Ecological Effects of Re-building Beaches on Intertidal Habitats in Wales

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CRYNODEB GWEITHREDOL

Ailadeiladu traethau – a elwir hefyd adfer traethau neu ail-lenwi traethau – yw'r broses o ychwanegu gwaddod at draeth i'w wneud yn uwch ac yn lletach. Ar yr adeg hon pan fo lefel y môr yn codi, mae traethau o dan fygythiad difrifol – mae amddiffynfeydd o waith dyn eisoes wedi effeithio'n andwyol ar lawer ohonynt trwy leihau'r cyflenwad gwaddod naturiol. Mae traethau'n un o adnoddau naturiol, cymdeithasol ac economaidd allweddol Cymru. Maent yn chwarae rhan hanfodol mewn cynnal twristiaeth arfordirol ac yn sail i safleoedd sy'n bwysig o ran cadwraeth natur a'r dirwedd ac yn gweithredu fel amddiffynfeydd arfordirol 'naturiol', trwy leihau egni tonnau, gan helpu i amddiffyn strwythurau naturiol a strwythurau o waith dyn fel ei gilydd.

Mae'r astudiaeth ben desg hon yn adeiladu ar ddau brosiect cynharach a gyflawnwyd gan Atkins i Gyngor Cefn Gwlad Cymru. Ymchwiliodd yr Astudiaeth Beilot gychwynnol[1] i'r gofynion posibl o ran maint y deunydd adfer traethau (tywod, graean, gro ac ati) y bydd ei angen o bosibl i gynnal traethau Cymru sydd mewn perygl yn awr ac yn y dyfodol. Edrychodd astudiaeth Cam 2[2] ar amrywiaeth o wybodaeth am agweddau ymarferol ailadeiladu traethau, gan gynnwys gweithdai gyda rhanddeiliaid allweddol, adolygiad o'r holl adolygiadau Cynlluniau Rheoli Traethlin (SMP2) Cymru, ac ymchwiliad i'r cyfyngiadau economaidd a'r cyfyngiadau o ran adnoddau ar waith adfer traethau.

Mae'r adolygiad hwn o ddata a llenyddiaeth yn ymchwilio i un o'r argymhellion o'r astudiaeth Cam 2, i ganfod lefel bresennol y wybodaeth am effeithiau ecolegol (rhai cadarnhaol a rhai negyddol) gwaith adfer traethau ar ecoleg rynglanwol traethau Cymru. Dim ond ar yr effeithiau ecolegol ar yr ecoleg rynglanwol mae'n edrych ac nid yw'n ystyried effeithiau amgylcheddol eraill e.e. ar dirwedd, daeareg neu brosesau arfordirol. Nid yw'n ystyried effeithiau ar y mannau tirol neu islanwol nac effeithiau mynd ag agregau morol neu dirol. Nid yw ychwaith yn ystyried effeithiau llai uniongyrchol megis carbon a defnydd ynni wrth dynnu, cludo a gosod deunyddiau.

Biotopau traethau Cymru

Nodwyd cynefinoedd rhynglanwol sydd o bosibl mewn perygl o waith adfer traethau ar y 10 traeth astudiaeth achos a ddefnyddiwyd yn y ddwy astudiaeth flaenorol gan ddefnyddio biotopau a nodwyd gyda system Dosbarthu Cynefinoedd MNCR 2004 o asesiadau cynefinoedd Cam 1 Cyngor Cefn Gwlad Cymru (gweler ***Adran 2.1*** i gael gwybodaeth am ddiffinio'r biotopau a'r traethau).

Nodwyd 68 o fathau o fïotop i gyd i lefel 6 EUNIS, a daethpwyd o hyd i fiotopau lluosog ar bob traeth (gan amrywio o 11 bïotop gwahanol ar draeth Morfa Dyffryn i 55 o fiotopau gwahanol ym Mae Abertawe) (gweler ***Adran 3.1*** i gael mwy o wybodaeth am y biotopau a nodwyd ac ***Atodiad 1*** i weld mapiau o'r traethau a'r biotopau).

