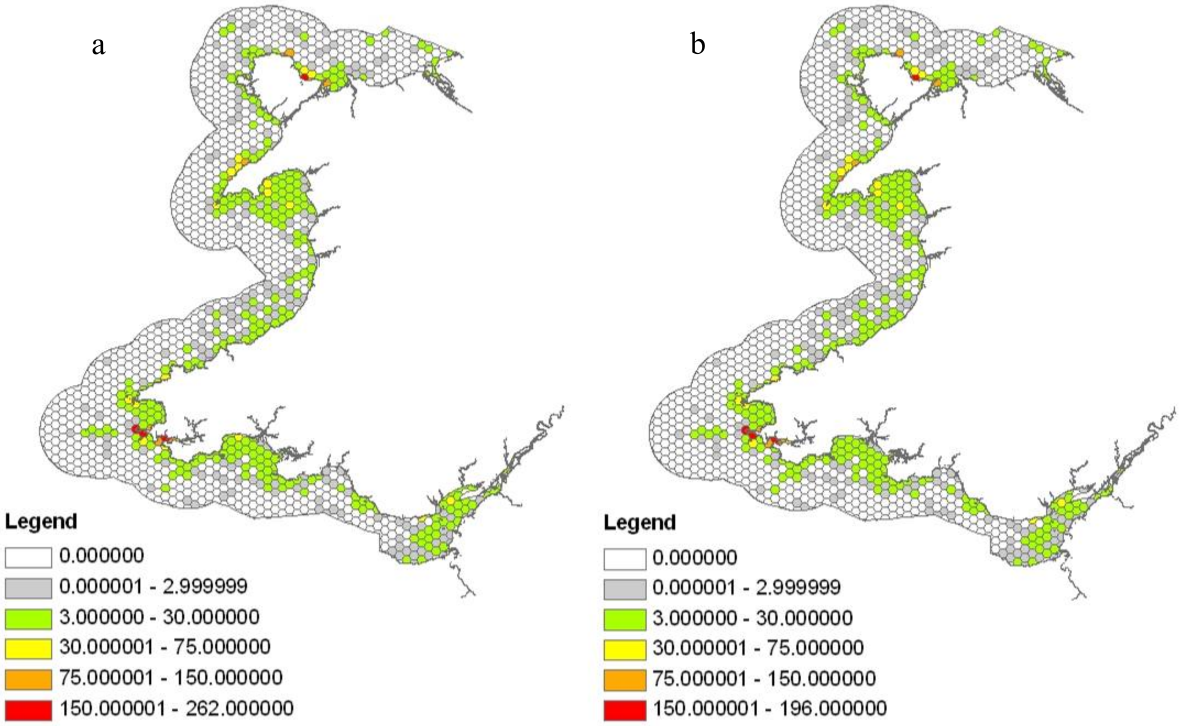


Figure 4 Number of unique species samples available within 15km^2 hexagon grid for subtidal Welsh waters, using (a) all surveys and (b) surveys categorised as medium and above quality.

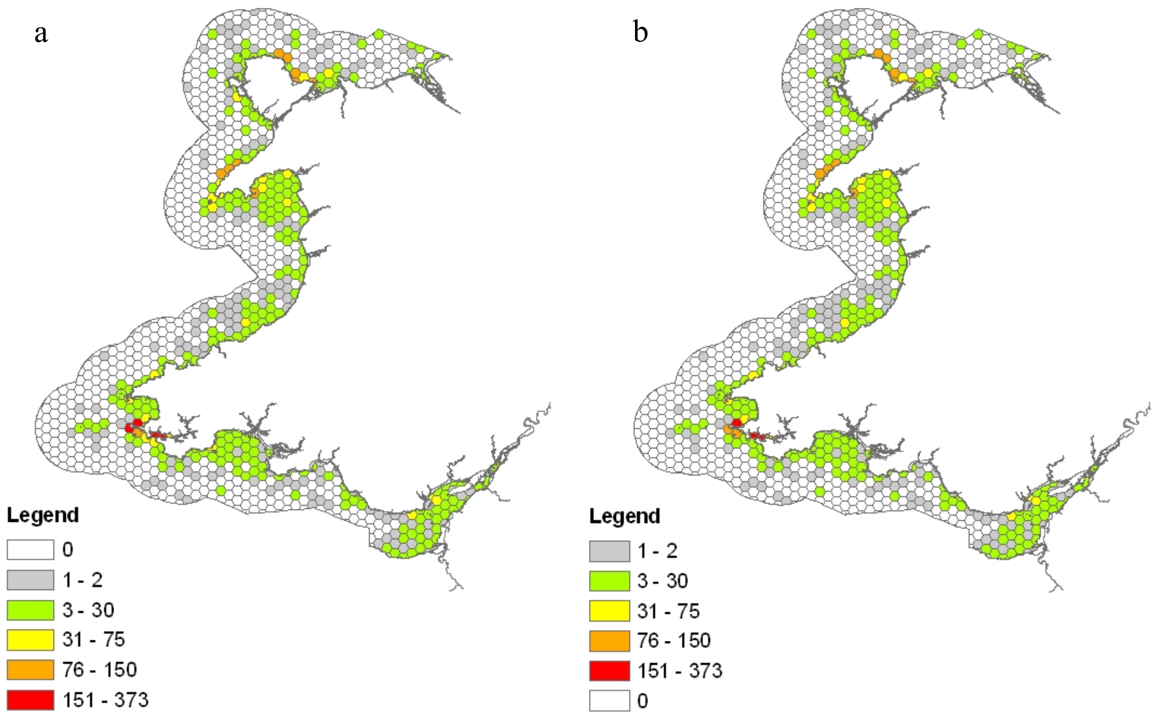


Figure 5 Number of unique species samples available within 20km^2 hexagon grid for subtidal Welsh waters, using (a) all surveys and (b) surveys categorised as medium and above quality.

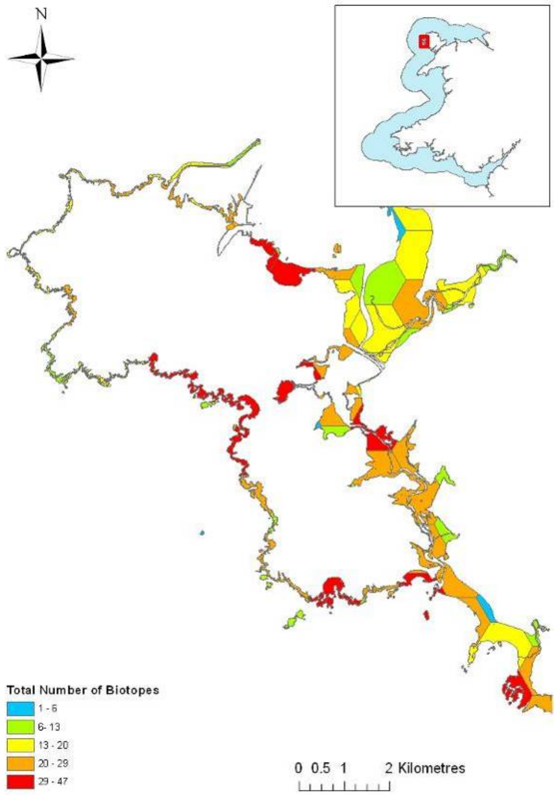


Figure 6 Example run of the number of biotopes using a 1km^2 hexagon grid for the intertidal around Holy Island, using Phase 1 biotope survey data.

For the biotope layers, a "one-size-fits-all" layer needs to be based on both polygon and point data, integrated post-analysis, because use of either only point or polygon data would result in misrepresentation of either the intertidal or subtidal respectively. Due to these issues, no biotope layer will be produced at this resolution.

3.3 Biodiversity measures

The proposed metrics to represent marine biodiversity in Wales were species richness, biotope richness, average taxonomic distinctness, biotope distinctness and the number of priority features (a summary of the measures and their method of calculation is presented in Table 5). Each measure was presented on a continuous scale and as a separate layer. For each layer, data was queried and analysed using a normal hexagonal grid and then this process was repeated using a neighbourhood approach so that differences can be examined. An example of neighbourhood influence on subtidal sample number is shown in Figure 7). Data gaps were clearly displayed as no data.

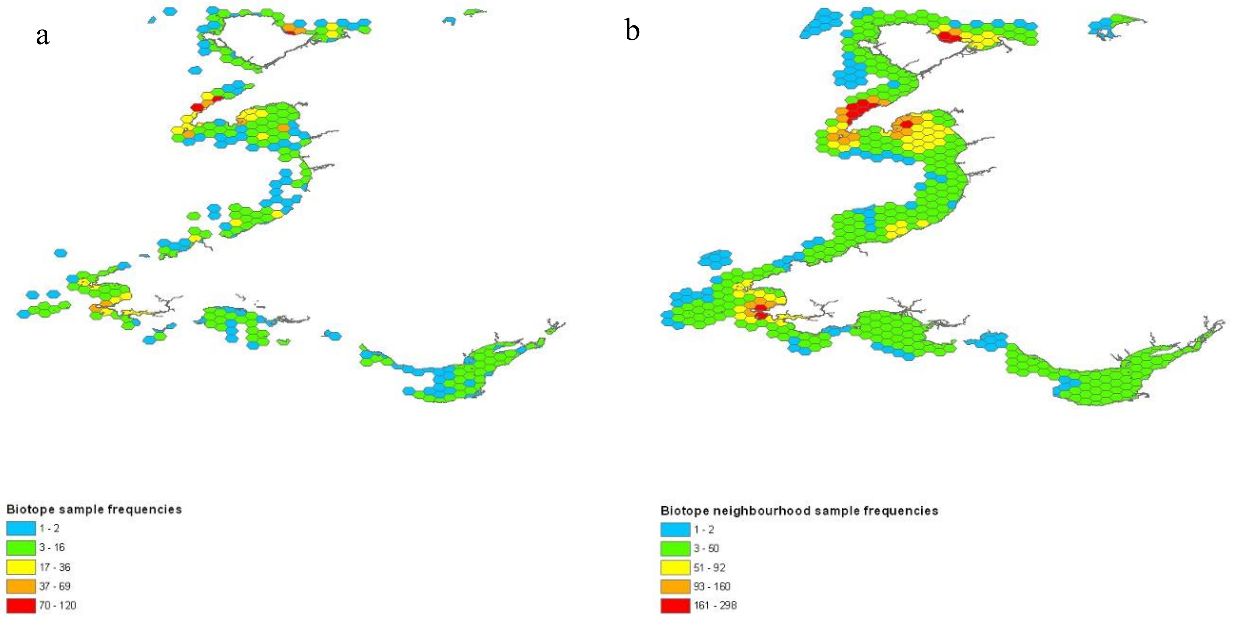


Figure 7 Subtidal biotope data sample point frequencies calculated (a) per cell, and (b) using neighbourhood statistics

In order to standardise for bias due to method of collection, the data were subsetted into broad method types (see Table 4 for a breakdown of method categories) and analysed separately before recombining (by taking the median value). Intertidal biotopes were not subsetted because all data were collected using one standardised method.

Table 4 Categorisation system of broad method types

Broad Method Category	Sampling Method
High quality/Phase 2	Quadrat
	Recording (Phase II)
	Recording (Phase II) - Sub Habitat
	Seasearch (Survey)
	Transect (belt, line)
	Trawl (Beam, Otter, unspecified)
Infaunal high	Core (box, hand-held, unspecified)
	Grab (Birge Eckman, Day, Hamon, Hunter, Smith McIntyre, Van Veen, unspecified)
Infaunal low	Dredge (anchor, pipe, unspecified)
	Suction sampler
Low quality/Phase 1	Netting
	Photography - underwater
	Recording (Phase I)
	Seasearch - Observation
	Video - underwater (drop-down)
	Visual survey (Scuba diving, Boat based)
Sightings	Shored based - visual survey
	Casual observation
Taxon-Specific	Taxon specific search/collection
Unknown	Unknown

3.3.1 Species richness

For each broad method type, the number of unique samples and the number of species was queried in GIS for each cell. Both datasets were log_{10} transformed: 1) to spread the data out along the x axis (number of samples) and 2) to straighten the species accumulation curve, and a simple linear regression was performed to allow species richness to be correlated with sampling intensity. A regression plot was generated for each broad method type, together with its 95% confidence intervals, indicating the range where 95% of the data would fall if measurements were repeated. Using the residuals from the regression analysis for each hexagon (by sampling method), the position for each hexagon, relative to the 95% confidence intervals, was determined, informing on how unusual that hexagon was (i.e. the confidence that that particular hexagon is part of the population). This is an advance on the scoring system used by Hiscock and Breckels (2006) and Langmead et al. (2008) that simply allocated each hexagon to one of three discrete groupings (>95% confidence interval), expected or below expected (<95% confidence interval).

3.3.2 Biotope richness

In order to examine biotope richness, an assessment at a similar level of classification was required. The available habitat data included sub-biotope codes and in some cases levels broader than biotope were reported. In the current study we based analyses of biotope richness on the EUNIS classification (Phase 1 biotopes were translated from MNCR) throughout, and where possible EUNIS Level 5 was used. Level 6 biotopes were reduced to Level 5. Any habitats classified at EUNIS Level 4 and above were only included in analyses if they represented a distinct biotope within the cell (i.e. had no hierarchical children in the same cell).

For the intertidal, no separation was made for method as only Phase 1 data was used. Also because the intertidal assessment was based on full coverage polygon layers, no standardisation for sampling effort was required. For the subtidal biotope richness, data were not separated by method (as highlighted above) and analyses were based on point data using regression techniques to correct for sampling bias (as above).

3.3.3 Taxonomic distinctness

Since different sampling methods result in different species being observed not all the species data were used in this part of the analysis: only species from nine phyla/groups were analysed (Cnidaria, Crustacea, Annelida, Mollusca, Porifera, Algae, Bryozoa, Ascidea and Echinodermata). This is because these phyla are widely distributed and have full taxonomic classifications.

Master species lists for these nine phyla were compiled for each broad method type occurring within each hexagon cell. Master species lists for each broad method type were then used to calculate the average taxonomic distinctness, using PRIMER^{e} version 6. The analysis generated a funnel plot for each method type indicating the 95% confidence intervals for random 'expected' distinctness based on 1000 random permutations of the same number of species from a master list for each method type (i.e. all the species from the Welsh records found by that method type). An example is shown in Figure 9. The funnel plots were used to assess statistical departures from the expected. As stated previously, the residuals and confidence limits of the funnel plot can provide a value on a continuous scale that indicates the unusualness of each hexagon. Two measures of taxonomic distinctness were calculated using this average taxonomic distinctness analysis:

$\Delta+$ (delta+) is defined as the average taxonomic distance apart of all pairs of species in a sample, based on an established taxonomic hierarchy termed a master list; and

1. $\Lambda+$ (lambda+) is defined as the variance in the taxonomic distances between each pair of species at a site. This measure reflects the evenness with which species within a sample

are distributed among higher levels of the taxonomic hierarchy and can provide additional information about diversity of a site.

Figure 8 shows two theoretical trees from two samples with the same species richness but with a different taxonomy. The mean path length between species is the same for the two trees and thus Δ+ is identical. The tree structure has a greater unevenness or variability in sample b compared to sample a, thus the variation in taxonomic distinctness (Λ+) is higher for sample b (Clarke & Warwick 2001).

Whilst both measures are complimentary descriptors of species diversity when used together, in the present study we present the values of variation in taxonomic distinctness (Λ+) as a measure to compliment species and biotope richness values by identifying which of the areas with high species richness have a the more diverse phylogentic tree.

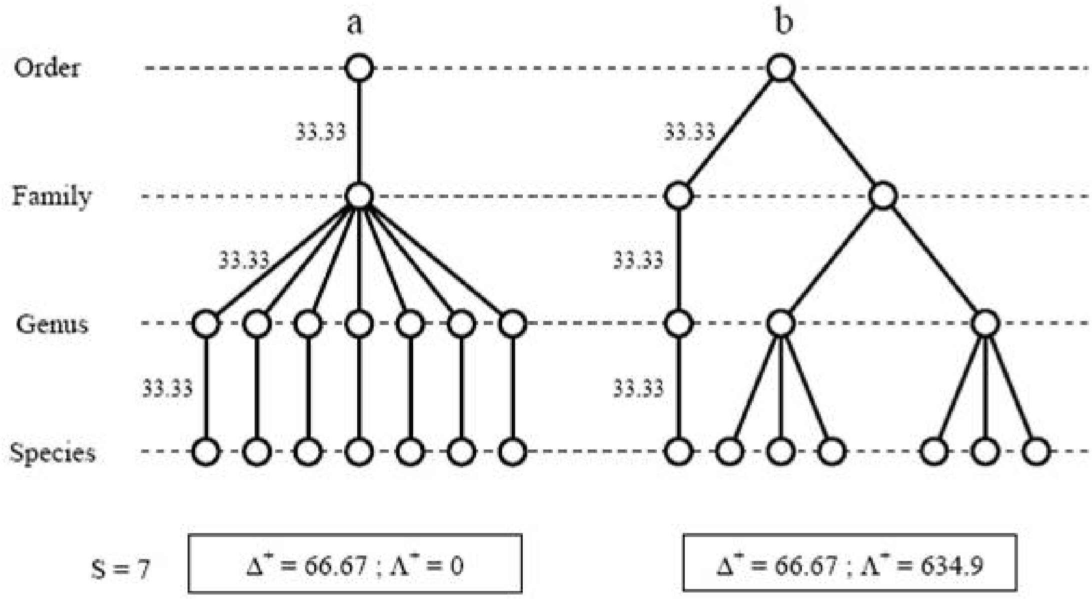


Figure 8 Examples of the phylogenetic trees of two samples (a and b) each containing 7 samples. Average taxonomic distinctness (Δ+) is the same, but the variation in taxonomic distinctness (Λ+) is substantially different. (Source: Clarke & Warwick 2001)

3.3.4 Biotope distinctness

Biotope distinctness, like biotope richness, requires measures to be analysed at a comparable level of biotope classification. Once again, EUNIS level 5 was used, and any Level 6 biotopes were reduced to level 5. Any habitats classified at EUNIS Level 4 and above were only included in the analysis if they represented a distinct biotope within the cell (i.e. had no hierarchical children in the same cell). Funnel plots were generated for Λ+ and values of biotope distinctness calculated on a continuous scale for the sites with high levels of biotope richness in the same way as for taxonomic distinctness.

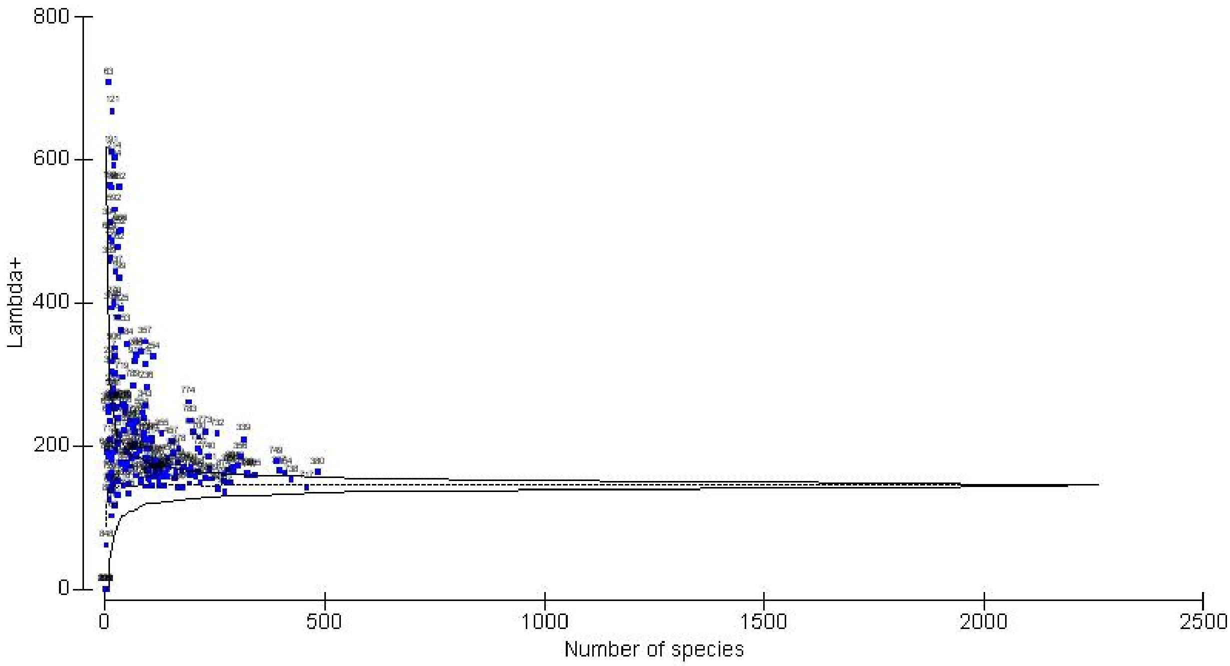


Figure 9 Example of the funnel plot output from average taxonomic distinctness analyses

3.3.5 Priority feature hotspots

The assessment of priority feature hotspots[7] comprised all records and data; including those rejected for analyses of species richness and taxonomic distinctness, such as individual sightings data and counts, and incidences where there were less than three records in a cell. This is because priority feature records often result from targeted searches yielding isolated sightings records, so it was necessary important to include all of these records. Separate assessments of priority species and habitat hotspots were carried out: 1) for the species hotspots we used a revised[8] list of Welsh Nationally Important Marine Features (see Appendix 3) and 2) for habitats the Wales Section 42 (BAP) habitat list (see Appendix 4).

[7] N.B. These should be referred to as hotspots not diversity hotspots, as they include no measure of diversity.

[8] The list of Nationally Important Marine Features (Hiscock et al 2006), was cross checked against species occurring in Wales, and reviewed by CCW project officers to remove irrelevant taxa.

Table 5 Summary table of metrics chosen to measure biodiversity and method of calculation

Field	Method of calculation
Species richness	Only cells with 3 or more samples were included. Sightings data and taxon specific data skewed effort and were removed from the analysis. For each broad method type, the number of unique samples and the number of species was queried in GIS for each cell. Sampling effort and number of species were logarithmic (log_{10}) transformed to straighten the species accumulation curve and spread the data in small sample sizes respectively and a linear regression was performed to correlate species richness with sampling intensity. Using the residuals from the regression analysis for each hexagon (by sampling method), the position for each hexagon was determined and translated to a value on a continuous scale between +1 and -1 based on where it lay in the regression (i.e. the confidence that that particular hexagon is part of the population). The median of the values between method types was calculated.
Taxonomic distinctness	Species aggregation files were constructed for each method using standard taxonomic classifications (WoRMS), and the taxonomic levels of species, genus, family, order, class and phylum. Equal branch length weights were used. The aggregation file was used to generate the distribution of values of average TD Δ and variation of TD Δ+ and the sample data were superimposed. The funnel plot generated for each method type indicated the 95% confidence intervals for random 'expected' distinctness based on 1000 random permutations of the same number of species from a master list specific for each method type. The funnel plots were used to assess statistical departures from the expected, but the values of Δ and Δ+ were used to provide a value on a continuous scale to indicate the diversity of each hexagon. The median value of Δ and Δ+ across broad methods was used to indicate values for each cell.
Biotope richness	For the subtidal, biotope richness was calculated as for species richness. For the intertidal biotope polygons, there was no effort variability and biotope richness was simply given as the number of biotopes (EUNIS level 5) present within a cell.
Biotope distinctness	All biotopes within a cell were converted to EUNIS level 5. Any Level 6 biotopes were reduced to level 5. Any habitats classified at EUNIS Level 4 and above were included in the analysis if they represented a distinct biotope within the cell (i.e. had no hierarchical children in the same cell). Values for biotope distinctness were calculated on a continuous scale using Δ+. The aggregation file for the biotope distinctness was compiled using all biotopes recorded in Welsh intertidal and Welsh subtidal for the respective analyses. Data were not separated by method as records of subtidal biotopes were predominantly from high quality surveys.

Field	Method of calculation
Number of priority species	This is the number of unique priority species occurring within a cell (and within the neighbouring cells for the neighbourhood analysis). The measure includes all records and data rejected in species richness and taxonomic distinctness, such as individual sightings data and counts and incidences where there were less than three records in a cell.
Number of priority habitats	This is the number of priority habitats occurring within a cell (and within the neighbouring cells for the neighbourhood analysis). The measure includes all records and data rejected in biotope richness and biotope distinctness, such as individual sightings data and counts, and incidences where there were less than three records in a cell. Priority habitat names were used for this measure, because translating to the EUNIS classification gives one to many results and an anomalous outputs.

3.4 Validation methods and confidence assessments

In addition to the quality criteria applied to the collated data sets, confidence ratings based on the quality and quantity of data used in the final analysis were calculated for each hexagonal unit to provide users with a view of the underlying data when examining hotspot occurrence.

A confidence rating was calculated using a three point categorical scale from high to low. The average quality for each hexagon was calculated by assigning numerical values to each sample (high, medium and low were allocated 3, 2 and 1 respectively) and then the mean for each hexagon was calculated. The sample counts per hexagon were also aggregated into high, medium and low, using the natural breaks classification. Once the high, medium and low values were calculated for each hexagon, confidence was calculated using the matrix below (Table 6).

Table 6 Matrix used to calculate confidence rating for each hexagon.

		Average quality		
		High ≥ 3	**Medium >1 <3**	**Low ≤ 1**
Number of samples	**High ≥ 8**	High	High	Medium
	Medium 4-7	High	Medium	Low
	Low ≤ 3	Medium	Low	Low

The confidence map layer also flags where invasive species have contributed to the hotspot. The list of species found in Welsh coastal waters was matched to the DAISIE list of European non native marine species (DAISIE 2009) and their distributions plotted and appended to the confidence layer. An area of high biodiversity with low confidence (i.e. based on low quality data and a low number of samples) could then be identified as a priority area for resurvey.

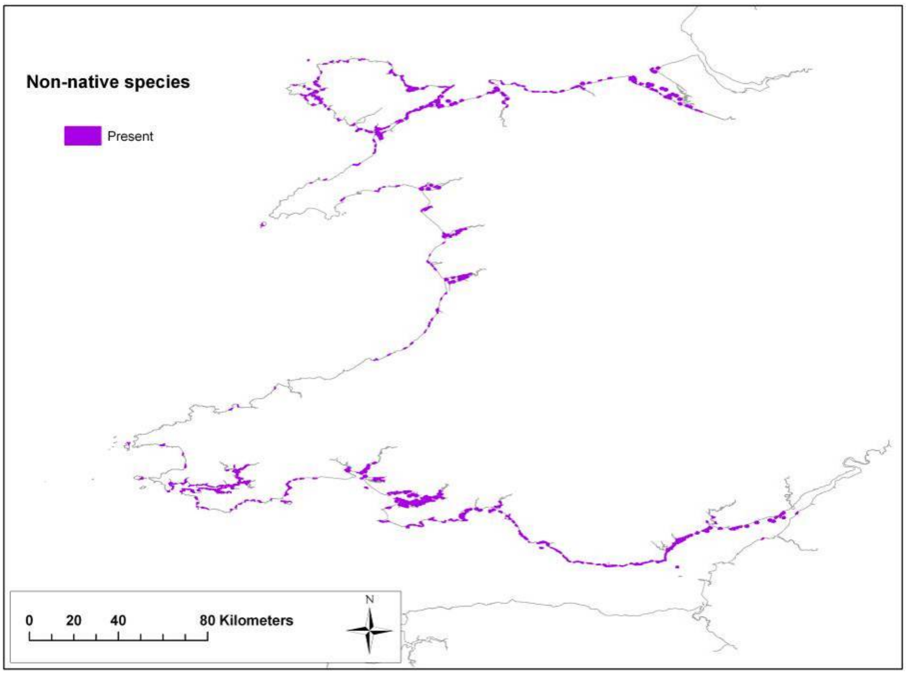


Figure 10 Occurrence of non-native species within intertidal 1km^2 hexagons.

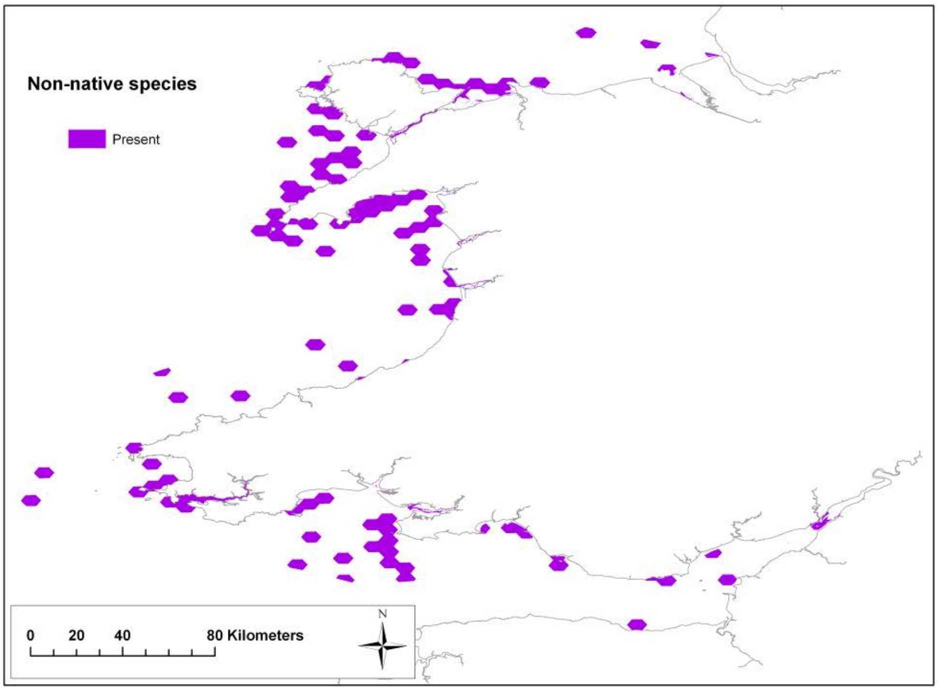


Figure 11 Occurrence of non-native species within subtidal 20 km^2 hexagons.

A number of techniques (known as estimators) exist for extrapolating species richness from limited numbers of samples (Foggo et al. 2003) and these can be used to check for artefacts in the diversity analyses. The Chao2 estimator was applied in this study. This is based on the concept that rare species carry most information about the number of missing species, and this approach looks at species that occur in only one or two samples within a defined area (Foggo et al. 2003). Chao2 estimator was calculated for each hexagon using the following equation:

$$Chao2 = S_{obs} + (Q_1)^2 / 2(Q_2+1)$$

Where S_{obs} is the number of species observed in the hexagon considered, Q_1 is the number of species occurring in one sample of the corresponding hexagon, and Q_2 is the number of species occurring in two samples.

An analysis of concordance (using Pearson's Product moment correlation statistic) between measures was used to quantify the independence of different measures, for example whether areas of high biotope richness match up with areas of high species richness.

4 RESULTS AND DISCUSSION

The following section summarises the output maps for the different measures of diversity, examines confidence in the maps, explores estimates of total species richness and where there are possible artefacts. The measures on the maps presented in this section have been categorised by the authors for display purposes. However, the data underlying the maps are on a continuous scale and can be interrogated and displayed in different ways using the MapInfo files which append this document (listed in Appendix 6). Please note that whole region (10km^2 hexagonal units) are provided as MapInfo files but are not discussed in the following text due to repetition.

4.1 Intertidal species diversity

4.1.1 Species richness

Figure 12 illustrates species richness (effort standardised measure) for the intertidal area around the coast of Wales (Figure 12). The map layer indicates areas of highest diversity at a large number of sites including Freshwater East (Pembrokeshire), Penrhyn Bay (near Llandudno), Porth Ruffydd (W of Trearddur Bay), Ravens Point, Bull Bay and east Cemaes Bay (Anglesey), Whiteshall Point (Gower) and Langland Bay (West Glamorgan). Low diversity was measured for many of the estuarine intertidal areas (e.g. Severn, Dee, Mawddach and Glaslyn).

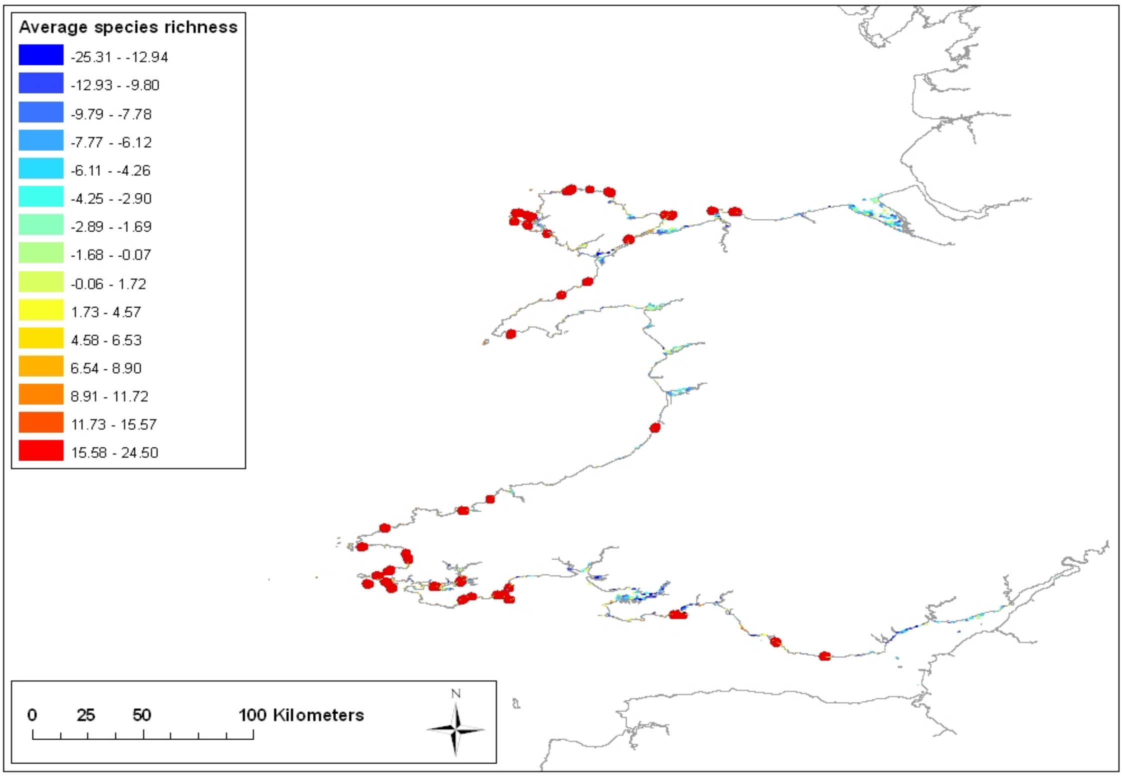


Figure 12 Average species richness for the intertidal region of the Welsh coast (the top category is presented in bold to aid identification of high diversity areas).

Applying a neighbourhood smoothing identified different regions of high diversity to the non neighbourhood layer (e.g. Bluck's Pool in Pembrokeshire and Skomer Island, see Figure 13) indicating that the areas of high diversity identified by the latter are due to fairly localised samples within a hexagonal unit (which would be very dependent on grid placement). The areas identified by the neighbourhood layer as highly diverse represent regions where the surrounding biodiversity is relatively higher than expected.

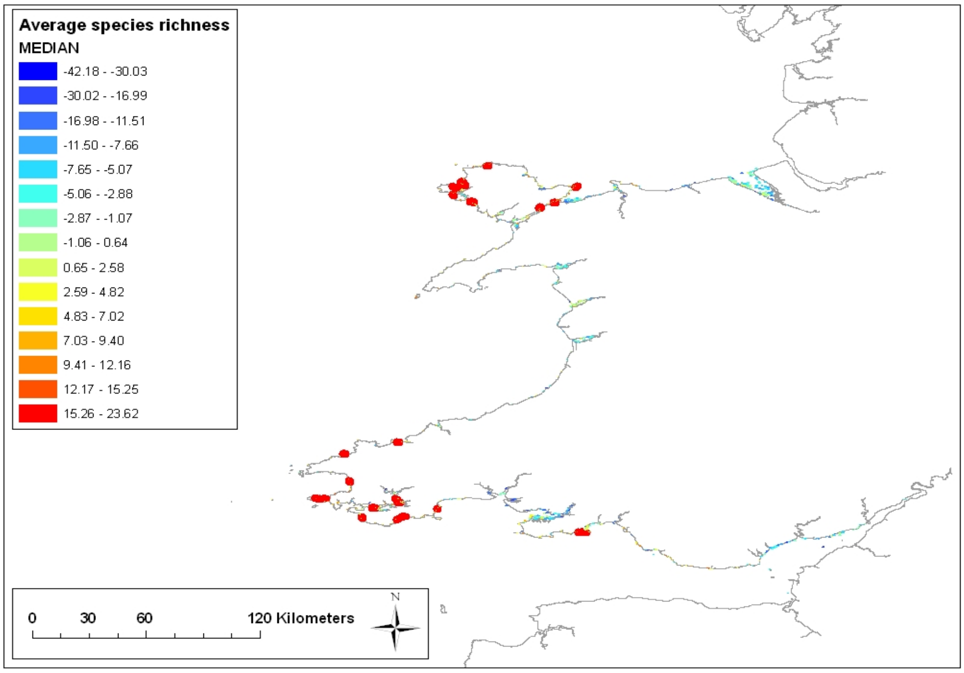


Figure 13 Neighbourhood smoothing of average species richness measure (the top level category is presented in bold to aid identification of high diversity areas).

Figure 14 shows the layer separated by two of broad sampling methods (Table 4) for the North West coast of Wales and illustrates the contribution of different sampling method types on overall species richness. For example the high diversity area in the Menai Strait is apparent from both high quality infaunal samples and from High quality/ Phase 2 samples, but the area of high diversity identified for Penrhyn is only evident from the infaunal high quality samples. The Menai Strait site and on Anglesey, Ravens Point, Bull Bay and east Cemaes Bay also appear as high diversity when the Chao 2 estimator is used to calculate estimated total species richness (Figure 14d and Figure 15), and there is high confidence in the data for these sites. Both the Chao 2 estimator and the confidence layer support the measure of lower relative diversity in estuarine regions.

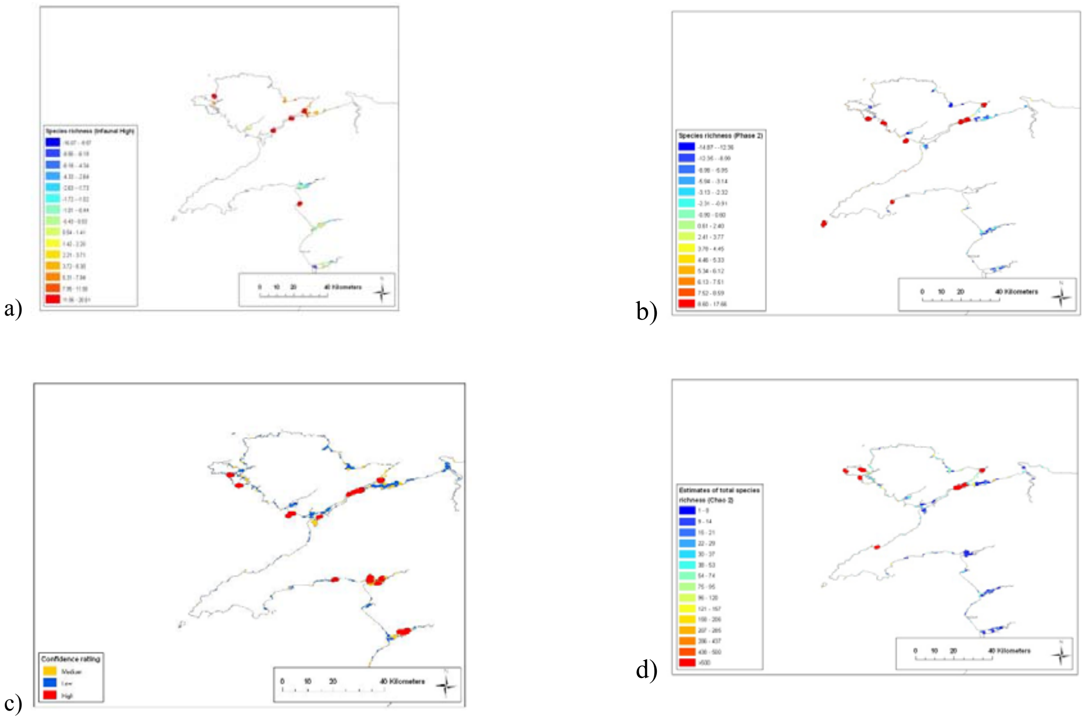


Figure 14 Zoomed in maps of North West Wales illustrating species richness measures based on (a) infaunal high samples only, (b) Phase 2/ High Quality samples only, (c) confidence rating and (d) the Chao 2 estimator.

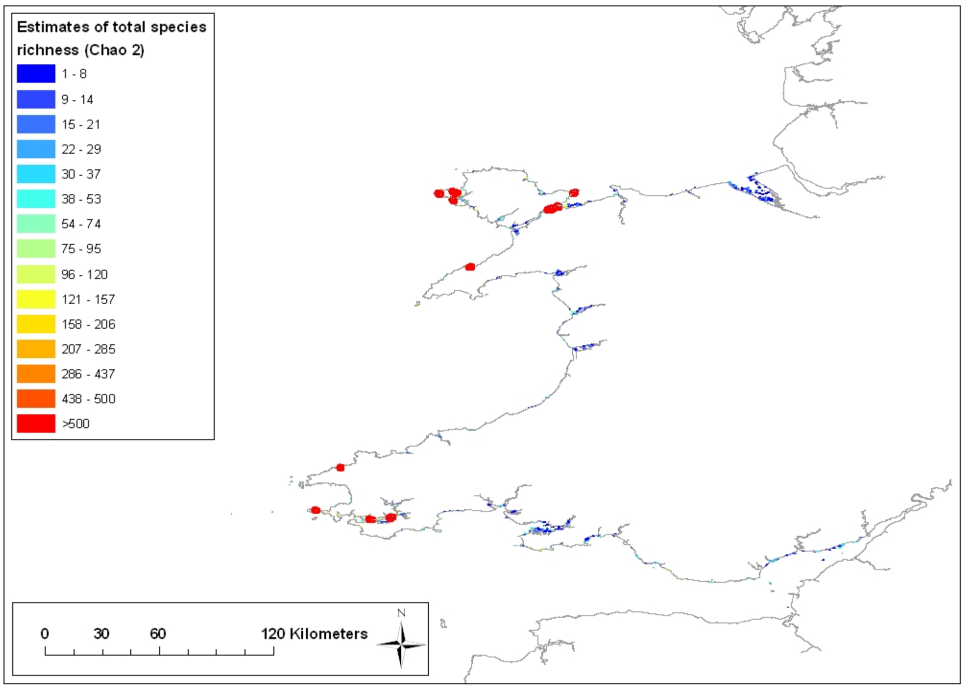


Figure 15 Chao 2 estimator of total species richness for the intertidal coast of Wales (the two top level categories are presented in bold to aid identification).

4.1.2 Taxonomic distinctness

In contrast to the species richness maps, highest taxonomic distinctness (Lambda +) was found predominantly within the estuaries (see Figure 16; particularly obvious following neighbourhood smoothing Figure 17). There are two explanations for this, firstly it may indicate that whilst species poor, estuaries contain species from a more diverse mixture of phyla, classes or genus. It may also be an artefact of the measure being strongly influenced by the number of species in the sample. For example there is a greater chance of species being markedly different in terms of their phylogeny in a species poor sample than a species rich sample, where there is a greater chance of some species from the same phyla). High taxonomic distinctness where species richness is also high is a good indicator of highly diverse areas. Such areas include Great Castle head (Pembrokeshire) and the east side of Pwllcrochan flats (Milford Haven) (Figure 17).

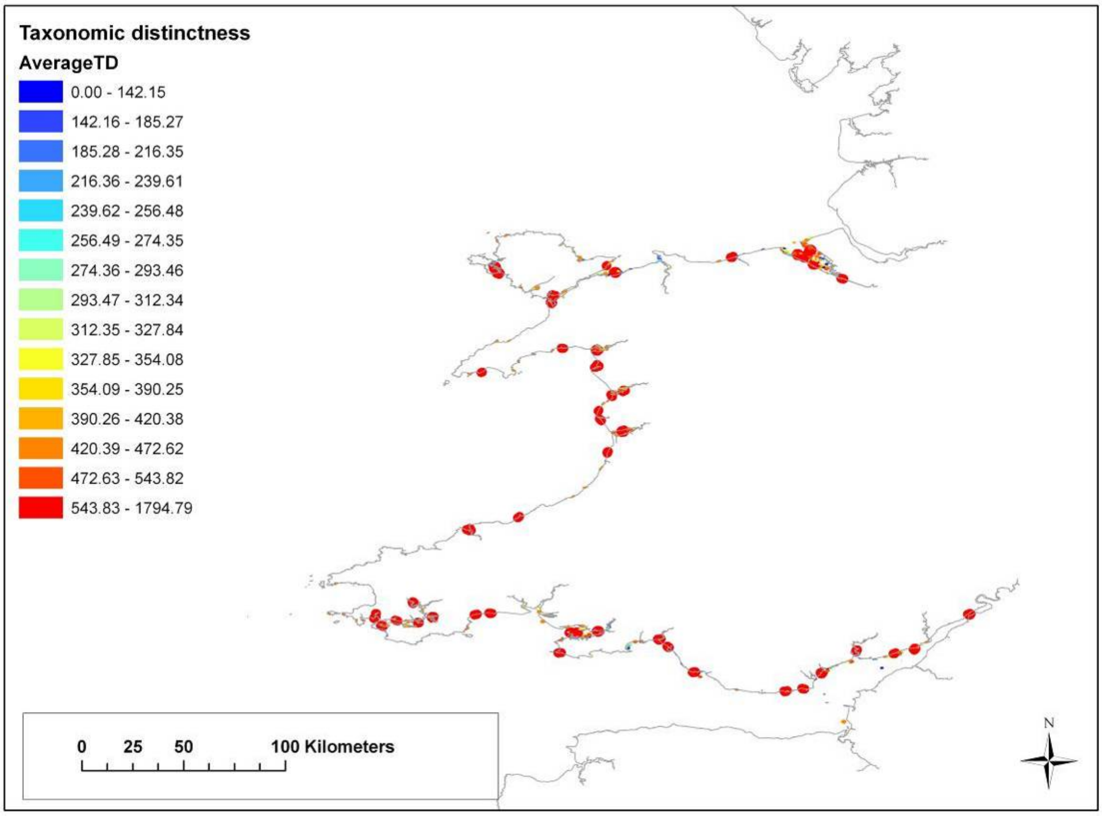


Figure 16 Taxonomic distinctness of intertidal samples from the Welsh intertidal area (the top level category is presented in bold to aid identification of high diversity areas).