Asesiad sensitifrwydd

Cafodd y biotopau eu grwpio i lefel 5 EUNIS a defnyddiwyd asesiadau sensitifrwydd MarLIN i bennu sensitifrwydd pob un o'r mathau o fiotopau ar gyfer 12 gwahanol ffactor amgylcheddol y gallai gwaith ailadeiladu traethau eu newid. Hefyd cafodd rhywogaethau a restrir o dan a42 Deddf yr Amgylchedd Naturiol a Chymunedau Gwledig[3] a gwelyau *Zostera* rhynglanwol eu cynnwys. Cafodd 56 o wahanol fiotopau / rhywogaethau i gyd eu hasesu am eu sensitifrwydd i waith adfer traethau. Ceir gwybodaeth am asesiad sensitifrwydd MarLIN yn ***Atodiad 3*** neu gellir ei gweld ar wefan MarLIN http://www.marlin.ac.uk/sensitivityrationale.php#table1.

[1] McCue, J.; Pye, K.; Wareing, A. 2010, Beach nourishment operations in Wales and likely future requirements for beach nourishment in an era of sea-level rise and climate change- A Pilot Study. Adroddiad Gwyddonol Cyngor Cefn Gwlad Cymru Rhif 928, Cyngor Cefn Gwlad Cymru, Cymru

[2] Winnard, K; McCue, J; Pye, K., 2011. *Re-building Welsh Beaches for Multiple Benefits,* Adroddiad Gwyddonol Cyngor Cefn Gwlad Cymru Rhif 974

[3] Deddf yr Amgylchedd Naturiol a Chymunedau Gwledig 2006

Mae un neu fwy o'r 12 ffactor posibl y mae gwaith adfer traethau efallai'n dylanwadu arnynt yn cael effaith gymedrol *ar y mwyaf* ar 70% o'r holl fiotopau y daethpwyd o hyd iddynt ym mannau'r astudiaethau achos. Nid oes unrhyw wybodaeth ar gael ar gyfer 9 o'r mathau o fïotop (16%) (gweler ***Tabl 5*** yn ***Adran 3.1.1*** i gael canlyniadau'r asesiad sensitifrwydd).

Dim ond 8 o'r 56 o fiotopau neu rywogaethau (14%) sy'n sensitif iawn / tu hwnt i un neu fwy o'r effeithiau y mae gwaith adfer traethau efallai'n eu hachosi (gweler ***Tabl 6*** yn ***Adran 3.1.1***) a dim ond tri o'r biotopau hyn a geir ar draethau'r astudiaethau achos.

Adolygiad o ddata a llenyddiaeth

Wrth chwilio am ddata, canolbwyntiwyd ar bum ffynhonnell gwybodaeth

1. Llawlyfrau rheoli, arweiniadau a gwerslyfrau (gweler ***Adran 3.2***)
2. Adolygiadau / trosolygon gan awduron eraill (gweler ***Adran 3.3***)
3. Erthyglau mewn cyfnodolion / a adolygwyd gan gymheiriaid (gweler ***Adran 3.4***)
4. Asesiadau o'r Effaith Amgylcheddol (gweler ***Adran 3.5***)
5. Prosiectau ailadeiladu traethau y gwyddys amdanynt yn y Deyrnas Unedig ac Ewrop (gweler ***Adran 3.6***)

Effeithiau adfer traethau

Mae'n bosibl nodi nifer o ffynonellau posibl effaith o waith adfer traethau o'r gwahanol ddeunyddiau a adolygwyd fel rhan o'r astudiaeth hon (gweler ***Adran 4.1***):

- Effeithiau sy'n gysylltiedig â phresenoldeb / tarfu gan beiriannau a gweithwyr ar y traeth. Mae hyn yn cynnwys:
  - Effeithiau ar adar (yn enwedig wrth iddynt nythu)
  - Effeithiau ar raean â llystyfiant
  - Cywasgu'r traeth
  - Effeithiau llygredd o beiriannau
- Effeithiau sy'n gysylltiedig â'r gwaith adfer. Mae'r effeithiau hyn yn ymwneud â:
  - Sut a ble ar y traeth mae'r gwaith adfer yn digwydd
  - Pa mor gyflym mae'r deunydd adfer yn cael ei osod
  - Ble mae'r deunydd yn cael ei osod ar y traeth
- Effeithiau sy'n gysylltiedig â'r deunydd adfer. Mae hyn yn cynnwys:
  - Effeithiau o ddefnyddio deunydd nad yw'n cyd-fynd yn dda gyda'r deunydd a geir eisoes ar y traeth
  - Llygru/halogi'r gwaddod
- Effeithiau sy'n gysylltiedig â chynllun y prosiect adfer. Mae'r effeithiau'n ymwneud â:
  - Arwynebedd / cyfran y traeth i gael ei adfer
  - Amseru'r gwaith adfer
  - Y defnydd o strwythurau rheoli traeth ar y cyd gyda'r gwaith adfer