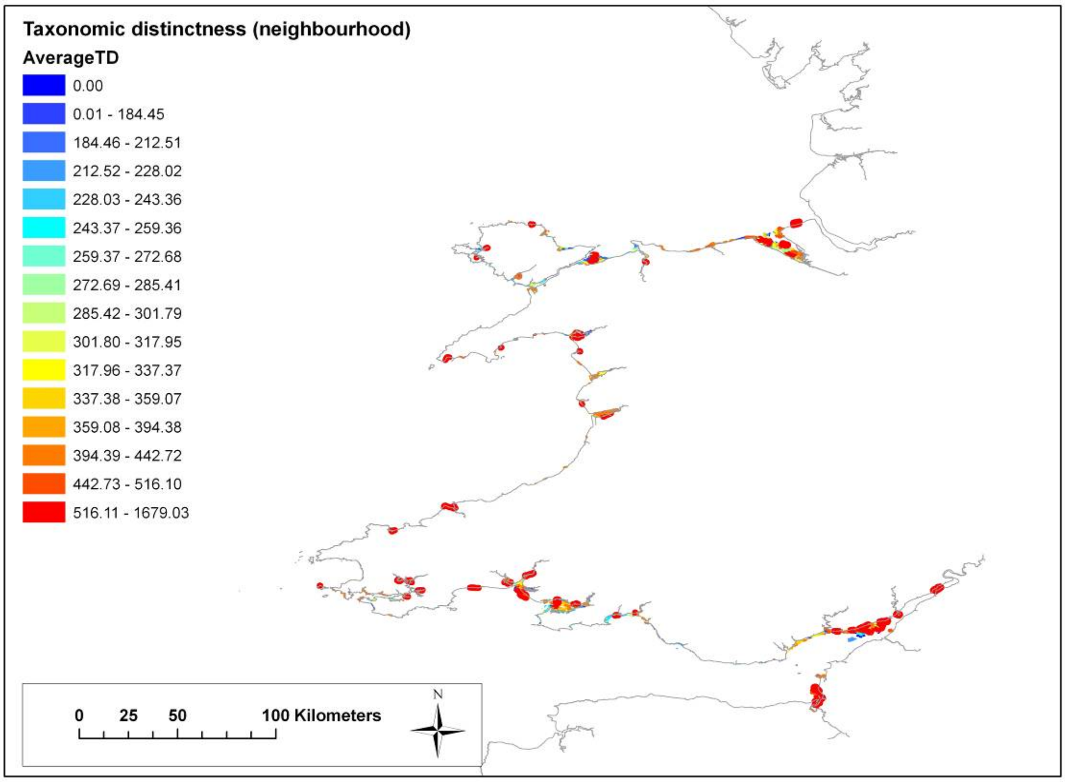


Figure 17 Taxonomic distinctness of intertidal samples from around the Welsh coast with neighbourhood smoothing applied (the top level category is presented in bold to aid identification of high diversity areas).

4.1.3 Priority Species

Although Skomer Island does not appear as having relatively high species richness or taxonomic distinctness (but see the high estimated total species richness, Chao 2, for this location, Figure 15), the island does have one of the highest concentrations of priority species, second only to those recorded for the Swellies in the Menai Strait (Figure 18 and Figure 19). Both sites have been intensively sampled and data confidence is high for both regions (Figure 20). However, it is important to note that the priority species data was not adjusted for sampling effort.

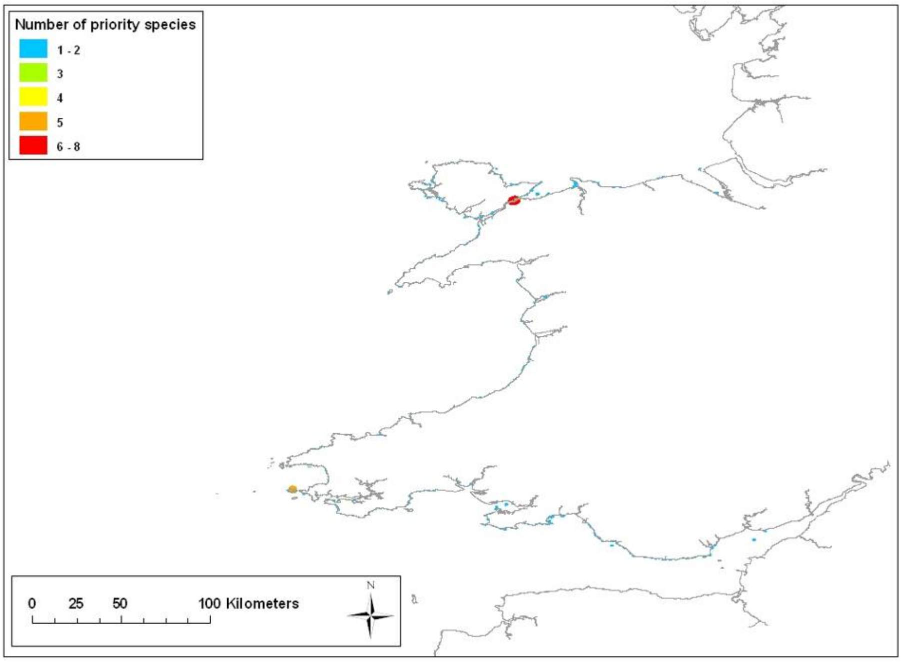


Figure 18 Number of priority species recorded per hexagon from Welsh intertidal areas (the top level category is presented in bold to aid identification of high diversity areas). N.B. these values have not been standardised by sampling effort (see section 3.3.5)

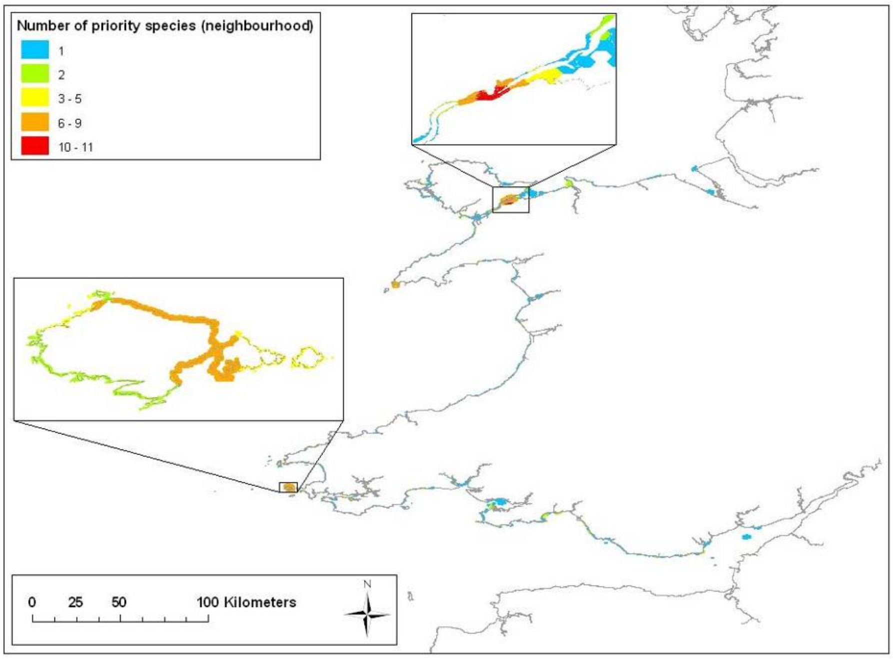


Figure 19 Neighbourhood smoothing of the number of priority species recorded per hexagon from Welsh intertidal areas (the two top level categories are presented in bold, and insets for the Menai Strait and Skomer have been added to aid identification of high diversity areas). N.B. these values have not been standardised by sampling effort (see section 3.3.5)

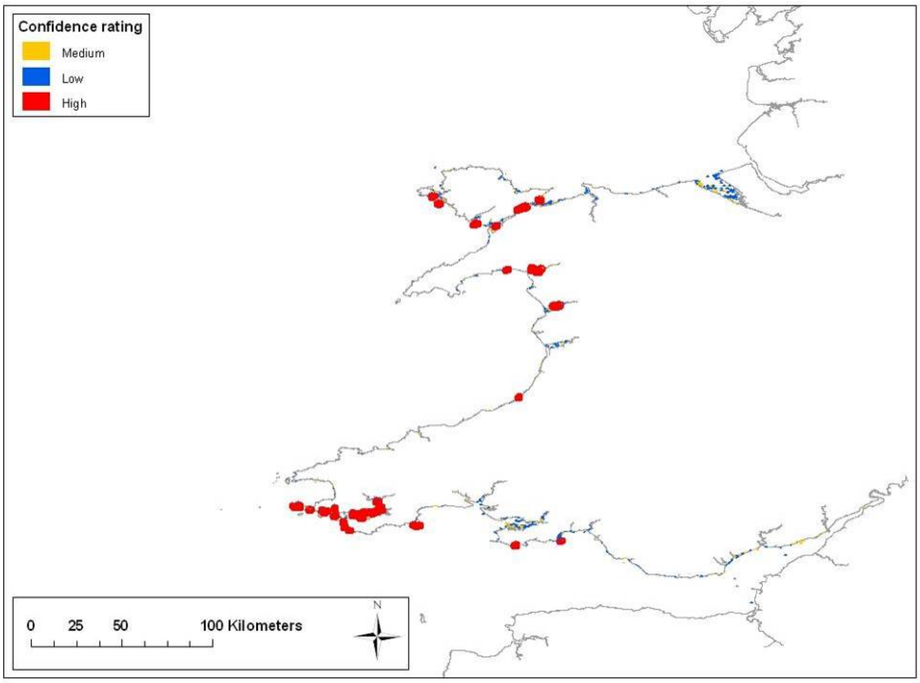


Figure 20 Confidence rating for Welsh intertidal species data (the top level category is presented in bold to aid identification of high diversity areas)

4.2 Subtidal species diversity

4.2.1 Species richness

The relative species richness for the Welsh subtidal region is shown in Figure 21, and with neighbourhood smoothing, in Figure 22. Areas of relatively high species richness are found around most coasts although, estuarine regions for the subtidal, like the intertidal, appear species poor.

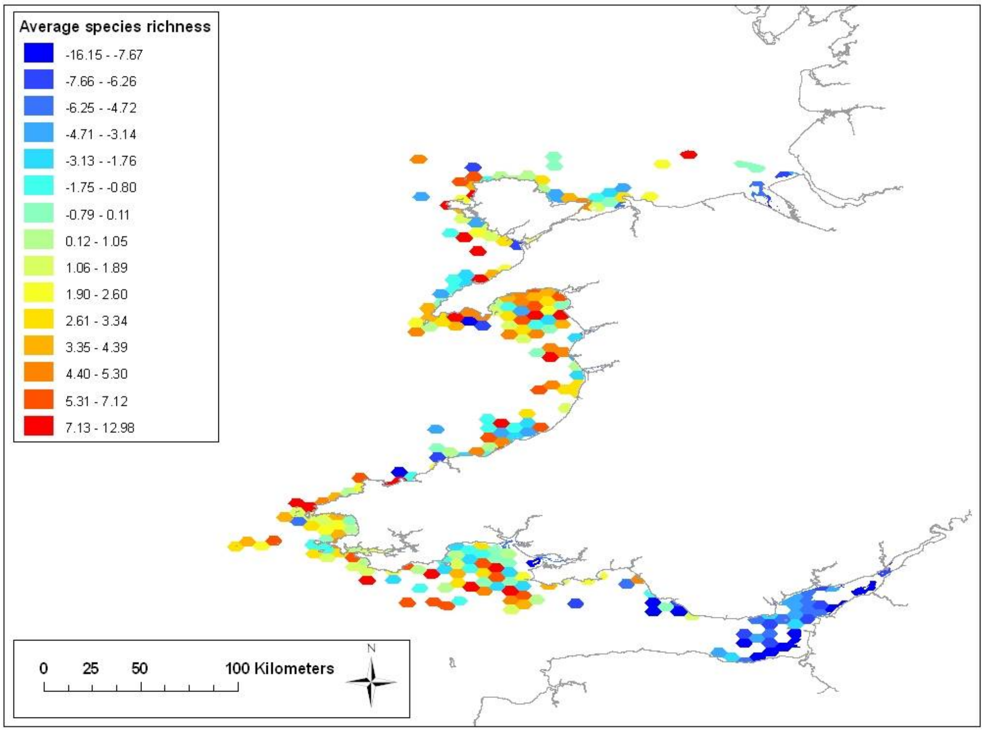


Figure 21 Average species richness measure for the Welsh subtidal waters (hexagons are 20km^2).

High species richness areas include an area north of Ramsey island and off the north western corner of Anglesey (both with high data confidence, see Figure 23), in Carmarthen Bay (low to medium confidence) and parts of Tremadog Bay (low confidence).

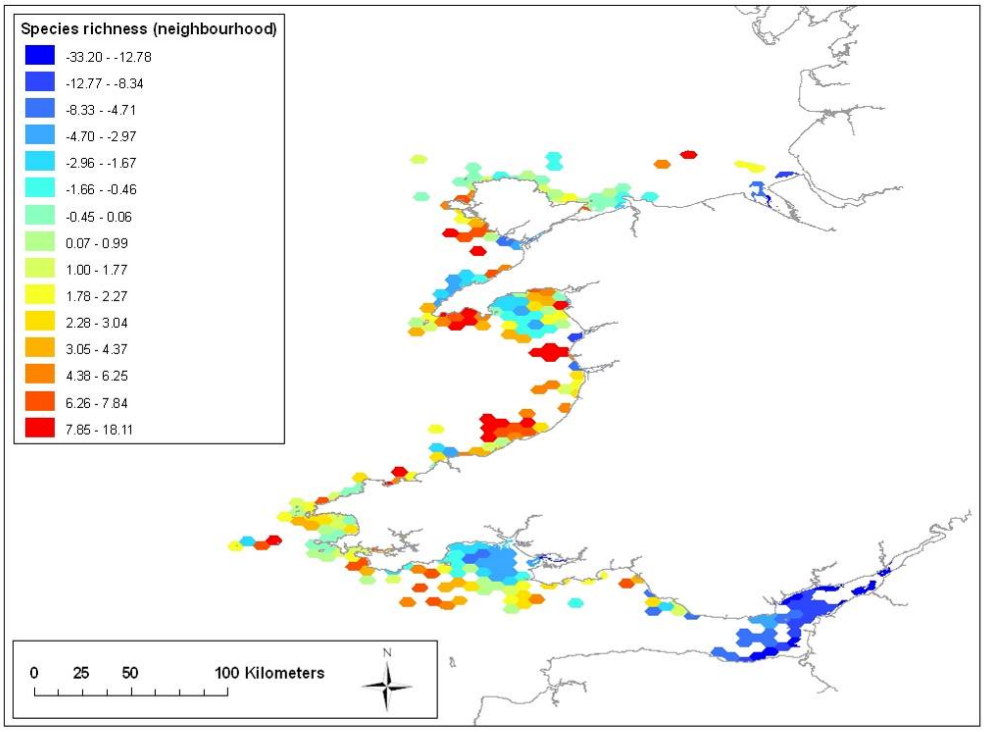


Figure 22 Neighbourhood smoothing of average species richness measures for the Welsh subtidal waters (hexagons are 20km2).

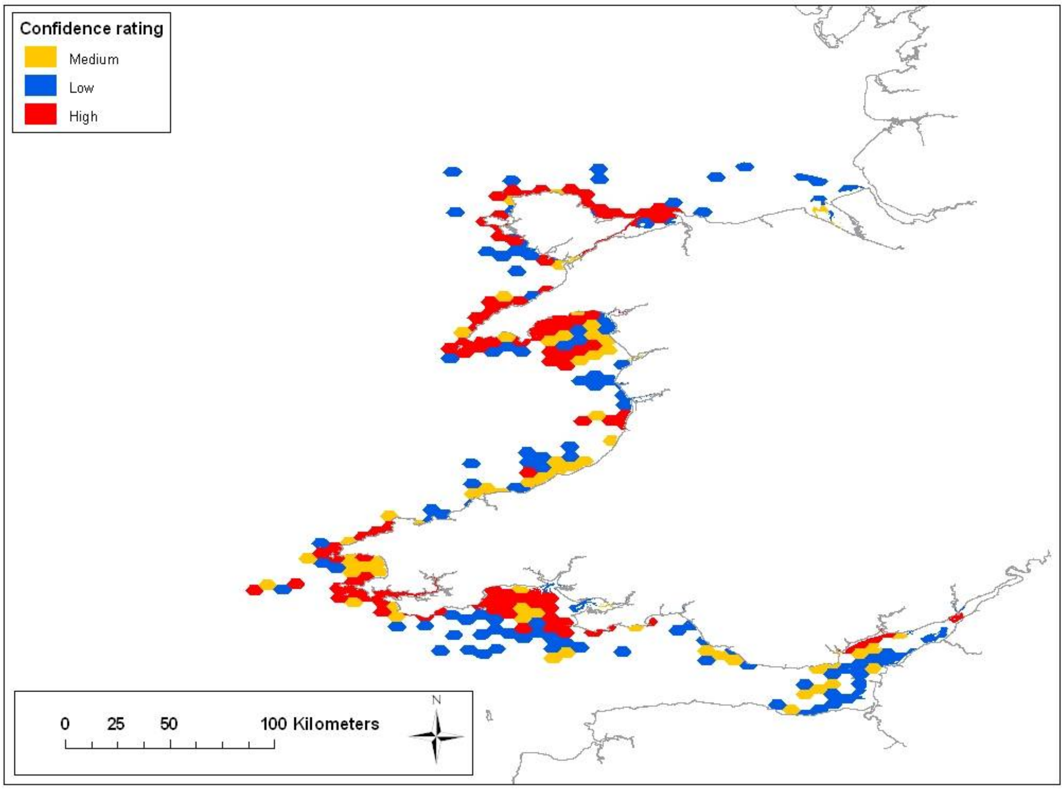


Figure 23 Confidence rating for Welsh subtidal species data.

Some of the areas of high species richness within Carmarthen Bay may be an artefact of the type of survey carried out here. Whilst data were standardised in terms of effort for this measure and method type was taken into consideration in the analysis, not all surveys within the broad method type were of the same quality. For example there may have been differences in how samples were processed (e.g. sorted, species identification). Figure 24 illustrates that the high species richness values for Carmarthen Bay are primarily from high quality infaunal samples (identified primarily as National Museum of Wales (NMW) RV Prince Madog grab samples). It is possible that the number of species identified per sample for these samples maybe greater than some other samples within the same broad method type in analysis which may inflate species richness values in this region. One of the assumptions of the regression technique is that the data are comparable, if not, then this will introduce bias into subsequent analysis. Furthermore, high species richness in Carmarthen Bay is not supported by the Chao2 estimator (Figure 26).

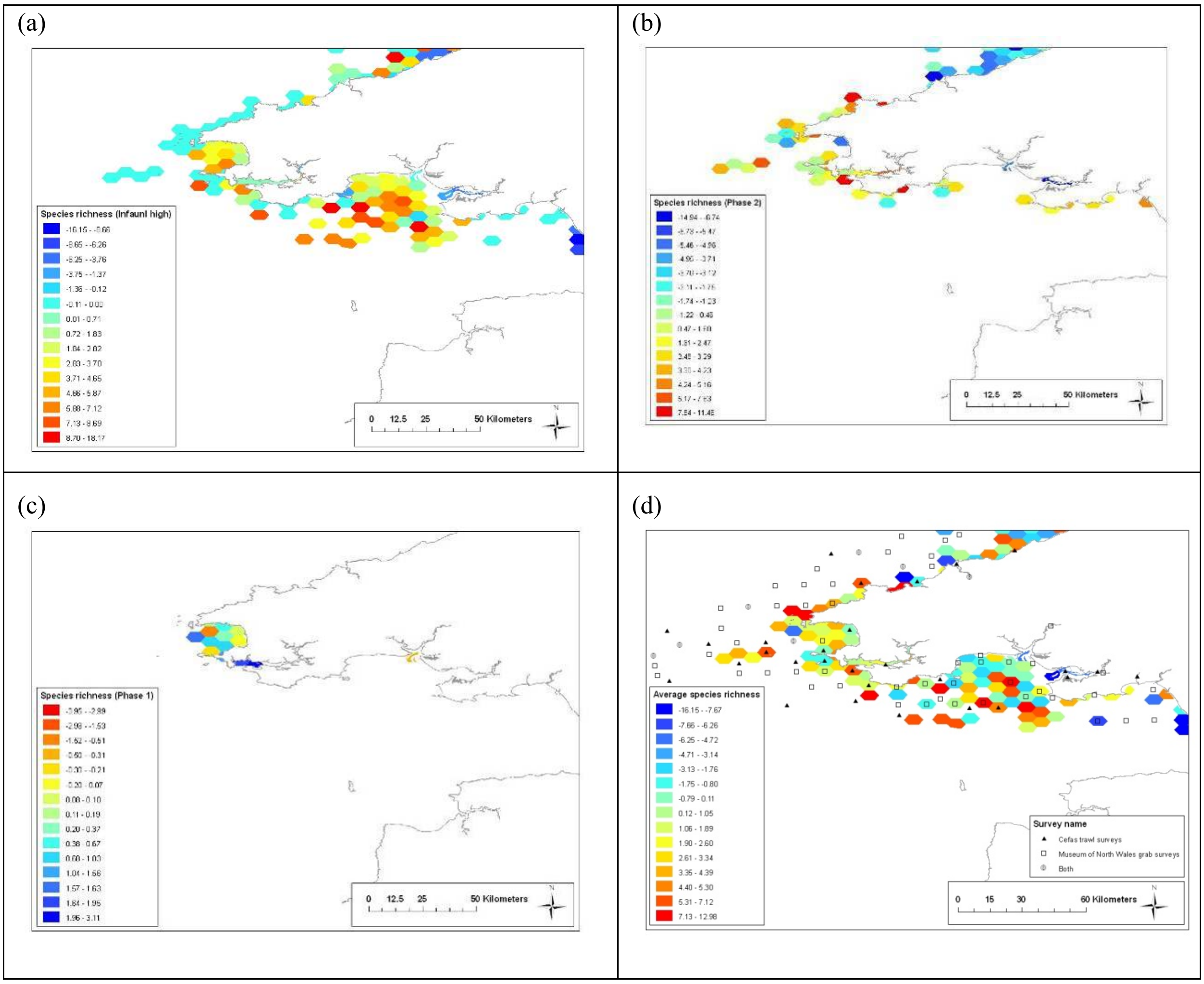


Figure 24 Relative subtidal species richness for Carmarthen Bay, separated by broad method type (a) high quality infaunal (b) Low Quality/Phase 1 (c) High Quality/Phase 2 and d) a map showing the distribution of CEFAS and NMW surveys within hexagons.

The influence of survey quality and also quantity may explain the low species richness around the island of Skomer (Figure 21 and Figure 22) despite the Chao 2 estimator suggesting it is an area of high total species richness. There has been intense sampling effort around Skomer (see Figure 3) and, due to the islands conservation status as a Marine Nature Reserve, some surveys may focus on priority species (see Figure 29 and Figure 30). This means that for this site, there are a large number of surveys but relatively low numbers of species (in terms of position on the regression). The graph in Figure 25 shows an example of one of the regressions used to calculate effort standardised species richness, with the points relating to Skomer identified. Whilst species richness is high at this site the samples lie below the lower confidence interval, indicating that there are less species than could be expected at these sampling intensities. The regression technique included log transformation of the y (number of species) axis, effectively transforming the typical species accumulation curve shape to a straight line, so there is no asymptote for these regressions and this is reflected also with the delineation of confidence intervals.

Areas where there is high confidence in the data which have high species richness (Figure 22), which are supported by the Chao 2 estimated total species richness map (Figure 26) include an area off Criccieth in Tremadog Bay and Port Eynon Bay on the Gower Peninsula.

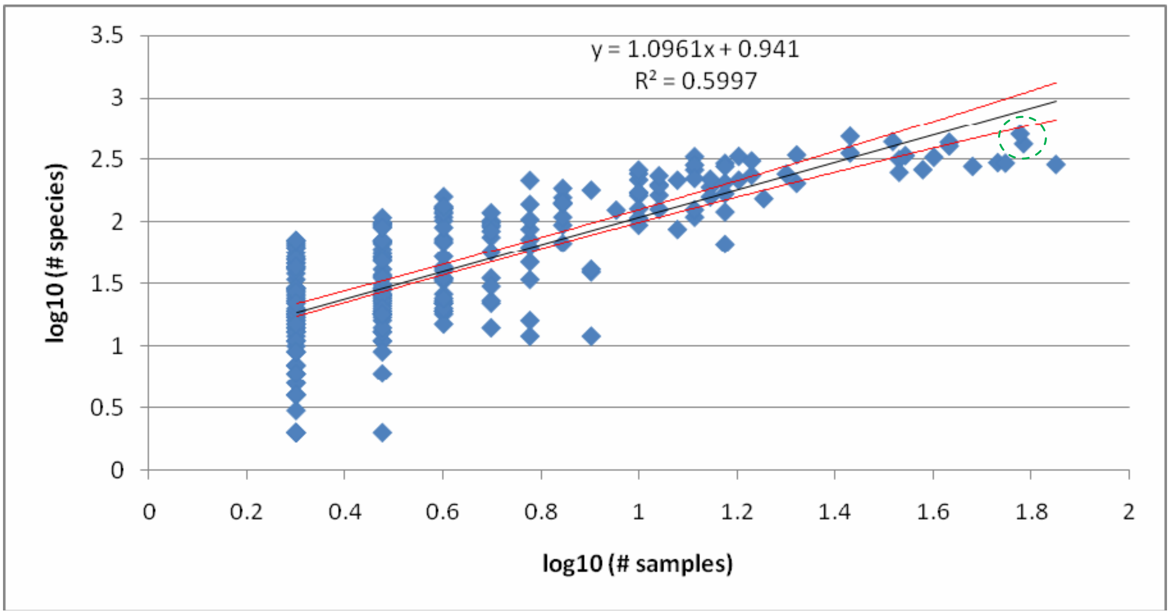


Figure 25 Example of regression used to calculate the effort standardised measure of species richness. Points within the green dashed circle represent hexagons from around Skomer.

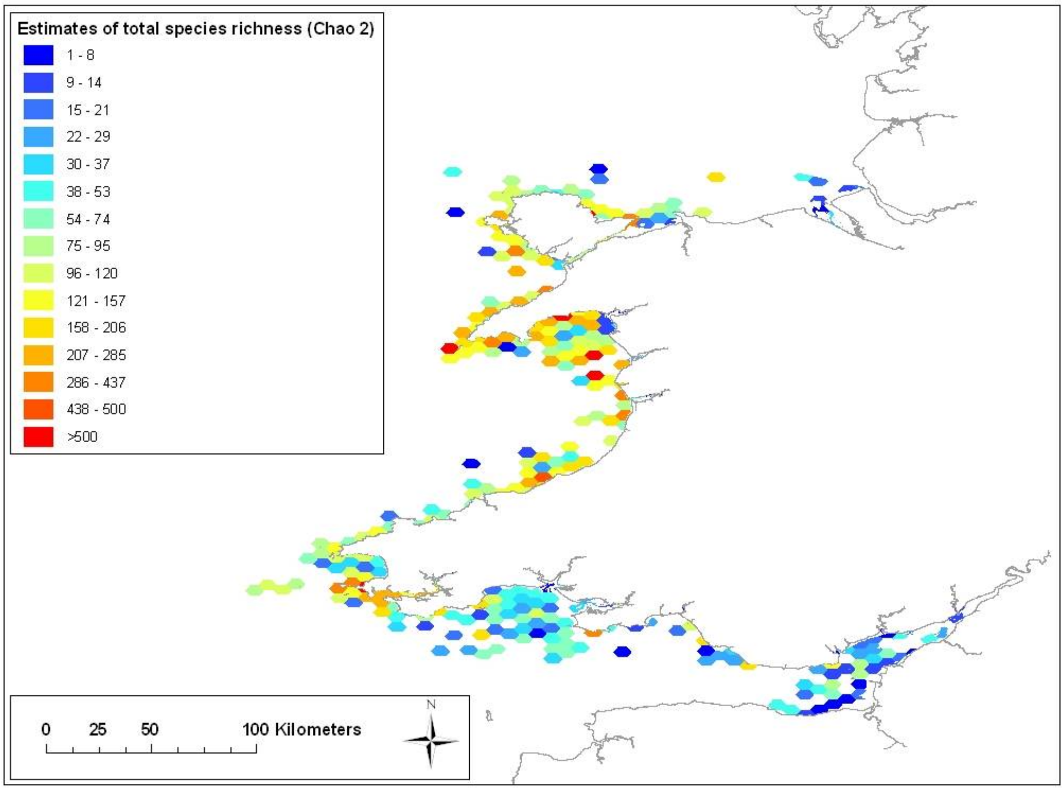


Figure 26 Chao 2 estimate of total species richness for the Welsh subtidal region

4.2.2 Taxonomic distinctness

The maps of taxonomic distinctness (Lamda +) show high values for parts of Carmarthen Bay and the Severn Estuary, the latter being an area where species richness is low (Figure 27 and Figure 28). Again this illustrates that this measure cannot be used in isolation as an indicator of species diversity (discussed with relation to the intertidal), but where species richness is high it indicates that the species pool comes from a diverse range of phlya, orders or classes.

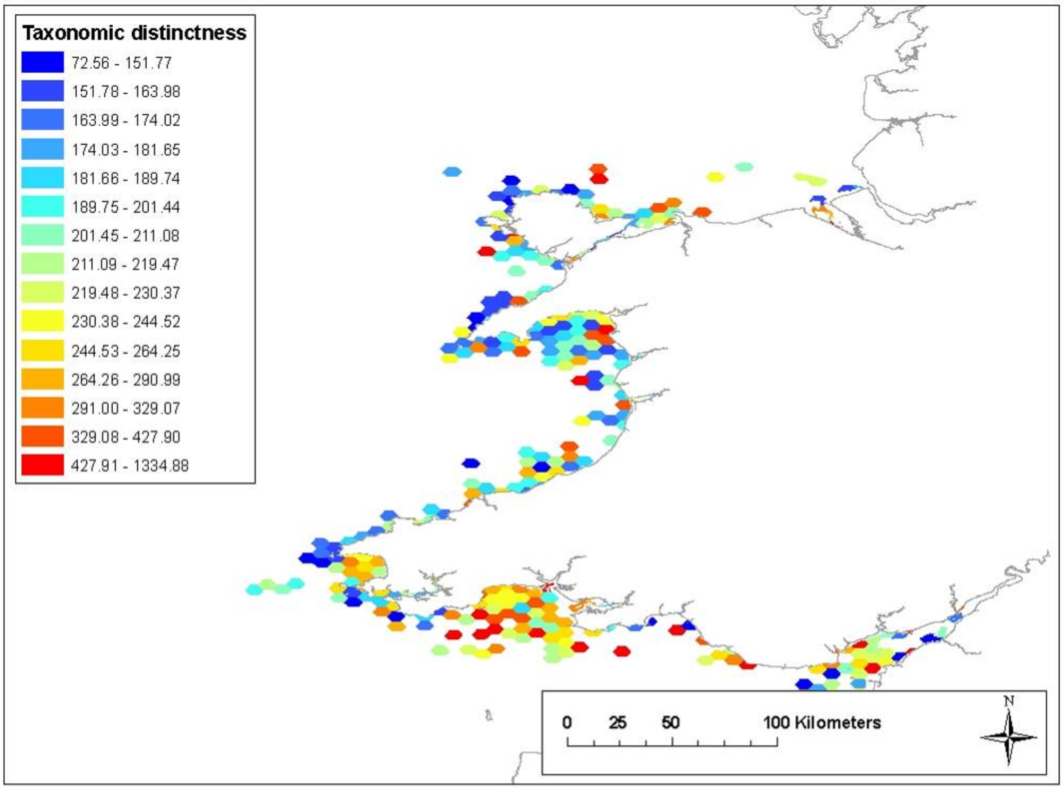


Figure 27 Taxonomic distinctness of species samples from the Welsh subtidal waters.

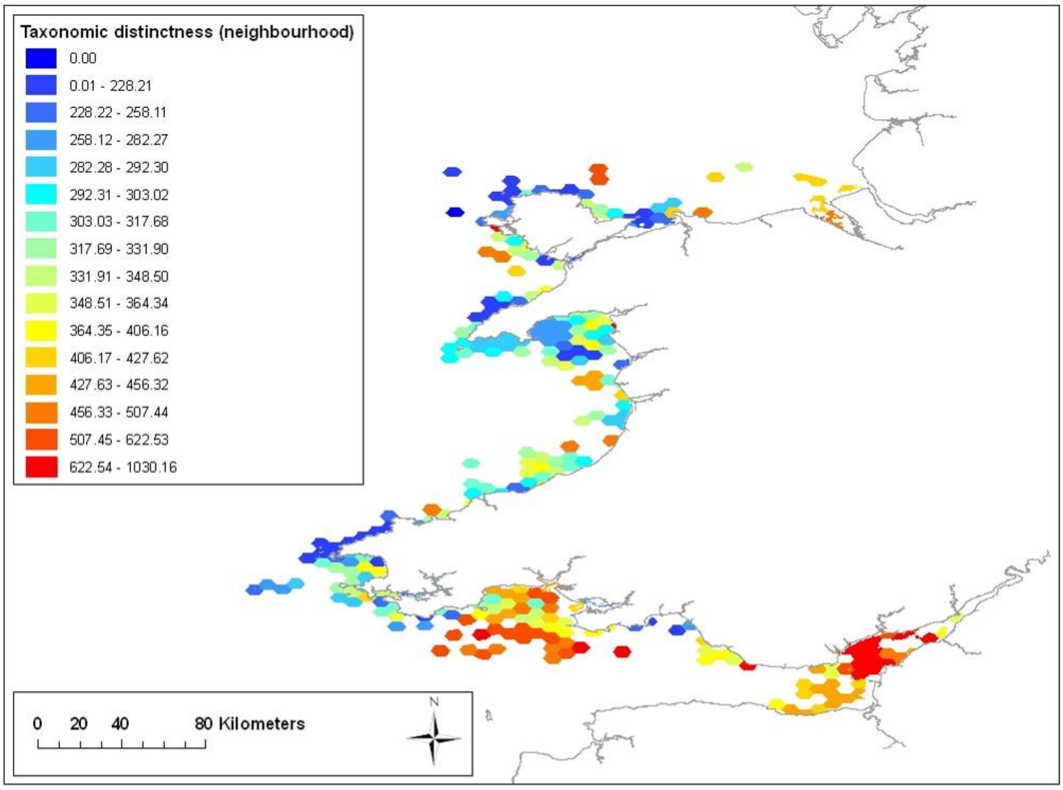


Figure 28 Neighbourhood smoothing of taxonomic distinctness of species samples from the Welsh subtidal waters.

4.2.3 Priority species

In terms of richness of priority species, the most diverse sites appear to be Skomer Island and parts of Milford Haven (Figure 29 and Figure 30). Other areas important for priority species (Figure 30) include two sites on the Lleyn peninsula (around Bardsey Island and off the coast of Abersoch (including St Tudwal's Islands)).

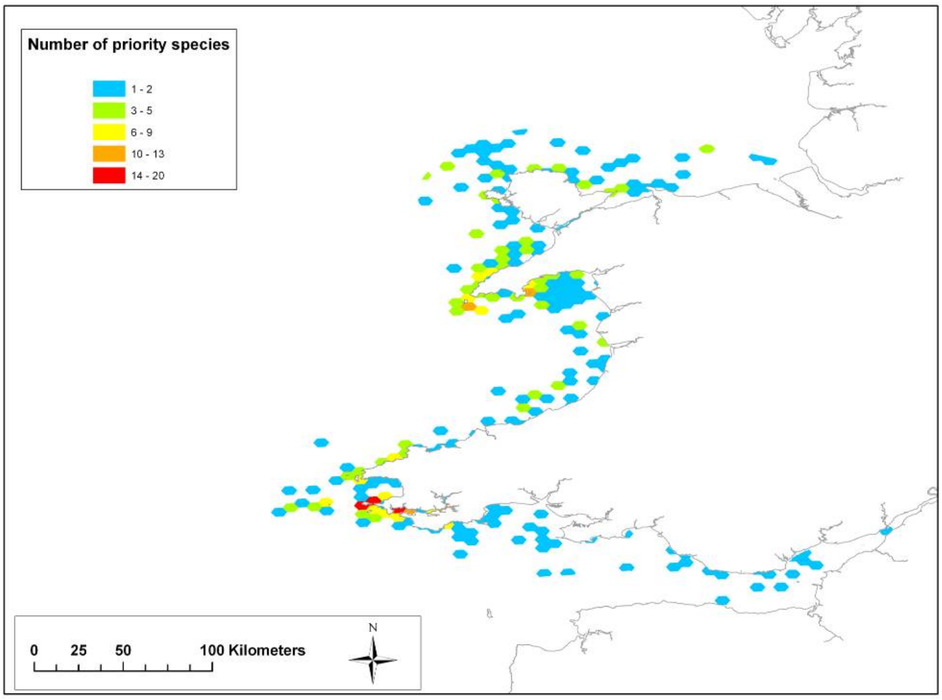


Figure 29 Number of priority species recorded per hexagon from Welsh subtidal area. N.B. these values have not been standardised by sampling effort (see section 3.3.5)

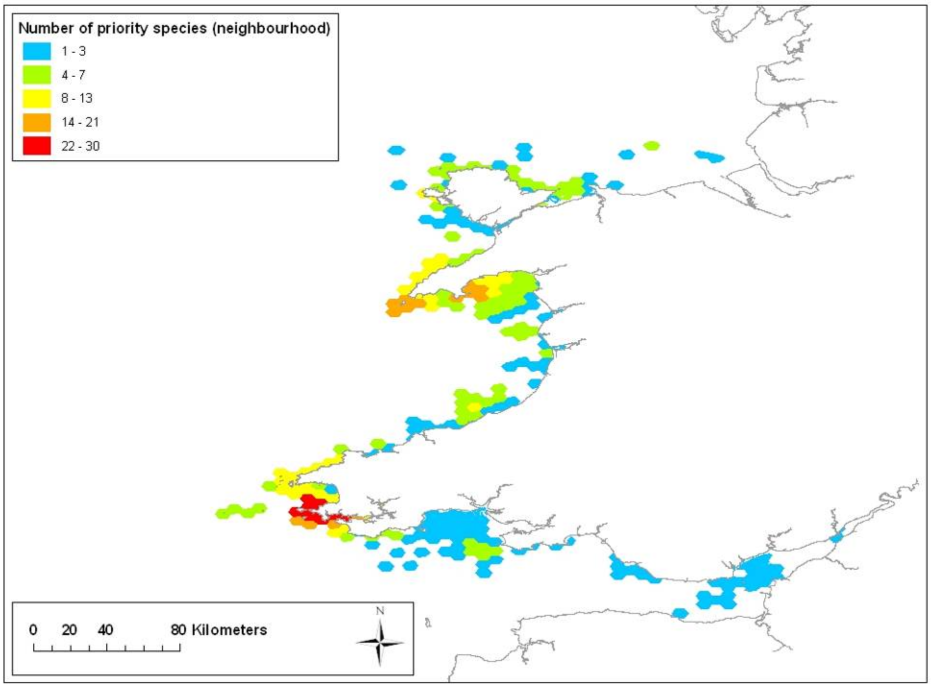


Figure 30 Neighbourhood smoothing of the number of priority species recorded per hexagon from Welsh subtidal area. N.B. these values have not been standardised by sampling effort (see section 3.3.5)

4.3 Intertidal Biotope diversity

4.3.1 Biotope richness

Biotope information for the Welsh intertidal is full coverage and the data was collected using standardised methods, therefore the map showing biotope richness can be viewed with a high degree of confidence and without the need for a confidence map (Figure 31, areas of high biotope richness have been highlighted on the map as they occur on thin slithers of coastline).

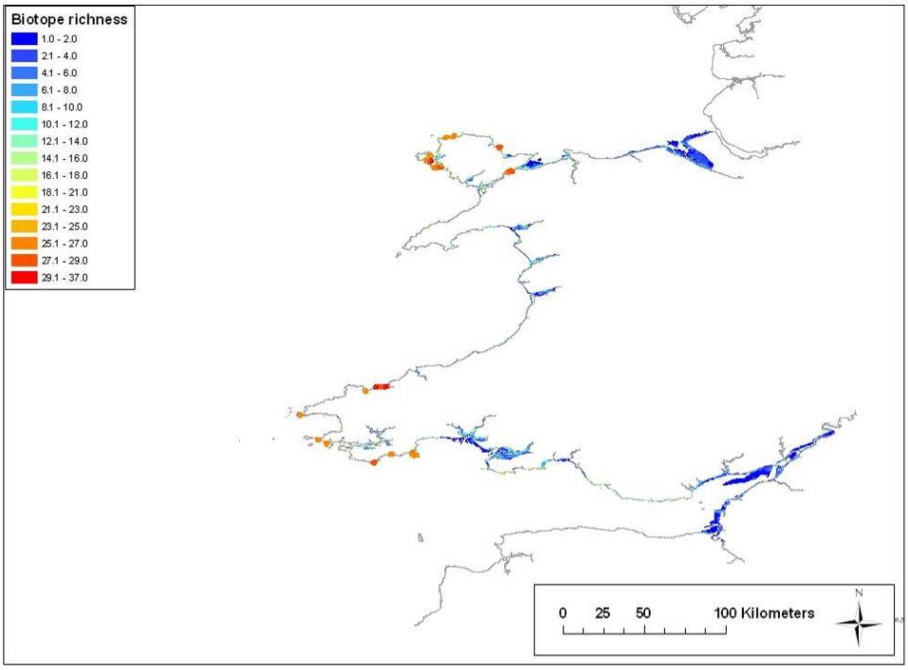


Figure 31 Biotope richness of the Welsh intertidal zone. Hexagons with > 25 biotopes have been emphasized on the map to improve their visibility at this scale.

Biotope richness was particularly high on intertidal regions around the coasts of Anglesey (Moelfre, Trearddur Bay and the Swellies in the Menai Strait) and Pembrokeshire (Between Newport Sands and Dinas Island, south-west of Dinas Island and St Govan's Head). All but the southern Pembrokeshire areas continue to appear as the richest sites when a neighbourhood approach is taken (Figure 32). The neighbourhood calculation identified a further rich site at Mumbles Head near Swansea. Similar to the species richness maps, biotope richness appears low in the estuarine regions.

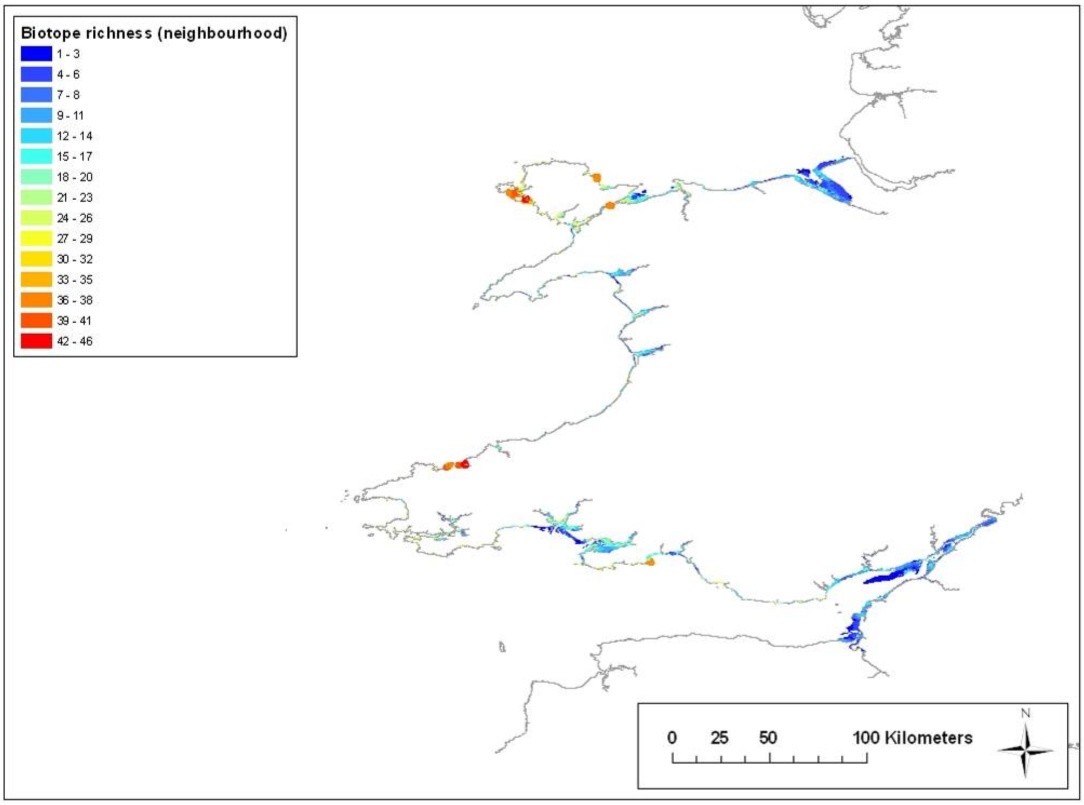


Figure 32 Neighbourhood biotope richness of the Welsh intertidal zone. Hexagons with > 35 biotopes have been emphasized on the map to improve their visibility at this scale.

4.3.2 Biotope distinctness

Intertidal biotope distinctness maps show a number of highly diverse areas in terms of biotopes from a diverse range of broader habitat types (Figure 33), however like the species maps, low numbers of biotopes may skew biotope distinctness results. In an attempt to rectify this a combination measure was calculated based on the sum of the ranks of both biotope richness and biotope distinctness, which would show which areas of high biotope richness were also diverse in terms of the classification hierarchy of those habitats (Figure 34). This combination measure shows that areas such as the Severn Estuary as lower diversity in terms of biotopes than for example Skomer and Milford Haven (Figure 35).

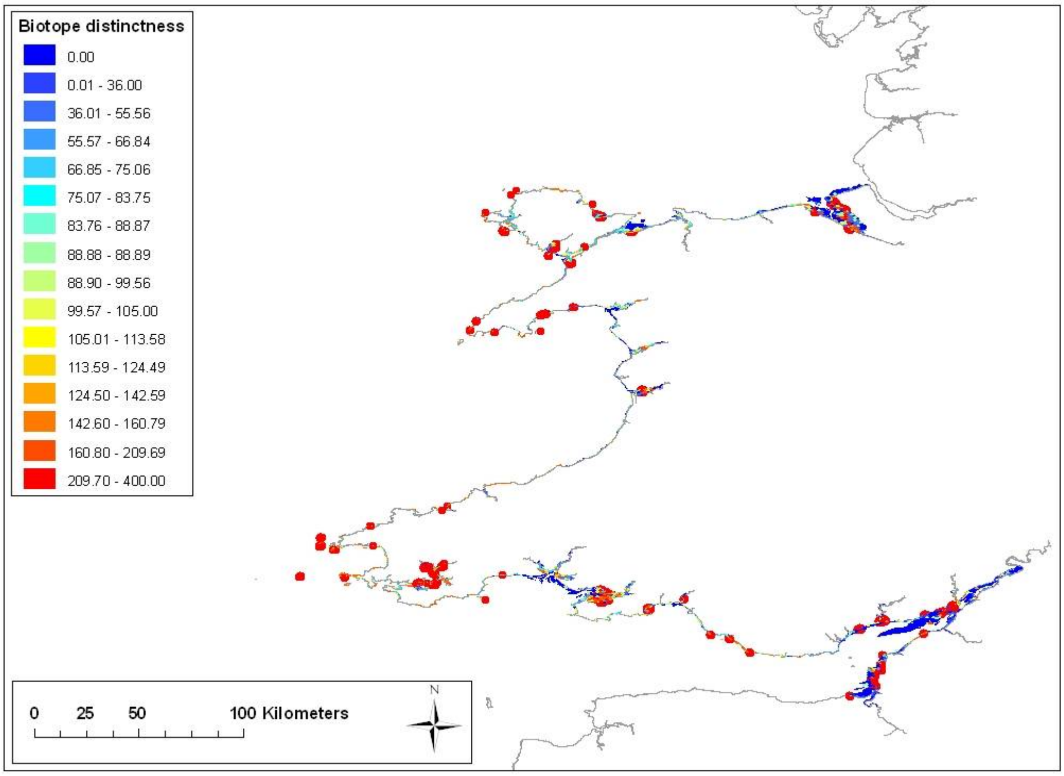


Figure 33 Biotope distinctness of samples from around the Welsh coast intertidal area (the top level category is presented in bold to aid identification of high diversity areas).