Effeithiau buddiol

Nid oes braidd dim tystiolaeth bod gwaith adfer traethau'n dod â buddion ecolegol i'r parth rhynglanwol ac eithrio mewn perthynas â darparu cynefin ychwanegol neu ddiogelu cynefin i adar sy'n nythu ar draethau tywod neu raean (gweler ***Adran 4.2***).

Wrth ystyried hyn, dylid cydnabod bod cwmpas yr astudiaeth hon wedi'i gyfyngu i effeithiau ecolegol gwaith adfer traethau ar y parth rhynglanwol yn unig ac nad yw'n rhoi'r darlun cyfan yn nhermau effeithiau posibl gwaith adfer traethau y tu hwnt i'r parth rhynglanwol nac i dderbynyddion amgylcheddol eraill megis llifogydd ac erydu arfordirol, twristiaeth, neu effeithiau ar y dirwedd. Fel arfer mae'r effeithiau ehangach hyn yn cael eu codi'n effeithiol mewn Datganiadau Amgylcheddol (gweler ***Adran 3.5***). Mae'r potensial i waith adfer traethau ddod â buddion ehangach yn cael sylw manylach yn adroddiad y prosiect Cam 2 (Winnard *et al*, 2011).

Monitro

Mae llawer o'r papurau, llyfrau, erthyglau ac ati a adolygwyd yn dweud nad oes digon o fonitro ar ôl adfer traethau yn gyffredinol, ac yn benodol mai cyfyngedig yw monitro'r effeithiau mae gwaith adfer yn eu cael ar y fioleg/ecoleg (gweler ***Adran 4.3*** i gael mwy o wybodaeth).

Yn ogystal â monitro annigonol ar ôl adfer traethau, mae diffyg monitro digonol cyn eu hadfer yn ei gwneud yn anos dod i gasgliadau ynglŷn ag effeithiau ecolegol gwaith adfer traethau.

Mae llawer o Ddatganiadau Amgylcheddol yn argymell monitro ecolegol a/neu ffisegol ar ôl adfer traethau. Fodd bynnag, nid oes digon o wybodaeth ar gael yn gyhoeddus ynglŷn â monitro ar ôl cynlluniau i ddod i unrhyw gasgliadau ar ba mor briodol yw'r monitro nac ar ba mor effeithiol yw unrhyw fesurau lliniaru.

Ymadfer

Nodwyd bod ymadfer ar ôl gwaith ailadeiladu yn un o'r meysydd allweddol oedd yn peri pryder i Gyngor Cefn Gwlad Cymru. Dim ond y llenyddiaeth academaidd sy'n ymdrin â'r pwnc mewn gwirionedd, ac mae'r amserau ymadfer y sonnir amdanynt yn amrywio o ddyddiau i wythnosau i nifer o flynyddoedd (neu byth). Cytunir yn gyffredinol gan lawer fod cynlluniau 'da' yn ymadfer yn gynt na chynlluniau 'drwg', a bod y graddau y ceir cydweddu â'r gwaddod sydd ar y traeth eisoes yn chwarae rhan arwyddocaol yng nghyflymder ymadfer ar ôl gwaith ailadeiladu.

Mae'r ymadfer yn debygol o ddeillio o gyfuniad o gynnydd yn nifer y larfau a mewnfudo o fannau cyfagos, er nad yw'n glir pa un yw'r pwysicaf ac mae'n bosibl bod hyn yn dibynnu ar gyfansoddiad cymunedau ffawna'r traeth (gweler ***Adran 4.4*** i gael mwy o fanylion).

Casgliadau

Mewn perthynas â'r casgliadau ac argymhellion canlynol (***Adran 5***), caiff y darllenydd ei atgoffa bod cwmpas yr astudiaeth hon yn ymwneud *dim ond* ag *effeithiau ecolegol* posibl gwaith adfer traethau ar *ecoleg rynglanwol* traethau Cymru. Dylid hefyd cydnabod bod traethau sydd angen gwaith adfer yn tueddu i fod mewn cyflwr annaturiol eisoes, gan fod gweithgarwch pobl neu ddatblygiadau'n eu rhwystro rhag symud i mewn i'r tir.

Adfer traethau yw'r dewis callaf yn ecolegol – er y gall gwaith adfer traethau effeithio ar ecoleg traethau a mannau cyfagos, fel arfer mae dewisiadau ar wahân i waith adfer yn fwy niweidiol (e.e. Speybroek *et al,* 2006).

Ychydig iawn o fuddion ecolegol mae gwaith adfer traethau'n eu creu i'r parth rhynglanwol ac mae hynny o fuddion sydd yn tueddu i fod yn gyfyngedig i draethau graean.

Nid yw'r rhan fwyaf o'r biotopau a geir ar draethau Cymru'n **sensitif iawn i waith adfer traethau** (gweler ***Adran 3.1*** a ***Thabl 5*** yn benodol).

Nodwyd bod wyth bïotop yn sensitif iawn i rai o effeithiau gwaith adfer traethau. Fodd bynnag, dim ond mewn mannau lleol penodol iawn y ceir y rhain.

I'r rhan fwyaf o draethau tywod **na cheir arnynt unrhyw gynefin arbennig o bwysig, ni fydd** gwaith adfer traethau'n **cael effeithiau ecolegol hirdymor**, ar yr amod y dilynir rhai 'rheolau' clir:

- Defnyddio gwaddod y mae maint ei ronynnau'n debyg, ac sydd o ddeunydd tebyg, i'r hyn a geir ar y traeth eisoes.

- Cyfyngu ar faint y deunydd mân iawn a'r deunydd garw, gan gynnwys ysgyrion cregyn, yn y deunydd adfer

Mae'r amodau hyn yn cael eu gosod eisoes ar lawer o brosiectau adfer traethau.

Ni ellir pwysleisio ormod pa mor bwysig yw defnyddio gwaddod sy'n cydweddu'n dda er mwyn lleihau effeithiau'r gwaith adfer a hyrwyddo ymadfer cyflymach.

Gellid hefyd defnyddio'r mesurau canlynol i leihau'r effeithiau tymor byr yn fwy byth a hyrwyddo ymadfer cyflymach:

- Gosod y deunydd adfer yn araf, mewn haenau cymharol denau (<1 m o drwch) – er nad yw'n glir pa mor ymarferol yw hyn
- Peidio â gorchuddio'r traeth cyfan / darnau mawr iawn o'r draethlin (<1 km) i alluogi mannau cyfagos i ail-gytrefu'r mannau sydd wedi cael eu hadfer
- Gwneud gwaith adfer yn ystod misoedd y gaeaf pan fo llai o organebau ar y traeth
- Peidio â chaniatáu i waith adfer barhau am gyfnodau hir

I'r traethau hynny nad ydynt yn dywodlyd (h.y. traethau graean) neu lle bo yna bryderon eraill ynglŷn â chynefinoedd a/neu rywogaethau, mae angen mesurau ychwanegol i leihau'r effeithiau ar y rhannau hyn o'r traeth sy'n fwy agored i niwed. Mae'r **pryderon ychwanegol a'r gofynion lliniaru ychwanegol hyn yn cael eu codi trwy broses Asesu'r Effaith Amgylcheddol.** Ymddengys fod gwybodaeth MarLIN am sensitifrwydd biotopau yn adnodd nas defnyddir digon, a gallai fod yn offeryn cyfeirio defnyddiol i ymarferwyr Asesu'r Effaith Amgylcheddol, er y cydnabyddir bod iddo rai cyfyngiadau (gweler ***Adran 3.1***).

Mae'n amlwg **nad oes digon o waith monitro ecolegol, os unrhyw waith o gwbl, yn cael ei wneud cyn neu ar ôl adfer traethau** neu ar gyfer prosiectau amddiffyn yr arfordir sy'n cynnwys rhywfaint o waith adfer traethau.