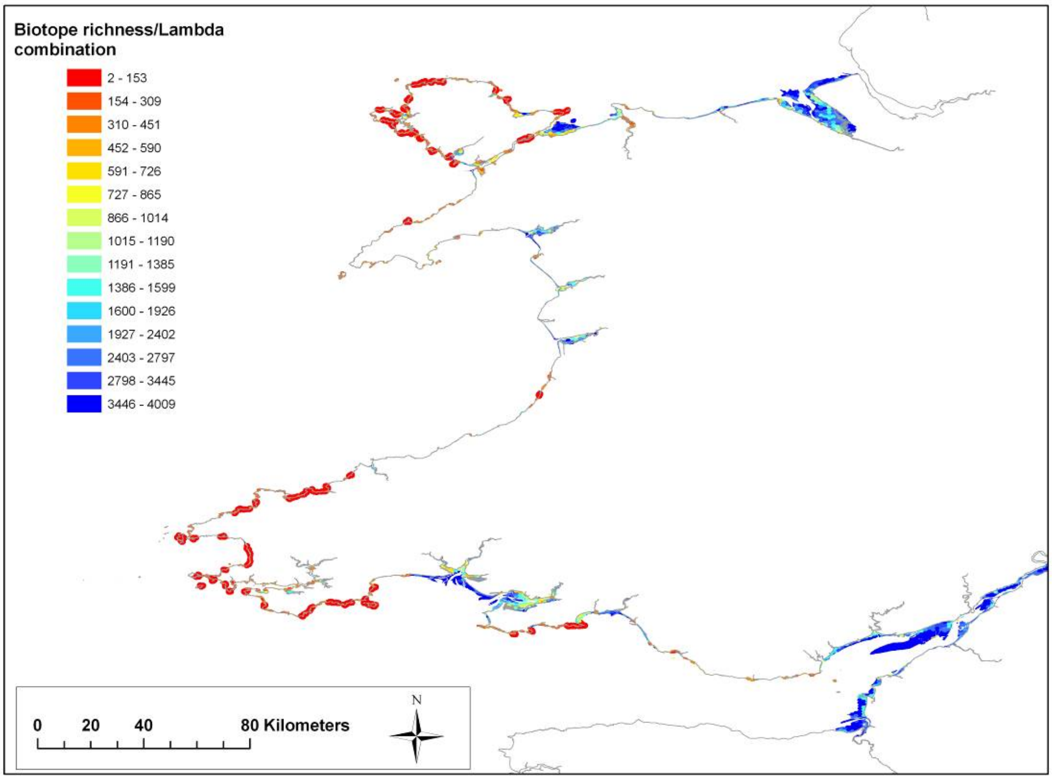


Figure 34 Biotope richness/ distinctness (Lambda +) combination for the Welsh Intertidal zone (the top level category is presented in bold to aid identification of high diversity areas)

a)

b)

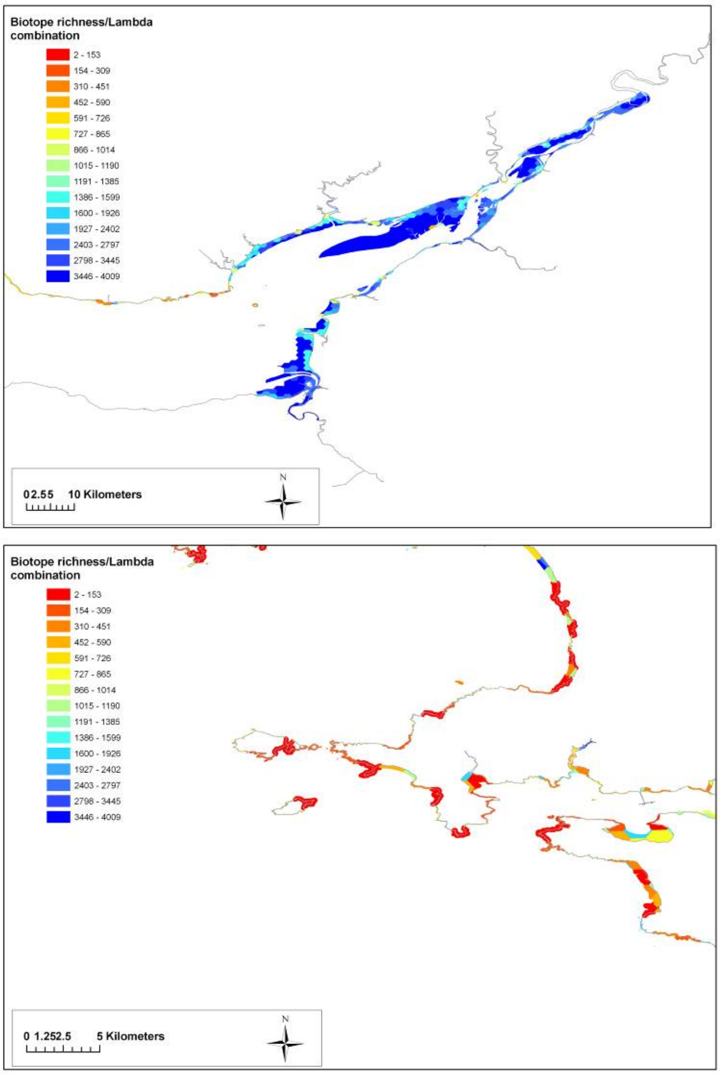
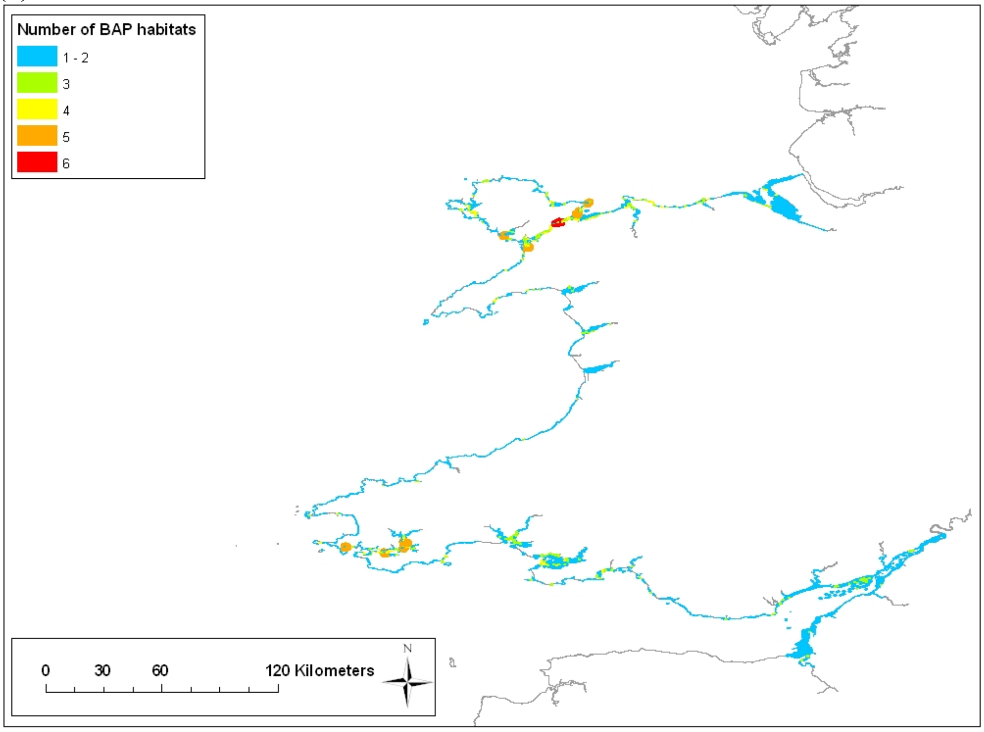


Figure 35 Biotope richness/ distinctness combination zoomed in on (a) the Severn Estuary and (b) Skomer and Milford Haven.

4.3.3 Priority habitats

The number of Wales BAP Section 42 habitats recorded for each 1 km intertidal hexagon is illustrated in Figure 36. Since the intertidal data was from a full coverage survey with standard methodologies these maps are an accurate representation of priority habitat richness. The map of values in individual hexagons (Figure 36a) shows that there is at least one priority habitat on almost all the Welsh coast. The one area with particularly high levels of priority habitats is in the Menai Strait (near Menai Bridge), with six BAP habitats found within the 1km^2 hexagon. Areas with five BAP habitats include Malltraeth Bay (Anglesey), Musslewick (at the mouth of Milford Haven). Figure 36b also shows high numbers of priority habitat at these locations but also highlights other potential locations e.g. Caernarfon Bay and Milford Haven, which may not have been identified in Figure 36a due to the size and location of the hexagonal grid. However, for intertidal areas, neighbourhood maps should be viewed with caution as they may incorporate adjacent narrow strips of coastline which can have a disproportionate effect on the neighbourhood statistics.

(a)



(b)

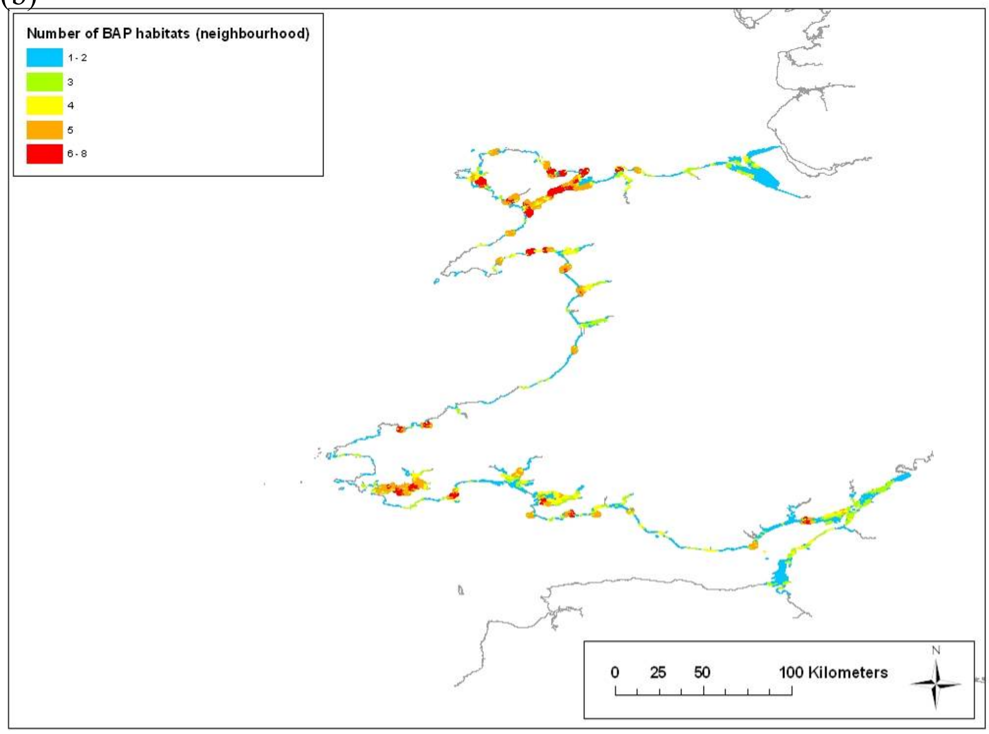


Figure 36 Number of priority habitats per 1km hexagon, for individual hexagons (a) and applying neighbourhood smoothing (b). Top two categories are shown in bold

4.4 Subtidal Biotope diversity

4.4.1 Biotope richness

Subtidal biotope data is much patchier than species data (Figure 37) prior to smoothing (Figure 38). For hexagons which do have underlying data, high biotope richness is evident in the upper reaches of the Severn estuary north of the road bridge, the mouth of Milford Haven, and area off Aberporth in Cardigan Bay, south of the Lleyn Peninsula and numerous sites around the coast of Anglesey (Figure 38). Carmarthen Bay, the majority of the Severn estuary and Tremadog Bay all show low biotope richness.

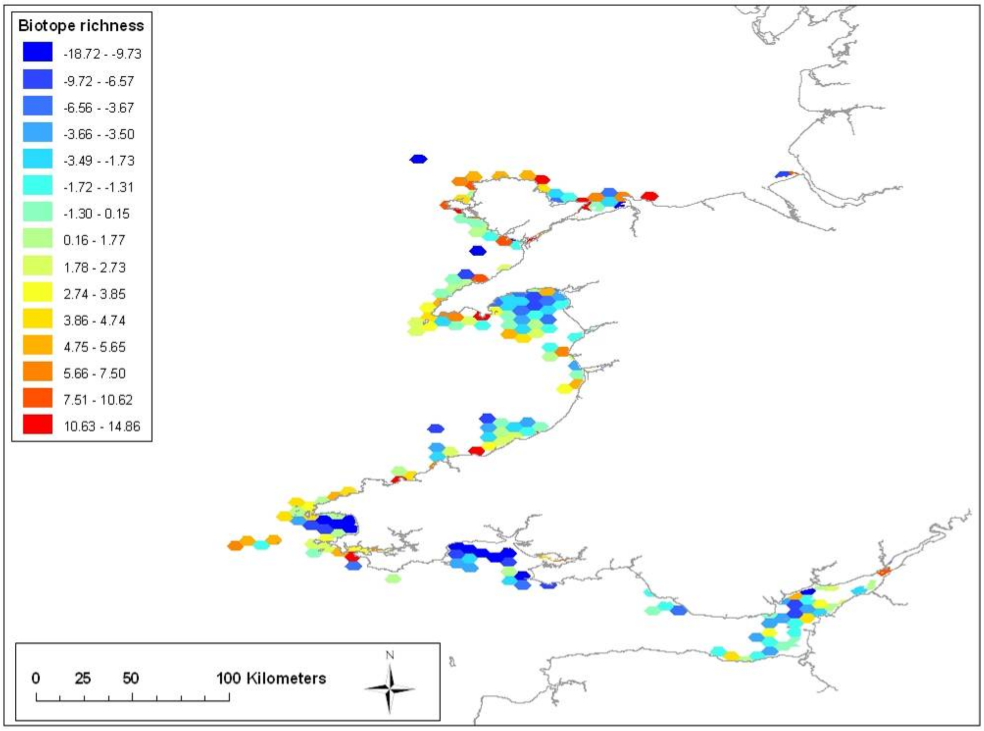


Figure 37 Biotope richness for the Welsh subtidal areas (effort standardised measure)

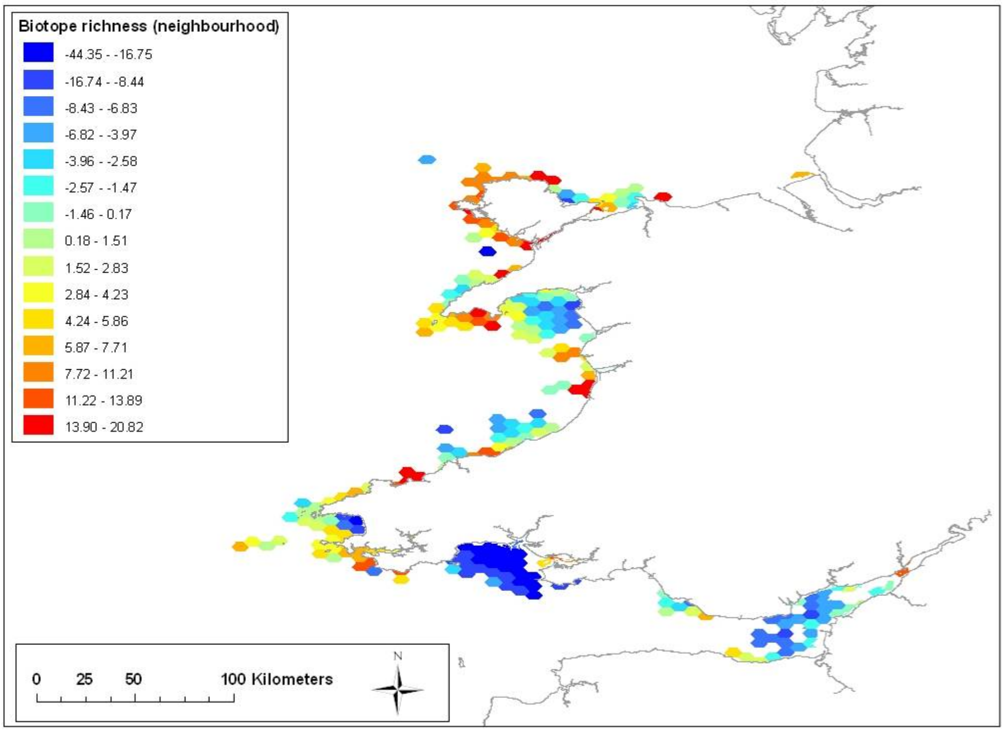


Figure 38 Neighbourhood smoothing of Biotope richness for the Welsh subtidal areas (effort standardised measure)

4.4.2 Biotope distinctness

Subtidal biotope distinctness, like that for the intertidal, is influenced by low numbers of biotopes, resulting in high levels of biotope distinctness in areas such as the Severn Estuary and Carmarthen Bay (Figure 39). Once again a combined measure showing the areas where high biotope richness and high biotope distinctness occur together was calculated and mapped with neighbourhood smoothing. Once applied a few areas stand out as having particularly high biotope diversity including the subtidal region around Anglesey, the waters off Hell’s Mouth on the Lleyn Peninsula, the waters off Aberystwyth, off Aberporth in Cardigan Bay, Fishguard and Newport Bay

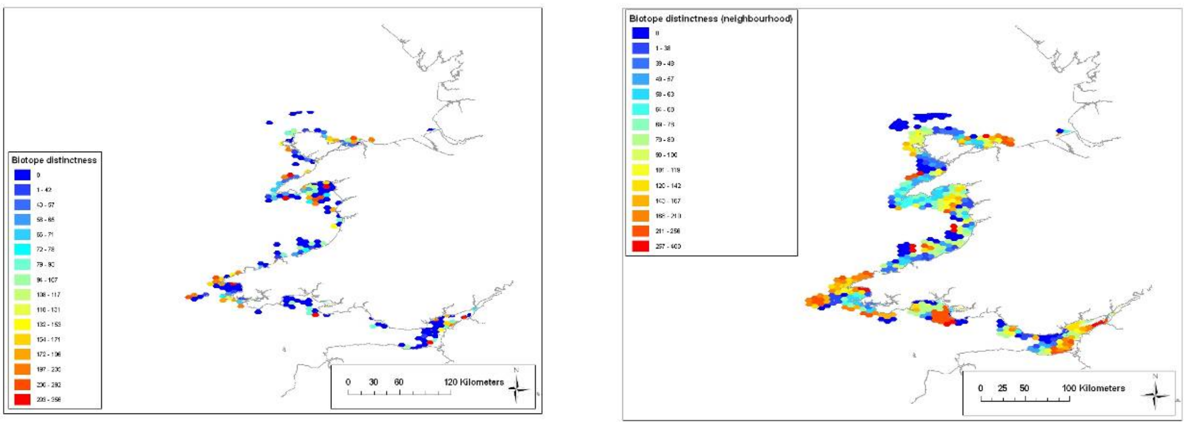


Figure 39 Biotope distinctness (Lambda+) measure for the Welsh subtidal region, (a) for individual hexagons and (b) applying neighbourhood calculations.

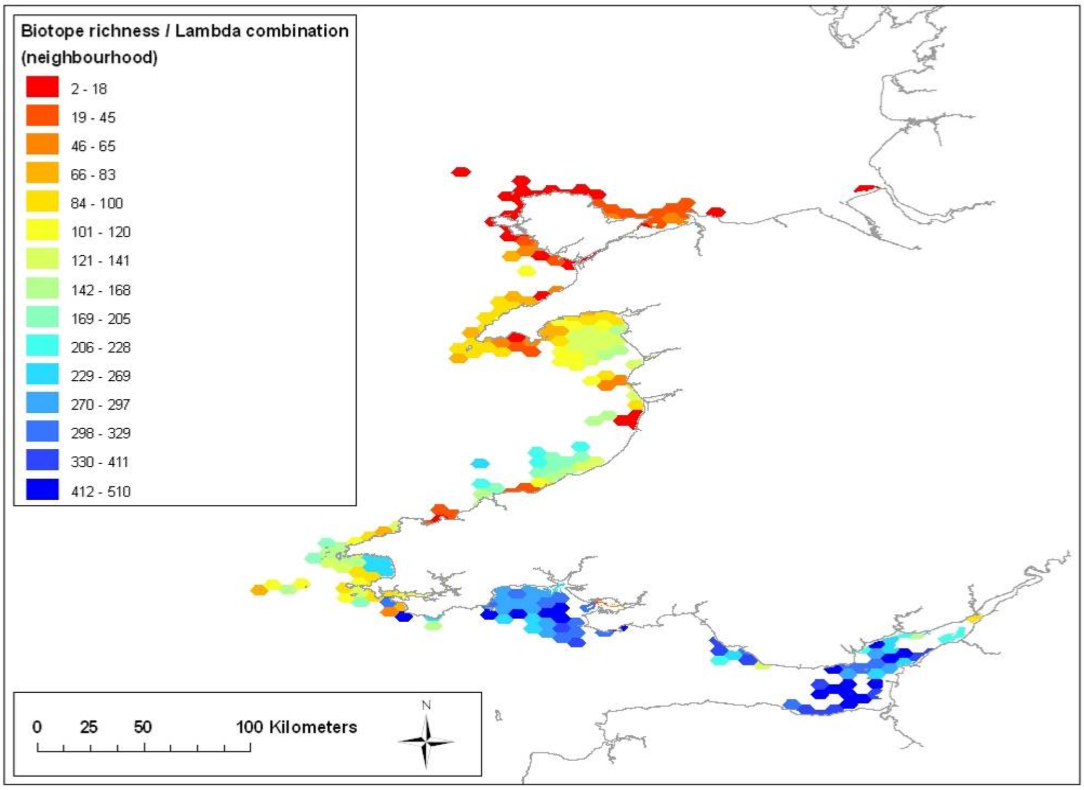


Figure 40 Neighbourhood smoothing of the combined measure of biotope richness and biotope distinctness for the Welsh subtidal areas.

4.4.3 Priority Habitats

The most important areas for concentrations of priority habitats (Figure 41 and Figure 42) include the western tip of Anglesey (Penmon, Puffin Island), the north coast of the Lleyn Peninsula and an area to the south of the Lleyn Peninsula encompassing the sea off Abersoch and Porth Ceiriad, Offshore from Aberystwyth, Milford Haven and Skomer. High richness of priority habitats are predominantly in near inshore areas due to the types of habitats included in this list.

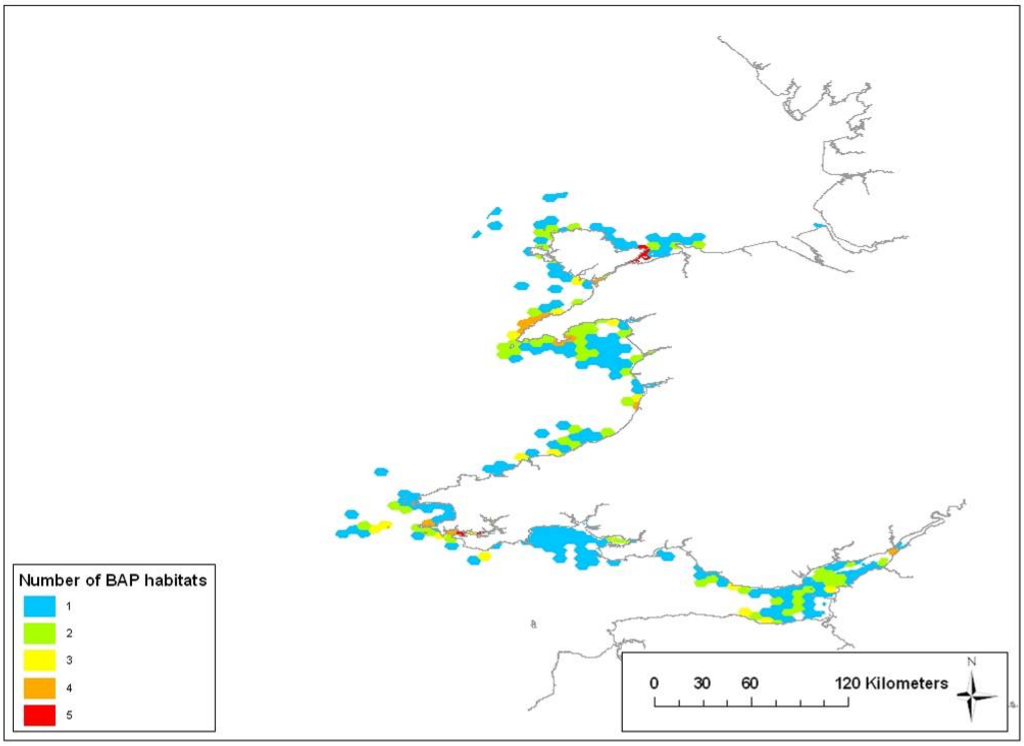


Figure 41 Number of priority habitats recorded for the subtidal waters of Wales.

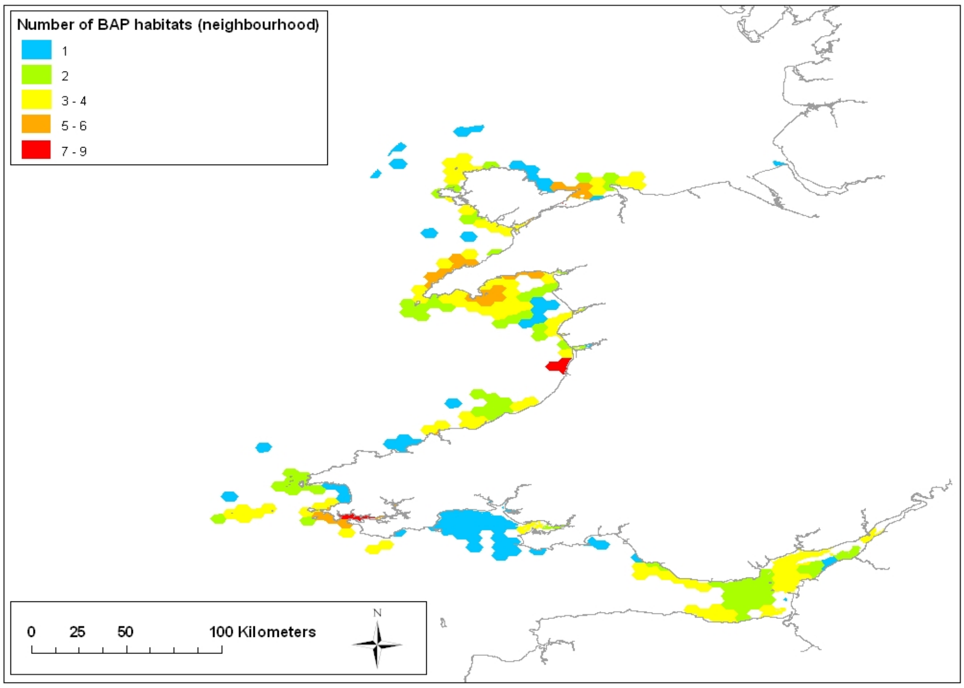


Figure 42 Neighbourhood smoothing of the number of priority habitats recorded for the subtidal waters of Wales.

4.4.4 Concordance of measures

A large number of maps have been presented in this report, showing different metrics to quantify diversity for Welsh waters. The layers could be used within decision support software such as

Marxan to weight particular areas for inclusion within a network design for protected areas, or each layer could be used and analysed within GIS to highlight areas that require safeguarding for different reasons depending on the specific objectives of the plan. When using the layers it is useful to know the independence of each measure. Table 7 shows the correlation between the different measures.

Table 7 Pearson's Product Moment correlation of (correlations in red are significant at $p<0.05$)

	Priority Habitats	Species Chao 2 estimator	Biotope Distinctness Delta+	Biotope Lambda+	Biotope_richness	Priority Species	Species richness median	Species TD_Lambda+
Priority Habitats		0.01	0.09	0.11	0.15	0.36	-0.10	-0.02
Species Chao 2 estimator	0.01		0.14	-0.06	0.11	0.15	0.14	-0.07
Biotope_Delta+	0.09	0.14		0.51	0.58	0.08	-0.19	-0.13
Biotope Lambda+	0.11	-0.06	0.51		0.23	0.14	-0.24	0.03
biotope_richness	0.15	0.11	0.58	0.23		0.10	-0.06	-0.01
Priority Species	0.36	0.15	0.08	0.14	0.10		-0.06	-0.10
Species richness median	-0.10	0.14	-0.19	-0.24	-0.06	-0.06		0.08
Species TD_Lambda+	-0.02	-0.07	-0.13	0.03	-0.01	-0.10	0.08	

Most of the measures are fairly independent of each other. Interestingly the Chao 2 estimator shows some positive correlation with both biotope and species richness and priority species (although not significant) suggesting that this estimate of total species richness may be a useful tool in identifying overall diversity. Also of interest is that areas with high numbers of priority habitats show some correlation with those of high priority species richness. Few of the measures showed any agreement with the biotope distinctness measure.

5 CONCLUSIONS AND LIMITATIONS

As the report illustrates there are a large number of methods for identifying areas of high biodiversity, both in terms of the measures used, the scale examined and the way in which the layers can be combined or interrogated. All the layers developed here are on a continuous scale but are presented within this report in terms of a set number of categories and a subjective choice of what might be considered the highest level of the measure. The choice of thresholds and categories can greatly influence interpretation and should be made on a case by case basis relevant to the task at hand in order to meet specific criteria or to be consistent with wider scale assessments.

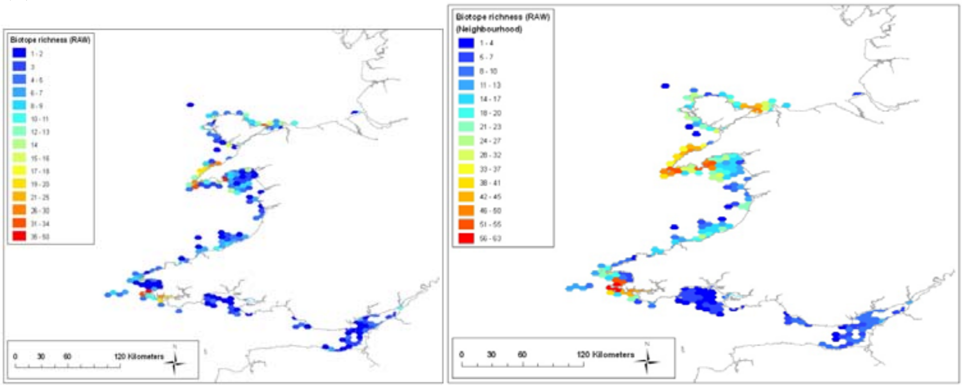
It is clear from the analysis of concordance that no one measure captures all aspects of marine biodiversity. Also each measure is capturing a slightly different aspect of diversity and is influenced to a greater or lesser extent by factors such as sampling intensity or technique. Therefore, in the context of using these maps to aid in the identification of MPAs, for example, multiple measures could be used, depending on the focus. For example, the priority species and habitats richness maps highlight specific areas where protection might give the most "value for money", that is they would protect high numbers of species and habitats identified as priority features. Similarly when ensuring that a network of MPAs is representative of all the habitats within the region (using maps of habitat distributions and decision support tools) the maps of biotope richness could be used to help prioritise areas from a range of possible options.

If the aim was to make sure that locations with diverse communities (which can provide resilience to environmental perturbations) are identified and protected, the Chao 2 estimates of total species richness map may be a useful tool as this validation method appears to overcome some of the issues of sample effort and quality bias that other measures do not do adequately address. Taxonomic distinctness measures may not be very meaningful when used in isolation but in combination with layers of species richness or Chao 2 estimates they may indicate areas where communities are highly diverse not just at the species level but in terms of phylogeny which may be linked to ecosystem functions. Functional traits diversity which is thought to affect ecosystem processes through niche complimentarily and dominance of particular subsets of complementary species is more directly a function of phylogenetic diversity than species richness for larger species pools (Loreau et al. 2001, Palumbi et al. 2009).

The limitations of the individual measures for indicating biodiversity are discussed in 3.3, but there are other limitations to the work presented in this report. Firstly, despite the wealth of information available for identifying important marine biodiversity for Welsh waters, it is clear that the data here do not present a full picture and further areas of high biodiversity may be revealed with increasing survey coverage. In addition, there may well be errors in the data and inconsistency in data collection which influence the results. For example, it was discovered after data analysis had been completed that some surveys had incorrectly assigned survey methods, which may have reduced diversity scores in some areas (in particular around the Llŷn Peninsula and Sarn Badrig). The maps of survey effort and confidence in the underlying data presented in this report are a useful tool for identifying areas which are priority for future survey effort. In addition areas which are identified as highly diverse areas but are based on low confidence data may need to be resurveyed. It is also likely that differences in the application of sampling methods (e.g. differing sieve sizes and sieving techniques, differing levels of taxonomic expertise amongst surveyors) affect the reliability of the analyses (as discussed in 4.2.1). A standardised systematic survey covering all of Welsh waters in detail would address this problem but would also be very costly. The results of this analysis of biodiversity need to be interpreted with caution and with a full understanding of the limitations.

Finally, the process of building these layers and discussions of the map outputs has highlighted the importance of standardising for effort when trying to measure relative diversity. Often there are preconceptions of which areas are diverse which are influenced by the large quantity of data that is available for those sites (as illustrated by Figure 43).

(a)



(b)

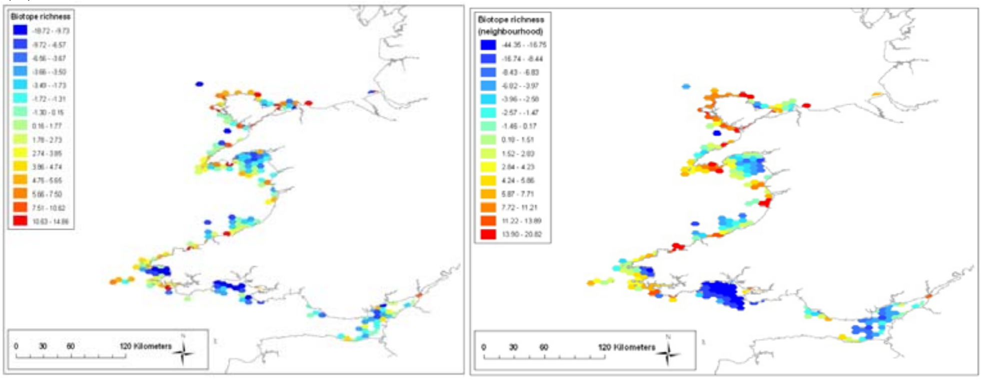


Figure 43 Biotope richness without (a) and with (b) effort standardisation (neighbourhood smoothing is applied to the maps on the right)

6 ACKNOWLEDGEMENTS

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APPENDIX 1: SURVEYS USED IN THE MARINE BIODIVERSITY ANALYSIS

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
1890-1995 North Wales Marine Fauna	MRMLN00400000077	5	5	1	Yes	3
1918-1984 England, Wales and Scotland geographical distribution of Sabellaria alveolata	MRMLN00200000007	2	6	1	Yes	1
1920-1974 Modiolus modiolus in small Mid-tidal rock pools at Penrhyn Bay, North Wales.	MRMLN00200000005	3	6	1	Yes	1
1947-2006 Velella, Physalia, Janthina and Lepas records	MRMLN004000000A1	2	5	1	Yes	2
1965 Crothers PMSA -Dale Roads crab survey	MRCCW10000000039	2	3	2	Yes	3
1965-1972 Variation in the shell of the dog-whelk Nucella lapillus: Pembrokeshire	MRMLN00200000022	1	1	1	Yes	1
1968 Coughlan PMSA -Milford Haven, Pwllcrochan preliminary species survey	MRCCW10000000008	3	3	1	Yes	3
1969 Rees - RWB69 Sublittoral grab sampling survey of Red Wharf Bay	MRCCW90000000017	2	1	2	Yes	1
1970 Aberystwyth Pectenogammarus planicrurus survey	MRMLN00200000026	3	1	1	Yes	1
1970-2004, NMA - United Kingdom Marine Fish Recording Scheme (Welsh data)	MRMLN00400000003	4	4	1	Yes	2
1970-80 SMBA/MBA Great Britain littoral survey	JNCCMNCR10000265	6	1	1	Yes	1
1971 Rees - RW71 sublittoral sediment sampling off Moelfre, NE Anglesey	MRCCW90000000008	2	1	2	Yes	2
1971-1976 Gillham Dee Estuary littoral sediment survey, 1971-76	MRCCW90000000002	1	1	1	Yes	1
1972 - 1973 University of Wales, Bangor. Benthic survey off Benllech	MRCCW30000000016	6	1	1	Yes	2
1972 Naylor PMSA -Estuarine isopod survey	MRCCW10000000025	4	3	1	Yes	3
1972-1973 Bristol Channel sublittoral macrofaunal survey	MRMLN001000000F3	1	1	1	Yes	1
1973 Rees - RWJan73 Sublittoral grab sampling survey off Red Wharf Bay	MRCCW90000000019	2	1	2	Yes	2
1973 University of Bristol Severn estuary littoral survey	JNCCMNCR10000495	3	2	1	Yes	1
1973-75 University of Bristol Severn estuary littoral sediment survey	JNCCMNCR10000488	4	1	1	Yes	1
1973-76 UCWC Bristol Channel and Severn estuary littoral survey	JNCCMNCR10000487	6	6	2	Yes	2
1974 Rees - CB74 Sublittoral grab sampling of Conwy Bay	MRCCW9000000000F	2	1	2	Yes	2
1974-1983 Countryside Council for Wales Coastal surveillance unit monitoring programme	MRMLN0010000006B	2	2	1	Yes	1
1975-1977 Fish collected from intake	MRCCW9000000000D	1	3	1	Yes	2

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
screens of Uskmouth power station, Severn Estuary						
1975-78 University of Bristol Severn Estuary littoral rock survey	JNCCMNCR10000490	4	3	2	Yes	3
1975-91 Picton PMSA -Skomer Island species and habitats surveys	MRCCW10000000033	4	4	1	Yes	3
1976 Rees - CB76 Sublittoral grab sampling of Conwy Bay	MRCCW90000000010	2	1	2	Yes	2
1976 Survey of shallow sublittoral sediments off Llanddona Beach, Red Wharf Bay, Anglesey	MRCCW9000000000E	2	1	2	Yes	2
1976-Rees Red Wharf Bay Benthos	MRCCW3000000002B	2	1	2	Yes	2
1977 SWBSS Ramsey sublittoral survey	JNCCMNCR10000067	2	6	1	Yes	3
1977 UCNW Bardsey Island survey	JNCCMNCR10000228	6	1	1	Yes	1
1977 Wales underwater observation scheme	MRMLN00100000091	4	5	2	Yes	3
1977/78 Case PMSA -Daugleddau estuary, sublittoral survey	MRCCW10000000007	4	3	1	Yes	3
1977-1980 MNCR sector UK09 Bristol Channel and approaches Underwater Observation Scheme	MRMLN0040000005C	4	4	2	Yes	3
1977-1986 north Wales distribution of some sublittoral species	MRMLN0020000002C	3	5	2	Yes	3
1977-1997 Rees_RWT_University of Wales Bangor -Red Wharf bay Student Surveys	MRCCW9000000001A	2	1	2	Yes	2
1977-78 WWA Usk and Wye estuaries sublittoral survey	JNCCMNCR10000486	2	1	1	Yes	1
1977-79 Hiscock PMSA -West Pembrokeshire SWBSS sublittoral survey	MRCCW10000000004	4	3	1	Yes	3
1977-79 SWBSS Grassholm, Skomer & Marloes Peninsula survey	JNCCMNCR10000073	2	6	1	Yes	3
1978 SWBSS South Pembrokeshire sublittoral survey	JNCCMNCR10000071	2	6	1	Yes	3
1978 UCNW Glaslyn/Dwyryd estuary littoral sediment survey	JNCCMNCR10000633	4	4	1	Yes	3
1978-1981 Studies on populations of Echinus esculentus from Skomer Voluntary Marine Nature Reserve	MRMLN00200000039	1	1	1	Yes	1
1978-79 SWBSS Milford Haven survey	JNCCMNCR10000078	2	6	1	Yes	3
1978-79 SWBSS Upper Bristol Channel sublittoral survey	JNCCMNCR10000070	2	6	1	Yes	3
1979 Adams PMSA - Skomer Island, North and South Havens Littoral survey	MRCCW10000000067	4	4	1	Yes	3
1979 Little PMSA -Milford Haven rocky shore transects survey	MRCCW10000000066	4	4	1	Yes	3
1979 MNCR sector UK10 Cardigan Bay and North Wales Underwater Observation Scheme	MRMLN00400000050	4	4	2	Yes	3

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
1979 SWBSS North Pembrokeshire sublittoral survey	JNCCMNCR10000072	2	6	1	Yes	3
1980 Hiscock PMSA -Milford Haven, Amoco refinery jetty piles sublittoral survey	MRCCW10000000015	3	2	1	Yes	2
1980 WWA Severn Bridge to Cardiff sediment survey	JNCCMNCR10000492	3	4	1	Yes	3
1980-1984 Fish and arthropods captured during cooling-water extraction at Oldbury Power Station	MRCCW9000000000C	1	3	1	Yes	2
1980-present MarLIN UK expert sighting records	MRMLN0040000007E	2	1	1	Yes	1
1981 Bishop PMSA -Skomer Island Echinus esculentus survey	MRCCW10000000062	4	4	1	Yes	3
1981 Hiscock PMSA -Milford Haven, Amoco refinery jetty piles sublittoral survey	MRCCW10000000016	3	2	3	Yes	2
1981-1991 JNCC candidate rare species files, Palinurus elephas records	MRMLN0020000000F	2	2	1	Yes	2
1982 Hiscock PMSA -Skomer MNR boundary sublittoral survey	MRCCW10000000061	2	4	2	Yes	3
1982 Hiscock PMSA -Skomer MNR seaward survey	MRCCW10000000063	4	4	1	Yes	3
1982 Jones Menai Strait littoral rock survey	JNCCMNCR10000129	6	6	1	Yes	1
1982 Lumb Menai Strait sublittoral survey	JNCCMNCR10000293	2	1	1	Yes	2
1982 OPRU Skomer littoral survey	JNCCMNCR10000160	3	1	1	Yes	1
1982 OPRU Skomer sublittoral survey	JNCCMNCR10000184	2	2	2	Yes	2
1982 Rees - RWDEAK Epibenthic sledge sampling north of Red Wharf Bay, Anglesey	MRCCW90000000009	2	1	2	Yes	2
1982 Rostron PMSA -Milford Haven sediment survey	MRCCW10000000020	1	1	1	Yes	1
1982 Rostron PMSA -Skomer Island habitats and species survey	MRCCW10000000055	4	4	1	Yes	3
1982 WWA Cardiff sewerage outfalls survey	JNCCMNCR10000491	3	4	1	Yes	3
1982-1984 Fish and arthropods captured during cooling-water extraction at Uskmouth power station	MRCCW9000000000B	1	3	1	Yes	2
1982-83 Bullimore Skomer sublittoral monitoring	JNCCMNCR10000156	6	2	1	Yes	1
1983 - Moore, J. University of Wales Bangor, MSc - Red Wharf Bay Survey	MRCCW30000000018	2	1	2	Yes	2
1983 MCS/FSC Skomer sublittoral survey	JNCCMNCR60000117	4	3	1	Yes	3
1983 OPRU Bardsey and the Lleyn Peninsula littoral survey	JNCCMNCR10000205	6	1	1	Yes	1
1983 OPRU Bardsey and the Lleyn Peninsula sublittoral survey	JNCCMNCR10000186	6	1	1	Yes	1
1983 Wales Okenia elegans record	MRMLN00200000040	2	6	1	Yes	2
1984 Bristol Channel benthic survey	MRMLN001000000E5	1	1	1	Yes	1
1984 Bunker/Hiscock Skomer sublittoral survey	JNCCMNCR10000161	3	3	1	Yes	2

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
1984 Sarn Badrig reef, mid Wales sublittoral algal community survey	MRMLN00200000010	1	1	1	Yes	1
1984 Wales Caloria elegans record	MRMLN0020000003F	2	6	1	Yes	1
1985 Bunker PMSA -Skomer Island Eunicella verrucosa survey	MRCCW10000000029	2	2	1	Yes	1
1985 Menai marine conservation area Molluscan and Polychaeta faunas of selected sites	MRMLN00200000012	1	1	1	Yes	1
1985 OPRU HRE Milford Haven and the Cleddau survey	JNCCMNCR10000246	6	1	1	Yes	1
1985 University of Bristol upper Severn Estuary survey	JNCCMNCR10000196	6	6	1	Yes	1
1985-1991 Wales Okenia elegans records (JNCC candidate rare specie files)	MRMLN00200000038	2	2	1	Yes	2
1986 Bunker PMSA -Skomer Island Pentapora folicaea survey	MRCCW10000000057	4	4	1	Yes	3
1986 Fecundity & seasonal changes in reproductive output of female Pectenogammarus planicrurus	MRMLN00200000024	3	1	1	Yes	1
1986 Hiscock mid-Wales' sarns sublittoral survey	JNCCMNCR10000125	6	2	1	Yes	1
1986 Hiscock PMSA -Milford Haven, Littlewick Bay Zostera survey	MRCCW10000000021	2	1	1	Yes	2
1986-1989 England, Wales and Scotland report on TBT contamination of Nucella lapillus	MRMLN0020000001E	1	1	1	Yes	1
1987 CEGB Mersey estuary littoral sediment survey	JNCCMNCR10000193	6	1	1	Yes	1
1987 North Wales River Clwyd - Aberystwyth survey of the coastal lagoons	MRMLN0020000001D	1	1	1	Yes	1
1987-1988 Skomer Marine Reserve subtidal monitoring project animal communities on stones	MRMLN0020000001F	1	1	1	Yes	1
1987-1990 Skomer Alcyonium glomeratum records (JNCC candidate rare species files)	MRMLN0020000001B	2	6	1	Yes	2
1988 George PMSA -Caldey Island marine survey	MRCCW10000000047	4	4	1	Yes	3
1988 OPRU Cosheston Trot (Milford Haven) sublittoral survey	JNCCMNCR10000671	1	1	1	Yes	1
1988 OPRU HRE Loughor Estuary/Burry Inlet survey	JNCCMNCR10000256	6	1	1	Yes	1
1988 OPRU HRE Taf, Tywi & Gwendraeth Estuaries survey	JNCCMNCR10000258	6	1	1	Yes	1
1988 STPG Severn Estuary sublittoral survey	JNCCMNCR10000460	1	1	1	Yes	1
1988-2001 Wales Polysyncraton lacazei records	MRMLN0020000003E	2	2	1	Yes	2
1989 FSCRC Daucleddau Estuary (Milford Haven) littoral survey	JNCCMNCR10000659	1	1	1	Yes	1
1989 FSCRC Lavan Sands littoral cockle	JNCCMNCR10000291	6	6	1	Yes	1

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
dredging study						
1989 Wales, Isle of Man, Irish Sea & Strangford Lough Modiolus modiolus study	MRMLN00200000003	2	1	1	Yes	1
1989-1990 Skomer Parazoanthus axinellae records (JNCC candidate rare species files)	MRMLN0020000001A	2	6	1	Yes	2
1989-91 Biomor southern Irish Sea sublittoral survey	JNCCMNCR10000634	1	1	1	Yes	1
1990 FSCRC Cosheston Pill littoral sediment survey	JNCCMNCR10000658	1	1	1	Yes	1
1990 FSCRC Lavan Sands littoral cockle dredging study	JNCCMNCR10000292	6	6	1	Yes	1
1990 MNCR Rhos Point to New Brighton littoral survey	JNCCMNCR10000240	2	1	1	Yes	1
1990 Porcupine/Conchological Society Anglesey littoral survey	JNCCMNCR60000280	1	4	1	Yes	2
1990-1996 UK National Marine Monitoring Programme	MBAMNMMP00000001	1	1	1	Yes	1
1991 Preliminary assessment of marine fish within the Usk Estuary	MRCCW9000000000A	6	3	1	Yes	2
1991-1992 Skomer Caryophyllia inornata records (JNCC candidate rare species files)	MRMLN0020000001C	2	6	1	Yes	2
1992 Milford Haven potential SSSI Survey	MRMLN00400000010	1	1	1	Yes	1
1993 - 1994 University of Liverpool - Liverpool Bay Baseline Survey	MRCCW30000000014	1	1	1	Yes	1
1993 - 1994 University of Liverpool, Liverpool bay species list	MRCCW30000000015	1	1	1	Yes	1
1993 - 2000 EA Milford Haven amphipod survey	MRCCW30000000011	1	1	1	Yes	1
1993 English Channel and Irish Sea CEFAS 2m beam trawl surveys (Cor.5b/93)	MRMLN0040000005F	1	1	1	Yes	1
1993 Irish Sea CEFAS 2m beam trawl surveys (Pr.Mad/93)	MRMLN00400000060	1	1	1	Yes	1
1993 Marine Seen Sarn Badrig reef sublittoral survey	JNCCMNCR40000498	6	1	1	Yes	1
1993 OPRU Milford Haven sublittoral sediment survey	JNCCMNCR10000657	1	1	1	Yes	1
1993 Rostron PMSA -Skomer MNR sediment infauna surveys	MRCCW10000000058	4	4	1	Yes	3
1993 Studies on the Crawfish Palinurus elephas in south Wales (and Cornwall)	MRMLN0020000000E	2	2	1	Yes	1
1993 WWA River Usk industrial discharge pipe littoral survey	JNCCMNCR10000493	3	4	1	Yes	3
1993 WWA Severn estuary industral discharge pipe littoral survey	JNCCMNCR10000494	3	4	1	Yes	3
1993-94 CCW Traeth Lafan hydraulic dredging impact survey	JNCCMNCR40000693	1	1	1	Yes	1
1994 Celtic Sea CEFAS 2m beam trawl surveys (Cir.2b/94)	MRMLN0040000005B	1	1	1	Yes	1
1994 MNCR Menai Strait littoral survey	JNCCMNCR10000468	1	1	1	Yes	1

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
1994 MNCR south Pembrokeshire sublittoral survey	JNCCMNCR10000467	1	1	1	Yes	1
1994/95 Rostron PMSA -Skomer Island sediment interface surveys	MRCCW10000000059	4	4	1	Yes	3
1995 - 2002 Seasearch Survey of North Anglesey	MRCCW3000000000D	2	1	2	Yes	2
1995 Cardigan Bay Caloria elegans record (JNCC candidate rare species files)	MRMLN00200000037	2	6	1	Yes	1
1995 Mettam Severn Estuary sublittoral survey	JNCCMNCR10000722	1	2	1	Yes	1
1995 MNCR Cardigan and Tremadoc Bays sediment sampling trial	JNCCMNCR10000631	1	2	1	Yes	1
1995 MNCR Cardigan Bay estuaries littoral survey	JNCCMNCR10000629	1	1	1	Yes	1
1995 MNCR Ceredigion coast littoral survey	JNCCMNCR10000625	1	1	1	Yes	1
1995 MNCR Lleyn Peninsula and Tremadoc Bay sublittoral survey	JNCCMNCR10000628	1	1	1	Yes	1
1995 MNCR north Lleyn Peninsula and Tremadoc Bay littoral survey	JNCCMNCR10000627	1	1	1	Yes	1
1995 MNCR north Pembrokeshire sublittoral survey	JNCCMNCR10000632	1	1	1	Yes	1
1995 MNCR Sarnau of Cardigan Bay sublittoral survey	JNCCMNCR10000630	1	1	1	Yes	1
1995 OPRU Milford Haven littoral rock monitoring	JNCCMNCR10000669	1	1	1	Yes	1
1995 Rees - CB95 HX Sublittoral grab sampling of Conwy Bay	MRCCW90000000011	1	1	2	Yes	1
1995-2000 South Llyn and Bardsey Seasearch Survey	JNCCMNCR60000819	2	1	2	Yes	2
1995-97 MNCR Ceredigion coast sublittoral survey	JNCCMNCR10000626	1	1	1	Yes	1
1995-98 Seasearch Menai Strait and Puffin Island sublittoral survey	JNCCMNCR60000816	2	1	2	Yes	2
1996 MNCR west Anglesey littoral survey	JNCCMNCR10000641	1	1	1	Yes	1
1996 MNCR west Anglesey sublittoral survey	JNCCMNCR10000640	1	1	1	Yes	1
1996 MNCR/CCW Bardsey Island littoral survey	JNCCMNCR10000638	1	1	1	Yes	1
1996 Moore PMSA -Milford Haven, Pennar Gut divers survey	MRCCW10000000009	4	3	1	Yes	3
1996 Posford Duvivier Environment Milford Haven sublittoral survey	JNCCMNCR10000656	1	1	1	Yes	1
1996-1997 Environment Agency macrobenthic monitoring in coastal waters adjacent to Milford Haven	MRCCW90000000003	1	1	1	Yes	1
1996-1998 Cockle raking studies in the Dee Estuary, 1996-98	MRCCW90000000004	1	1	1	Yes	1
1997 AES River Parrett (Severn Estuary) sediment survey	JNCCMNCR10000760	6	1	1	Yes	1

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
1997 CCW Britannia Bridge Mussel Survey	MRCCW3000000002F	2	2	1	Yes	2
1997 CCW, Roxanne Llyn - Ground truthing video drops	JNCCMNCR40000960	1	1	1	Yes	1
1997 MNCR Bardsey Island and SW Lleyn Peninsula sublittoral survey	JNCCMNCR10000644	1	1	1	Yes	1
1997 MNCR Cardigan Bay littoral survey	JNCCMNCR10000642	1	1	1	Yes	1
1997 MNCR east Anglesey littoral survey	JNCCMNCR10000646	1	1	1	Yes	1
1997 MNCR east Anglesey sublittoral survey	JNCCMNCR10000648	1	1	1	Yes	1
1997 MNCR Severn estuary littoral rock survey	JNCCMNCR10000685	1	1	1	Yes	1
1997 MNCR west Anglesey sublittoral survey	JNCCMNCR10000647	1	1	1	Yes	1
1997 NWNWSFC Cardigan Bay sublittoral sediment survey	JNCCMNCR10000643	1	1	1	Yes	1
1997 Rees - CB97 HX Sublittoral grab sampling of Conwy Bay	MRCCW90000000012	1	1	2	Yes	1
1998 - 2003 Seasearch survey of the Lleyn Peninsula	MRMCS00500000007	2	2	2	Yes	2
1998 - CCW Carmarthen Bay Infaunal/Scoter Survey	MRCCW30000000004	2	3	1	Yes	2
1998 - current Britain & Ireland volunteer collected Sealife Survey records	MRMLN00400000002	4	5	2	Yes	3
1998 CCW Benthos of Cardigan Bay cSAC	JNCCMNCR40000774	1	1	1	Yes	1
1998 CCW Llyn Peninsula sublittoral monitoring trials	JNCCMNCR40000772	2	2	1	Yes	2
1998 CCW Menai Strait sublittoral sites: Gallows Point	JNCCMNCR40000698	1	6	1	Yes	1
1998 CCW Sarnau sublittoral monitoring trials	JNCCMNCR40000773	2	2	1	Yes	2
1998 JNCC Milford Haven littoral sediment survey	JNCCMNCR10000710	1	1	1	Yes	1
1998 Marine Seen North Lleyn sublittoral survey	JNCCMNCR40000771	1	6	1	Yes	1
1998 Munro PMSA -Milford Haven rocky sublittoral survey	MRCCW10000000094	4	4	1	Yes	3
1998 NHM Wales saline lagoons and pools survey	JNCCMNCR40000799	1	1	1	Yes	1
1998 North Sea, English Channel, Bristol Channel and Irish Sea CEFAS 4m beam trawl survey	MBAMCFAS00000001	1	1	1	Yes	1
1998 Seasearch survey of Stackpole area	MRCCW20000000004	2	1	2	Yes	2
1998 UWB Conwy Bay sublittoral sediment survey	JNCCMNCR40000817	1	1	2	Yes	2
1998-2000 CEFAS beam trawl of Red Wharf Bay, Anglesey	MRCCW90000000018	1	1	1	Yes	1
1999 - 2001 Environment Agency Cardiff Bay Benthos	MRCCW30000000012	1	1	1	Yes	1
1999 - CCW Sarn Badrig Monitoring Trials	MRCCW30000000006	2	2	1	Yes	2

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
1999 Bristol Channel and Irish Sea CEFAS 4m Beam Trawl Survey (Cory 9-99)	MRMLN00300000004	1	1	1	Yes	1
1999 CCW in Cardigan Bay Survey for BAP Alga species Anotrichium barbatum	JNCCMNCR40000738	1	1	1	Yes	1
1999 CCW Mawddach estuary littoral monitoring trial	JNCCMNCR40000795	1	1	1	Yes	2
1999 CCW Modiolus monitoring trial survey off North Pen LLyn	JNCCMNCR40000775	1	1	1	Yes	3
1999 CCW Sarn Badrig Reef sublittoral monitoring trial	JNCCMNCR40000776	1	1	1	Yes	2
1999 CCW/Aquascan north Pen Llyn a'r Sarnau video survey monitoring trials	JNCCMNCR40000796	1	1	1	Yes	1
1999 CCW/Aquascan north Pen Llyn video survey	JNCCMNCR40000798	1	1	1	Yes	1
1999 CCW/Aquascan Sarn Badrig video survey	JNCCMNCR40000797	1	1	1	Yes	1
1999 CCW/NWNWSFC Mawddach Estuary littoral survey	JNCCMNCR40000739	1	1	1	Yes	1
1999 CES Gallows Point sublittoral survey	JNCCMNCR40000814	3	2	1	Yes	2
1999 Environment Agency sublittoral sediment survey east of Cardiff, Severn Estuary	MRCCW90000000016	1	1	1	Yes	1
1999 Marine Conservation Society Survey Dives, Skomer Marine Nature Reserve and St Brides Bay August	MRCCW1680000000A	2	1	2	Yes	1
1999 Seasearch Survey of Daugleddau Estuary	MRCCW3000000001D	2	1	2	Yes	1
1999-2000 Environment Agency NMMP Dee Estuary littoral sediment	MRCCW90000000013	1	1	1	Yes	1
1999-2000 Environment Agency NMMP Dovey Estuary littoral sediment	MRCCW90000000015	1	1	1	Yes	1
1999-2000 Environment Agency NMMP Mawddach Estuary littoral sediment	MRCCW90000000014	1	1	1	Yes	1
2000 - 2002 Celtic Sea CEFAS 2m beam trawl survey	MRMLN00300000002	1	1	1	Yes	1
2000 CCW St Brides Bay Sublittoral Sediment Benthic Survey	MRCCW30000000002	1	1	1	Yes	1
2000 Menai Sub-aqua Club Tremadoc Bay Mantis shrimp survey	JNCCMNCR40000815	2	2	2	No*	3
2000 North Llyn Seasearch Survey	JNCCMNCR60000821	2	1	2	Yes	1
2000 Onwards - Seasearch Surveys of the Menai Strait	MRCCW30000000028	2	1	1	Yes	1
2000 Seasearch Survey of Mid Wales	MRCCW20000000005	2	1	2	Yes	2
2000 Seasearch Survey of Ramsey Island	MRCCW30000000007	2	1	2	Yes	2
2000-01 Marine Seen and CCW survey of sea caves in Welsh SACs.	JNCCMNCR40000961	1	1	1	Yes	1
2001 CCW cSAC sandbanks survey Zooplankton analysis	MRCCW30000000037	1	1	1	Yes	1

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
2001 CCW/SOS - Survey of Sabellaria Reefs at Criccieth, North Wales	MRCCW30000000039	5	2	2	Yes	2
2001 Environment Agency Environmental impact assessment of Borden Chemicals long sea outfall	MRCCW90000000007	1	1	1	Yes	1
2001 NMGW/CCW Macrofaunal Survey of Welsh Sandbanks	MRCCW30000000008	1	1	1	Yes	1
2001 School of Ocean Sciences Beam Trawl Data - Essential Fish Habitat Project	MRCCW30000000035	1	1	1	Yes	1
2001 Seasearch Newbrough Seagrass Search	MRCCW30000000017	1	1	2	Yes	2
2001 Seasearch Survey of Criccieth	MRCCW3000000001B	1	1	2	Yes	2
2001 Skomer MNR Sediment epifauna community survey	MRCCW16800000009	1	1	1	Yes	1
2001 SOS/CCW Welsh sandbanks fish and epibenthos survey	MRCCW30000000038	1	1	1	Yes	1
2001 UMA Culver Sands Area 472	MRMLN0040000007B	1	1	1	Yes	1
2001/2002 CCW - Invertebrate Survey of Mussel Crumble in Burry Inlet	MRCCW30000000029	1	1	1	Yes	1
2001-2002 Seasearch Survey of W Anglesey	MRMCS00500000006	2	1	2	Yes	2
2002 - Marine Seen and CCW survey of sea caves in Welsh SACs.	MRCCW3000000001C	1	1	1	Yes	1
2002 CCW Epifloral diversity within eelgrass (Zostera marina) beds on the Welsh coast	MRCCW30000000036	1	1	1	Yes	1
2002 CCW Marine mud and muddy gravel characterisation in the Menai Strait	MRCCW30000000031	1	1	1	Yes	1
2002 CCW Survey of native oyster beds (Ostrea edulis) in Wales	MRCCW30000000032	1	1	1	Yes	1
2002 CCW/CALM Menai Strait tidally exposed seabed and shores	MRCCW80000000002	1	1	1	Yes	1
2002 CCW/CALM Milford Haven & Daugleddau Estuary tidally exposed seabed and shores	MRCCW80000000003	1	1	1	Yes	1
2002 Environment Agency Dee Estuary Survey	MRCCW30000000019	1	1	1	Yes	1
2002 Seasearch North Wales Seafan Survey	MRCCW30000000022	2	1	1	Yes	2
2002 Seasearch Survey of East Anglesey	MRCCW30000000013	2	1	2	Yes	2
2002 Seasearch Survey of Llyn Peninsula	MRCCW3000000000F	2	1	2	Yes	2
2002 Seasearch Survey of North Pembrokeshire Seafans	MRCCW30000000023	2	1	2	Yes	2
2002 Seasearch Survey of Skokholm Island	MRCCW30000000020	2	1	2	Yes	2
2002 Seasearch Survey of the Inland Sea, N W Anglesey	MRMCS0050000000A	2	1	2	Yes	2
2002 Seasearch Survey of W Anglesey	MRMCS00500000004	2	1	2	Yes	2
2002 Western English Channel, Celtic Sea and Bristol Channel CEFAS Beam Trawl Survey (Cory 13/02)	MRMLN00300000007	1	1	1	Yes	1
2003 CCW/CALM NW Anglesey tidally	MRCCW80000000004	1	1	1	Yes	1

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
exposed seabed and shores						
2003 CCW/CALM West Pembrokeshire tidally exposed seabed and shores	MRCCW80000000005	1	1	1	Yes	1
2003 Irish Sea off Anglesey JNCC benthic survey	MRMLN00400000013	1	1	1	Yes	1
2003 MCS Seasearch survey - Carmarthen Bay, S Wales	MRMCS00100000002	2	1	1	Yes	2
2003 MCS Seasearch Survey - Hog Reef, Skokholm, Pembrokeshire	MRMCS0010000000D	2	1	1	Yes	2
2003 MCS Seasearch Survey - Milford Haven, Pembrokeshire	MRMCS0010000000A	2	1	1	Yes	2
2003 MCS Seasearch Survey - South Haven, Skomer, Pembrokeshire	MRMCS0010000000C	2	1	2	Yes	2
2003 Seasearch - Tremadog Bay, Criccieth, North Wales	MRMCS00100000014	2	1	2	Yes	2
2003 Seasearch South Llyn survey	MRCCW1100000002F	2	1	2	Yes	2
2003 Seasearch survey Holyhead, N W Anglesey	MRMCS00500000005	2	1	2	Yes	2
2003 Seasearch survey of Milford Haven, S W Pembrokeshire	MRMCS00500000002	2	1	2	Yes	2
2003 Seasearch Survey of N Anglesey	MRMCS00500000009	2	1	2	Yes	2
2003 Seasearch survey of N W Anglesey	MRMCS00500000003	2	1	2	Yes	2
2003 Seasearch Survey of S E Anglesey	MRMCS00500000008	2	1	2	Yes	2
2003 Skomer MNR Echinus esculentus and selected starfish species survey	MRCCW16800000005	1	1	1	Yes	2
2003 Western English Channel, Bristol Channel and Irish Sea CEFAS 4m beam trawl survey	MRMLN00300000005	1	1	1	Yes	1
2003-x CCW Pen Llyn a'r Sarnau cSAC diving surveys	MRCCW30000000030	1	1	1	Yes	1
2004 CCW Tremadog Bay sublittoral sediment survey	MRCCW3010000000F	1	1	1	Yes	1
2004 IECS Cardigan Bay SAC LR.Rkp.SwSed pools survey	MRCCW3020000000E	1	1	1	Yes	1
2004 IECS Cardigan Bay SAC Sabellaria alveolata reefs survey	MRCCW3020000000F	1	1	1	Yes	1
2004 IECS Carmarthen Bay & Estuaries SAC Hydroid rockpool (LR.H) transect survey	MRCCW30200000015	1	1	1	Yes	1
2004 IECS Carmarthen Bay & Estuaries SAC Ophelia bicornis	MRCCW30200000011	1	1	1	Yes	1
2004 IECS Carmarthen Bay & Estuaries SAC Piddocks survey	MRCCW30200000013	1	1	1	Yes	1
2004 IECS Carmarthen Bay & Estuaries SAC Ruppia maritima survey	MRCCW30200000012	1	1	1	Yes	1
2004 IECS Carmarthen Bay & Estuaries SAC Zostera noltii survey	MRCCW30200000014	1	1	1	Yes	1
2004 IECS Carmarthen Bay & Estuaries SAC, Hydroid rockpool (LR.H) richness survey	MRCCW30200000017	1	1	1	Yes	1

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
2004 IECS Menai Strait & Conwy Bay SAC Muddy Gravels (LMX.Psyllid) Core Sampling	MRCCW30200000009	1	1	1	Yes	1
2004 IECS Menai Strait & Conwy Bay SAC Muddy Gravels (LMXPsyllid) survey	MRCCW30200000007	1	1	1	Yes	1
2004 IECS Menai Strait & Conwy Bay SAC Underboulder biotope mapping	MRCCW30200000006	1	1	1	Yes	1
2004 IECS Menai Strait & Conwy SAC Zostera noltii survey	MRCCW30200000008	1	1	1	Yes	1
2004 IECS Pen Llyn a'r Sarnau SAC Afon Mawddach biotope mapping	MRCCW3020000000A	1	1	1	Yes	1
2004 IECS Pen Llyn a'r Sarnau SAC Muddy Gravel Community (IMX.VsenMtru) survey	MRCCW3030000000B	1	1	1	Yes	1
2004 IECS Pen Llyn a'r Sarnau SAC Pectenogammarus planicrurus survey	MRCCW3020000000C	1	1	1	Yes	1
2004 IECS Pen Llyn a'r Sarnau SAC Sabellaria alveolata reefs monitoring	MRCCW30200000010	1	1	1	Yes	1
2004 IECS Pen Llyn a'r Sarnau SAC Zostera marina survey	MRCCW3020000000D	1	1	1	Yes	1
2004 Pelagial/Sea-Scope/CCW Cardigan Bay cSAC sublittoral monitoring survey	MRCCW3010000000B	1	1	1	Yes	1
2004 Seasearch North Pembrokeshire	MRMCS0010000001A	2	2	2	No	2
2004 Seasearch Skokholm, Pembrokeshire	MRMCS00800000003	2	2	2	No	2
2004 Seasearch Survey Marloes Peninsula, Skomer Marine Nature Reserve.	MRMCS00800000005	2	2	2	No	2
2004 Seasearch survey of NW Anglesey	MRMCS00300000003	2	2	2	No	2
2004 Seasearch survey of S Pen Llyn	MRMCS00300000004	2	2	2	No	2
2004 Seasearch survey of the Entrances of Milford Haven, Pembrokeshire	MRMCS00800000004	2	2	2	No	2
2005 - Ongoing UK MarLIN Shore Thing timed search results	MRMLN0040000007F	1	1	1	Yes	1
2005 CCW study of the Milford Haven Maerl Bed	MRCCW16500000002	1	1	1	Yes	1
2005 CCW Tremadog Bay sublittoral sediment survey	MRCCW3010000000E	1	1	1	Yes	1
2005 IECS Carmarthen Bay & Estuaries SAC Biotope survey	MRCCW3030000001E	1	1	1	Yes	1
2005 IECS Menai Strait & Conwy Bay SAC Underboulder habitat survey	MRCCW3020000001D	1	1	1	Yes	1
2005 IECS Menai Strait & Conwy Bay SAC Zostera noltii monitoring	MRCCW3020000001C	1	1	1	Yes	1
2005 IECS Pembrokeshire Marine SAC Milford Haven Rocky Reefs survey	MRCCW30200000018	1	1	1	Yes	1
2005 IECS Pen Llyn a'r Sarnau SAC Zostera marina survey	MRCCW3020000001A	1	1	1	Yes	1
2005 IECS Pen Llyn a'r Sarnau SAC Sabellaria alveolata reefs	MRCCW30200000019	1	1	1	Yes	1
2005 Pelagial/Sea-Scope/CCW Holden's Reef, Pen Llyn a'r Sarnau sublittoral survey	MRCCW3010000000D	1	1	1	Yes	1

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
2005 Seasearch Castlemartin Range, South Pembrokshire	MRMCS01200000006	2	2	2	Yes	2
2005 Seasearch Entrances of Milford Haven, Pembrokeshire	MRMCS00800000009	2	2	2	Yes	2
2005 Seasearch Gower	MRMCS01200000003	2	2	4	Yes	2
2005 Seasearch North Pembrokeshire Survey	MRMCS00500000003b	2	2	2	Yes	2
2005 Seasearch Pembrokeshire Offshore, Smalls and St Govan's Head	MRMCS01200000004	2	2	2	Yes	2
2005 Seasearch Skokholm, Pembrokeshire	MRMCS00800000007	2	2	2	Yes	2
2005 Seasearch St Brides Bay, Pembrokeshire	MRMCS00800000008	2	2	2	Yes	2
2005 Seasearch Survey of Aberystwyth & Sarn Cynfelin	MRMCS0050000000B	2	2	2	Yes	2
2005 Seasearch survey of North Anglesey	MRMCS00500000005b	2	2	2	Yes	2
2005 Seasearch survey of North Llyn Penninsula, North Wales	MRMCS00500000004b	2	2	2	Yes	2
2005 Seasearch survey of South Llyn Penninsula, north Wales	MRMCS00500000007b	2	2	2	Yes	2
2005 Seasearch survey of West Anglesey	MRMCS00500000009b	2	2	2	Yes	2
2005 Skomer MNR Territorial Fish Survey	MRCCW16800000002	1	1	2	Yes	2
2006 CCW - A survey of the tentacled lagoon worm (Alkmaria romijni) at Carew Castle Mill Pond	MRCCW30000000040	1	1	1	Yes	1
2006 Seasearch Gower	MRMCS01200000007	2	2	2	Yes	2
2006 Seasearch Linney Head and Crow Rock, South Pembrokeshire	MRMCS01200000009	2	2	2	Yes	2
2006 Seasearch Pembrokeshire Offshore; Smalls, Grassholm and Offing Patches off Caldey Island	MRMCS0120000000B	2	2	2	Yes	2
2006 Seasearch Survey of Aberystwyth & Sarn Cynfelin	MRMCS00500000013	2	2	2	Yes	2
2006 Seasearch Survey of Anglesey	MRMCS00500000010	2	2	2	Yes	2
2006 Seasearch Survey of Gateholm - east, Pembrokeshire	MRMCS00500000019	2	2	2	Yes	2
2006 Seasearch Survey of Milford Haven	MRMCS00500000018	2	2	2	Yes	2
2006 Seasearch Survey of North Anglesey	MRMCS00500000011	2	2	2	Yes	2
2006 Seasearch Survey of North Llyn Penninsula and Bardsey Island	MRMCS0050000000F	2	1	2	Yes	2
2006 Seasearch Survey of north Pembrokeshire	MRMCS00500000016	2	2	2	Yes	2
2006 Seasearch Survey of Skokholm Island, Pembrokeshire, West Wales	MRMCS00500000017	2	2	2	Yes	2
2006 Seasearch Survey of Skomer Marine Nature Reserve	MRMCS00500000014	2	2	2	Yes	2
2006 Seasearch Survey of South Llyn & Bardsey	MRMCS0050000000D	2	2	2	Yes	2

SurveyName	SurveyKey	Spatial Accuracy	Methodological Accuracy	Taxonomic Accuracy	Complete	Overall Quality
2006 Seasearch survey of Tremadog Bay	MRMCS0050000000E	2	2	2	Yes	2
2006 Seasearch Survey of West Anglesey	MRMCS0050000000C	2	2	2	Yes	2
2007 ASML/CCW Cardigan Bay SAC intertidal monitoring survey - Rockpools	MRCCW16300000004	1	1	1	Yes	1
2007 ASML/CCW Cardigan Bay SAC intertidal monitoring survey - Sabellaria reefs	MRCCW16300000002	1	1	1	Yes	1
2007 ASML/CCW Menai Strait & Conwy Bay SAC Survey - Britannia Bridge boulder shore	MRCCW16300000005	1	1	1	Yes	1
2007 Seasearch Gower	MRMCS0120000000D	2	2	2	Yes	2
2007 Seasearch North Llyn Survey	MRMES00200000005	2	2	2	Yes	2
2007 Seasearch South Pembrokeshire	MRMCS0120000000C	2	2	2	Yes	2
2007 Seasearch survey of Anglesey	MRMCS0050000001A	2	2	2	Yes	2
2007 Seasearch Survey of Barmouth Beach	MRMCS0050000001C	2	2	2	Yes	2
2007 Seasearch Survey of Milford Haven	MRMCS00500000023	2	2	2	Yes	2
2007 Seasearch Survey of north Pembrokeshire	MRMCS0050000001F	2	2	2	Yes	2
2007 Seasearch Survey of South Cardigan Bay	MRMCS00500000020	2	2	2	Yes	2
2007 Seasearch Survey of South Llyn	MRMCS0050000001B	2	2	2	Yes	2
2007 Seasearch Survey of South St. Brides Bay	MRMCS00500000021	2	2	2	Yes	2
Britain & Ireland marine molluscs records	MRMLN00200000028	1	4	1	Yes	2
CCW Phase 1 Intertidal Biotopes	DASSHCCW000002	1	1	1	Yes	1
CCW Phase 1 Species	DASSHCCW000001	1	1	1	Yes	1
Draft 1998-ongoing Sargassum muticum records Wales	MRCCW30000000047	3	2	1	Yes	2
Draft 2002 CCW Severn Estuary intertidal survey	MRCCW30000000045	1	1	1	Yes	1
English Nature Dee Phase 1 Intertidal Biotopes	DASSHCCW000004	1	1	1	Yes	1
English Nature Severn Phase 1 Intertidal Biotopes	DASSHCCW000003	1	1	1	Yes	1
Marine monitoring project: across Wales drop-down video monitoring survey	MRCCW16700000002	1	1	1	Yes	1
Skomer MNR Eunicella verrucosa monitoring project	MRCCW16800000004	1	1	1	Yes	1

* Only conspicuous species recorded

APPENDIX 2: SURVEYS REMOVED FROM THE ASSESSMENT DUE TO QUALITY OR METHOD

SurveyName	SurveyKey	Spatial Accuracy	Method Accuracy	Taxonomic Accuracy	Completeness	Overall Quality
1848 - 2002 BAP and SoCC Invertebrate species not previously on Marine Recorder	MRCCW3000000002E	3	3	1	No	3
1930 - 2001 BAP and SoCC Algae Species Not previously on Marine Recorder	MRCCW3000000002D	3	3	1	No	3
1966-1991 BAP Modiolus Beds Data	MRCCW3000000002C	2	1	1	Yes	1
1899 Span PMSA -Tenby and neighbourhood molluscs survey.	MRCCW10000000048	6	6	6	Yes	6
1948 Evans PMSA -South Pembrokeshire intertidal rocky shore survey	MRCCW10000000091	6	6	1	Yes	6
1950 Bassindale PMSA -Skomer Island survey	MRCCW10000000049	6	6	1	Yes	6
1956 Burrows PMSA -Dale Fort, algae survey	MRCCW10000000041	6	6	1	Yes	6
1957 Bassindale PMSA -Gann Flat, muddy beach survey	MRCCW10000000037	5	5	2	Yes	4
1958-69 Dias PMSA -Milford Haven plankton surveys	MRCCW10000000043	6	6	1	Yes	6
1959 Williams PMSA -St Annes Head marine algae survey	MRCCW10000000086	6	6	1	Yes	6
1960 Crothers PMSA -Dale Fort marine fauna survey	MRCCW10000000036	6	6	1	Yes	6
1960 Williams PMSA -Dale seaweed survey	MRCCW10000000042	6	6	1	Yes	6
1961 Moyse PMSA -Dale rocky shore zonation survey	MRCCW10000000064	6	6	1	Yes	6
1963 Smith PMSA -Milford Haven marine ecology survey	MRCCW10000000065	6	6	1	Yes	6
1966 Naylor PMSA -Species interspersion survey within the superspecies Jaera albifrons	MRCCW10000000026	6	6	1	Yes	6
1969/70 Crapp PMSA -Sandy and muddy shore survey	MRCCW10000000027	6	6	1	Yes	6
1971 Gabriel PMSA -Pembrokeshire, plankton associated with polluted water surveys	MRCCW10000000070	6	6	1	Yes	6
1972 Withers PMSA - SW Wales soft	MRCCW10000000040	6	6	1	Yes	6

shore macrofauna survey						
1973 Hiscock PMSA -Abereiddy Quarry sublittoral communities survey	MRCCW10000000050	6	6	1	Yes	6
1973 Hunnam PMSA -Pembrokeshire sublittoral nudibranch survey	MRCCW10000000051	6	6	1	Yes	6
1974 George PMSA -Annual macrofauna production in a Venus community	MRCCW10000000052	6	6	1	Yes	6
1975 Addy PMSA -Benthic community studies in areas of oil activity	MRCCW10000000019	6	6	1	Yes	6
1975 King PMSA -Milford Haven Pycnogonid survey	MRCCW10000000044	4	4	1	Yes	4
1976-78 Bartrop PMSA - South West Wales littoral zone survey	MRCCW10000000035	6	6	1	Yes	6
1978 Unknown PMSA -Skokholm survey data	MRCCW10000000034	6	6	1	Yes	6
1980 Pugh PMSA -Milford Haven, Amoco refinery jetty piles intertidal survey	MRCCW10000000002	6	6	1	Yes	6
1981/82 Roblin PMSA -Milford Haven, Amoco refinery jetty piles intertidal survey	MRCCW10000000013	6	6	5	Yes	6
1981/82 Roblin PMSA -Milford Haven, Texaco refinery jetty piles intertidal survey	MRCCW10000000012	6	6	5	Yes	6
1982 Woodman PMSA -Milford Haven rocky shore transects survey	MRCCW10000000024	6	6	1	Yes	6
1982-96 Smith PMSA -Dyfed mollusc survey	MRCCW10000000045	6	6	1	Yes	6
1985 Moore PMSA -Milford Haven, Daucleddau Estuary benthic and physiochemical study	MRCCW10000000023	6	6	1	Yes	6
1986-93 Potts PMSA -Pembrokeshire fish survey	MRCCW10000000087	6	6	1	Yes	6
1987 Rostron PMSA -Skomer MNR subtidal monitoring project	MRCCW10000000056	6	6	1	Yes	6
1988 Edwards PMSA -Gann Flat repeat survey	MRCCW10000000038	6	6	1	Yes	6
1988 University of Bristol River Severn subestuaries survey	JNCCMNCR10000489	6	1	1	Yes	6
1994 Rostron PMSA -Milford Haven soft sediment macrobenthos survey	MRCCW10000000001	3	4	1	Yes	3
1991 Ward PMSA -Barafundle Bay sessile marine organisms survey	MRCCW10000000046	6	6	1	Yes	6
1992 Crump PMSA - Skomer MNR littoral monitoring project	MRCCW10000000068	6	6	1	Yes	6
1996 Moore PMSA -Milford Haven, rocky shore monitoring following the Sea Empress oil spill	MRCCW10000000079	1	1	2	Yes	1
1996 Rostron PMSA -Sea Empress subtidal impact assesment	MRCCW10000000080	1	2	1	Yes	1
1994 Bamber PMSA -MHPA Pwllcrochan cargo terminal report	MRCCW10000000011	6	6	1	Yes	6
1996 Crump PMSA -Skomer MNR, post Sea Empress spill, littoral monitoring project	MRCCW10000000092	3	2	3	Yes	3
1994-96 Harries PMSA -South West	MRCCW10000000072	6	6	1	Yes	6

Wales, sandy shore meiofauna surveys						
1994-96 Llewellyn PMSA -Sediment shore impact assessment, strandline surveys	MRCCW10000000078	6	6	1	Yes	6
1995 Hudson PMSA -Skomer Island rocky shore communities survey	MRCCW10000000069	6	6	1	Yes	6
1995/96 Morley PMSA -pre and post Sea Empress oil spill littoral monitoring surveys	MRCCW10000000075	6	6	1	Yes	6
1996 Chamberlain PMSA -Sea Empress oil spill impacts on crustose coralline red algae survey	MRCCW10000000074	6	6	1	Yes	6
1996 Duvivier PMSA -Pembroke Dock development, MHPA environmental statement	MRCCW10000000010	6	6	1	Yes	6
1996 Hobbs PMSA -Millford Haven Waterway, subtidal macrobenthos survey	MRCCW10000000082	6	6	1	Yes	6
1996 Killeen PMSA -Sea Empress oil spill impact on Palundinella littorina survey	MRCCW10000000089	6	6	1	Yes	6
1996 Putron PMSA -Sea Empress oil spill effects on sessile marine invertebrate survey	MRCCW10000000090	6	6	1	Yes	6
1996 Rostron PMSA -Sea Empress oil spill, impact on coastal ecosystems rockpool survey	MRCCW10000000076	6	6	1	Yes	6
1996 Warwick PMSA -Appraisal of environmental impact and recovery using Laminaria holdfasts	MRCCW10000000093	6	6	1	Yes	6
1996/97 Smith PMSA -Milford Haven Coast, Macrobenthic monitoring following the Sea Empress oil spill	MRCCW10000000077	6	6	1	Yes	6
1996-97 Rostron PMSA -Sea Empress oil spill sediment shore impact assessment	MRCCW10000000083	6	6	1	Yes	6
1997 Hommersand PMSA -Pembrokeshire marine algae survey	MRCCW10000000081	6	6	1	Yes	6
1997 Smith PMSA -Milford Haven Waterway, Macrobenthic monitoring following the Sea Epress oil spill	MRCCW10000000084	6	6	1	Yes	6
1998 Barfield PMSA -Skomer MNR sublittoral macrobenthos survey	MRCCW10000000095	6	6	1	Yes	6
2003 Amlwch Parys Mountain Discharge Intertidal Monitoring Survey	MRCCW30000000024	6	6	1	Yes	6
2005 Skomer MNR subtidal algal survey	MRCCW16800000008	1	6	6	Yes	6
Marine Conservation Society Observation Scheme Records 1976 -1990	MRMLN01200000002	4	3	3	Yes	4

APPENDIX 3: DIVISION OF SAMPLING METHOD INTO BROAD METHOD TYPES

Category	Broad Method Type
High quality/Phase 2	Quadrat Recording (Phase II) Recording (Phase II) - Sub Habitat Seasearch - Survey Transect Transect - belt Transect - line Trawl - Beam Trawl - Otter Trawl - unspecified
Infaunal high	Core - box Core - hand-held Core - unspecified Grab - Birge Eckman Grab - Day Grab - Hamon Grab - Hunter Grab - Smith McIntyre Grab - unspecified Grab - Van Veen Dredge - anchor Dredge – pipe Dredge - unspecified Suction sampler
Low quality/Phase 1	Netting Photography – underwater Recording (Phase I, includes species from “biotope” and “target” but not “site”) Seasearch – Observation Video - underwater (drop-down) Scuba diving - visual survey Boat based - visual survey
Sightings	Shored based - visual survey Casual observation
Taxon-Specific	Taxon specific search/collection
Unknown	Unknown

APPENDIX 4: SPECIES INCLUDED IN THE PRIORITY SPECIES MAP

Species	Phylum	Class	Order	Family
Alkmaria romijni	Annelida	Polychaeta	Terebellida	Ampharetidae
Peltocoxa brevirostris	Arthropoda	Malacostraca	Amphipoda	Amphilochidae
Leptocheirus hirsutimanus	Arthropoda	Malacostraca	Amphipoda	Aoridae
Leptocheirus pectinatus	Arthropoda	Malacostraca	Amphipoda	Aoridae
Parvipalpus capillaceus	Arthropoda	Malacostraca	Amphipoda	Caprellidae
Colomastix pusilla	Arthropoda	Malacostraca	Amphipoda	Colomastigidae
Siphonoecetes striatus	Arthropoda	Malacostraca	Amphipoda	Corophiidae
Guernea coalita	Arthropoda	Malacostraca	Amphipoda	Dexaminidae
Tritaeta gibbosa	Arthropoda	Malacostraca	Amphipoda	Dexaminidae
Gammarus chevreuxi	Arthropoda	Malacostraca	Amphipoda	Gammaridae
Gammarus insensibilis	Arthropoda	Malacostraca	Amphipoda	Gammaridae
Leucothoe spinicarpa	Arthropoda	Malacostraca	Amphipoda	Leucothoidae
Leucothoe procera	Arthropoda	Malacostraca	Amphipoda	Leucothoidae
Listriella picta	Arthropoda	Malacostraca	Amphipoda	Liljeborgiidae
Liljeborgia kinahani	Arthropoda	Malacostraca	Amphipoda	Liljeborgiidae
Listriella mollis	Arthropoda	Malacostraca	Amphipoda	Liljeborgiidae
Allomelita pellucida	Arthropoda	Malacostraca	Amphipoda	Melitidae
Monoculodes borealis	Arthropoda	Malacostraca	Amphipoda	Oedicerotidae
Metaphoxus fultoni	Arthropoda	Malacostraca	Amphipoda	Phoxocephalidae
Metopa solsbergi	Arthropoda	Malacostraca	Amphipoda	Stenothoidae
Palinurus elephas	Arthropoda	Malacostraca	Decapoda	Palinuridae
Celleporina decipiens	Bryozoa	Gymnolaemata	Cheilostomatida	Celleporidae
Phallusia mammillata	Chordata	Ascidiacea	Enterogona	Ascidiidae
Polysyncraton lacazei	Chordata	Ascidiacea	Enterogona	Didemnidae
Synoicum incrustatum	Chordata	Ascidiacea	Enterogona	Polyclinidae
Pyura microcosmus	Chordata	Ascidiacea		Pyuridae
Anthopleura thallia	Cnidaria	Hexacorallia	Actiniaria	Actiniidae
Aiptasia mutabilis	Cnidaria	Hexacorallia	Actiniaria	Aiptasiidae
Scolanthus callimorphus	Cnidaria	Hexacorallia	Actiniaria	Edwardsiidae
Edwardsia timida	Cnidaria	Hexacorallia	Actiniaria	Edwardsiidae
Halcampoides elongatus	Cnidaria	Hexacorallia	Actiniaria	Halcampoididae
Paraphellia expansa	Cnidaria	Hexacorallia	Actiniaria	Hormathiidae
Caryophyllia inornata	Cnidaria	Hexacorallia	Scleractinia	Caryophylliidae
Parazoanthus anguicomus	Cnidaria	Hexacorallia	Zoanthidea	Parazoanthidae
Polyplumaria flabellata	Cnidaria	Hydroidomedusa	Conica	Plumulariidae
Laomedea angulata	Cnidaria	Hydroidomedusa	Proboscoida	Campanulariidae
Alcyonium glomeratum	Cnidaria	Octocorallia	Alcyonacea	Alcyoniidae
Eunicella verrucosa	Cnidaria	Octocorallia	Gorgonacea	Gorgoniidae
Lucernariopsis campanulata	Cnidaria	Staurozoa	Stauromedusae	Kishinouyeidae
Haliclystus auricula	Cnidaria	Staurozoa	Stauromedusae	Lucernariidae
Antedon petasus	Echinodermata	Crinoidea	Millericrinida	Antedonidae
Ocnus planci	Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae
Cucumaria frondosa	Echinodermata	Holothuroidea	Dendrochirotida	Cucumariidae
Asterina phylactica	Echinodermata	Stelleroidea	Valvatida	Asterinidae
Barnea candida	Mollusca	Bivalvia	Myoida	Pholadidae
Modiolus modiolus	Mollusca	Bivalvia	Mytiloida	Mytilidae
Ostrea edulis	Mollusca	Bivalvia	Ostreoida	Ostreidae
Arctica islandica	Mollusca	Bivalvia	Veneroida	Arcticidae
Skenea ossiansarsi	Mollusca	Gastropoda	Archaeogastropoda	Skeneidae
Otina ovata	Mollusca	Gastropoda	Archaeopulmonata	Otinidae
Cerithiopsis barleei	Mollusca	Gastropoda	Mesogastropoda	Cerithiopsidae
Leucandra gossei	Porifera	Calcarea	Leucosolenida	Grantiidae

Species	Phylum	Class	Order	Family
Spongionella pulchella	Porifera	Demospongiae	Dendroceratida	Dictyodendrillidae
Suberites massa	Porifera	Demospongiae	Hadromerida	Suberitidae
Axinella damicornis	Porifera	Demospongiae	Halichondrida	Axinellidae
Phakellia ventilabrum	Porifera	Demospongiae	Halichondrida	Axinellidae
Haliclona (Gellius) angulata	Porifera	Demospongiae	Haplosclerida	Chalinidae
Phorbas dives	Porifera	Demospongiae	Poecilosclerida	Hymedesmiidae
Eurypon clavatum	Porifera	Demospongiae	Poecilosclerida	Raspailiidae
Zanardinia typus	Ochrophyta	Phaeophyceae	Cutleriales	Cutleriaceae
Padina pavonica	Ochrophyta	Phaeophyceae	Dictyotales	Dictyotaceae
Sphacelaria mirabilis	Ochrophyta	Phaeophyceae	Sphacelariales	Sphacelariaceae
Aglaothamnion feldmanniae	Rhodophyta	Florideophyceae	Ceramiales	Ceramiaceae
Anotrichium barbatum	Rhodophyta	Florideophyceae	Ceramiales	Ceramiaceae
Pterosiphonia pennata	Rhodophyta	Florideophyceae	Ceramiales	Rhodomelaceae
Polysiphonia foetidissima	Rhodophyta	Florideophyceae	Ceramiales	Rhodomelaceae
Chondria coerulescens	Rhodophyta	Florideophyceae	Ceramiales	Rhodomelaceae
Lithothamnion corallioides	Rhodophyta	Florideophyceae	Corallinales	Hapalidiaceae
Gelidiella calcicola	Rhodophyta	Florideophyceae	Gelidiales	Gelidiellaceae
Schmitzia hiscockiana	Rhodophyta	Florideophyceae	Gigartinales	Calosiphonaceae
Cruoria cruoriaeformis	Rhodophyta	Florideophyceae	Gigartinales	Cruoriaceae
Gracilaria bursa-pastoris	Rhodophyta	Florideophyceae	Gracilariales	Gracilariaceae
Dermocorynus montagnei	Rhodophyta	Rhodophyta incertae sedis		

APPENDIX 5: HABITATS INCLUDED IN THE PRIORITY HABITAT MAP

(SOURCE: NATURAL ENVIRONMENT & RURAL COMMUNITIES ACT 2006: SECTION 42 LIST OF HABITATS OF PRINCIPAL IMPORTANCE FOR CONSERVATION OF BIOLOGICAL DIVERSITY IN WALES)

	Priority Habitat
Littoral Rock	Intertidal boulder communities
	Sabellaria alveolata reefs
	Estuarine rocky habitats
Littoral sediment	Coastal saltmarsh
	Intertidal mudflats
	Seagrass (Zostera) beds
	Sheltered muddy gravels
	Peat and clay exposures
	Blue mussel beds AND Intertidal mudflats
Sublittoral rock	Tide-swept channels
	Fragile sponge & anthozoan communities on subtidal rocky habitats
	Carbonate mounds
	Blue mussel beds AND Tide-swept channels
Sublittoral sediment	Horse mussel (Modiolus modiolus) beds
	Maerl beds
	Mud habitats in deep water
	Saline lagoons
	Blue mussel beds
	Subtidal sands and gravels
	Subtidal mixed muddy sediments
	Musculus discors beds

APPENDIX 6: DATA ARCHIVE APPENDIX

Data outputs associated with this project are archived as Project No. 260 and Media No. 956 on server–based storage at the Countryside Council for Wales

The data archive contains:

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

[B] A series of GIS layers on which the maps in the report are based.

The Table below lists the MapINFO Tables provided with this report and the fields included.

File name	Fields
intertidal_neighbourhood_species	HexID, priority species (PRIOR_SPEC), infaunal high (INFAU_HIGH), species richness (RICHNESS), phase 1 (PHASE1), phase 2 (PHASE2), unknown (UNKNOWN) and taxonomic distinctness (TAXON_DIST) fields.
intertidal_neighbourhood_biotope	HexID, biotope richness (B_RICHNESS), biotope distinctness (DISTINCTNESS), biotope richness/Lambda combo (RICH_LAMBDA) and count of priority habitats (BAPCOUNT) fields.
intertidal_non_neighbourhood_species	HexID, priority species (PRIOR_SPEC), infaunal high (INFAU_HIGH), species richness (RICHNESS), phase 1 (PHASE1), phase 2 (PHASE2), unknown (UNKNOWN) and taxonomic distinctness (TAXON_DIST) fields.
intertidal_non_neighbourhood_biotope	HexID, biotope richness (B_RICHNESS), biotope distinctness (DISTINCTNESS), biotope richness/Lambda combo (RICH_LAMBDA) and count of priority habitats (BAPCOUNT) fields.
subtidal_neighbourhood_species	HexID, priority species (PRIOR_SPEC), infaunal high (INFAU_HIGH), species richness (RICHNESS), phase 1 (PHASE1), phase 2 (PHASE2), unknown (UNKNOWN) and taxonomic distinctness (TAXON_DIST) fields.
subtidal_neighbourhood_biotope	HexID, biotope richness (B_RICHNESS), biotope distinctness (DISTINCTNESS), biotope richness/Lambda combo (RICH_LAMBDA) and count of priority habitats (BAPCOUNT) fields.
subtidal_non_neighbourhood_species	HexID, priority species (PRIOR_SPEC), infaunal high (INFAU_HIGH), species richness (RICHNESS), phase 1 (PHASE1), phase 2 (PHASE2), unknown (UNKNOWN) and taxonomic distinctness (TAXON_DIST) fields.
subtidal_non_neighbourhood_biotope	HexID, biotope richness (B_RICHNESS), biotope distinctness (DISTINCTNESS), biotope richness/Lambda combo (RICH_LAMBDA) and count of priority habitats (BAPCOUNT) fields.
whole_region_neighbourhood_species	HexID, priority species (PRIOR_SPEC), infaunal high (INFAU_HIGH), species richness (RICHNESS), phase 1 (PHASE1), phase 2 (PHASE2), unknown (UNKNOWN) and taxonomic distinctness (TAXON_DIST) fields.
whole_region_non_neighbourhood_species	HexID, priority species (PRIOR_SPEC), infaunal high (INFAU_HIGH), species richness (RICHNESS), phase 1 (PHASE1), phase 2 (PHASE2), unknown (UNKNOWN) and taxonomic distinctness (TAXON_DIST) fields.
intertidal_chao2	HexID, one occurance (ONE_OCCURA), two occurance (TWO_OCCURA), Chao2 (CHAO_2_EST)

subtidal_chao2	HexID, one occurance (ONE_OCCURA), two occurance (TWO_OCCURA), Chao2 (CHAO_2_EST)
whole_region_chao2	HexID, one occurance (ONE_OCCURA), two occurance (TWO_OCCURA), Chao2 (CHAO_2_EST)
intertidal_confidence	HexID, confidence (CONFIDENCE), nono-native (NON_NATIVE)
subtidal_confidence	HexID, confidence (CONFIDENCE), nono-native (NON_NATIVE)
whole_region_confidence	HexID, confidence (CONFIDENCE), nono-native (NON_NATIVE)
intertidal_priority_species	HexID, priority-species (PRIORITY_SPECIES)
subtidal_priority_species	HexID, priority-species (PRIORITY_SPECIES)
whole_region_priority_species	HexID, priority-species (PRIORITY_SPECIES)

Metadata for this project is publicly accessible through Countryside Council for Wales' Library Catalogue http://www-library.ccw.gov.uk/olibcgi/w24.cgi by searching 'Dataset Titles'. Metadata for the project as a whole is held as record no 111816. Metadata entries for individual GIS layers are also available in the catalogue.

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