At ei gilydd, ymddengys mai ychydig o angen sydd i Gyngor Cefn Gwlad Cymru newid ei ddull presennol o roi cyngor ynglŷn â'r rhan fwyaf o brosiectau 'arferol' i amddiffyn yr arfordir neu adfer traethau. Mae angen ystyriaeth ychwanegol a mwy o fanylion mewn asesiadau o'r effaith amgylcheddol mewn perthynas â phrosiectau sydd:

- Ar raddfa fawr (tebyg i Lincshore) neu a fyddai'n effeithio ar y traeth cyfan
- A fydd yn golygu adfer / ailbroffilio'n rheolaidd (bob 1 – 2 flynedd)
- Sy'n cynnwys strwythurau rheoli'r traeth yn ogystal â'i adfer

Argymhellion

1 – Cynyddu'r gwaith monitro ecolegol o brosiectau adfer traethau cyn ac ar ôl y gwaith adfer

2 – Cael gafael ar wybodaeth am effeithiau ecolegol gwaith adfer traethau mewn mannau eraill yn y Deyrnas Unedig

3 – Ymchwilio rhagor i'r effaith mae strwythurau rheoli traethau'n ei chael ar effeithiau ecolegol gwaith adfer traethau

4 – Dadlau dros ddefnyddio gwybodaeth asesu sensitifrwydd MarLIN mewn Asesiadau o'r Effaith Amgylcheddol ar gyfer prosiectau adfer traethau ac amddiffyn yr arfordir

EXECUTIVE SUMMARY

Beach re-building - also known as beach nourishment, beach re-nourishment, beach replenishment, beach feeding, beach recharge or beach fill - is the process of adding sediment to a beach to make it higher and wider. In an era of sea level rise, beaches are under serious threat - many are already adversely affected by manmade defences that have reduced the natural sediment supply. Beaches are a key natural, social and economic resource for Wales - they play a vital role in sustaining coastal tourism and underpin important nature conservation and landscape sites and acts as 'natural' coastal defences, dissipating wave energy, helping to protect both natural and manmade structures.

This desk based study builds on two earlier projects undertaken by Atkins for CCW. The initial Pilot Study[4] investigated the potential requirements for the quantity of beach nourishment material (sand, shingle, gravel, etc.) that may be needed to maintain Welsh beaches at current and future risk. The Phase 2 study[5] looked at a range of information regarding the practicalities of re-building beaches, including workshops with key stakeholders, a review of all Welsh Shoreline Management Plan reviews (SMP2s) and an investigation of the resource and economic constraints of beach nourishment.

This data and literature review explores one of the recommendations of the Phase 2 study, to establish the current level of knowledge regarding the ecological impacts (both positive and negative) of beach nourishment on the intertidal ecology of Welsh beaches. It concerns only the ecological effects on the intertidal ecology and does not consider other environmental effects, e.g. to landscape, geology or coastal processes. It does not consider effects to the terrestrial or subtidal areas or the impacts of removing marine or terrestrial aggregate. Neither does it consider less direct impacts such as carbon and energy use in winning, transporting and placing materials.

Welsh beach biotopes

Intertidal habitats potentially at risk from beach nourishment were identified on the 10 case study beaches used in the previous two studies using biotopes identified with the 2004 MNCR Habitat Classification system from CCW Phase 1 habitat assessments (see ***Section 2.1*** for information relating to defining the biotopes and beaches).

A total of 68 biotope types were identified to EUNIS level 6, with multiple biotopes being found on every beach (ranging from 11 different biotopes on Morfa Dyffryn to 55 different biotopes on Swansea Bay) (see ***Section 3.1*** for more information on the biotopes identified and ***Appendix 1*** for maps of the beaches and biotopes).

Sensitivity assessment

Biotopes were grouped to EUNIS level 5 and MarLIN sensitivity assessments were used to determine the sensitivity of each of the biotope types for 12 different environmental factors that could be altered by beach re-building operations. Species listed under s42 NERC[6] Act and intertidal *Zostera* beds were also included. A total of 56 different biotopes / species were assessed for their sensitivity to beach nourishment. Information on the MarLIN sensitivity assessment are set out in ***Appendix 3*** or can be found on the MarLIN website at http://www.marlin.ac.uk/sensitivityrationale.php#table1.

[4] McCue, J.; Pye, K.; Wareing, A. 2010, Beach nourishment operations in Wales and likely future requirements for beach nourishment in an era of sea-level rise and climate change- A Pilot Study. CCW Science Report No. 928, CCW, Wales

[5] Winnard, K; McCue, J; Pye, K., 2011. *Re-building Welsh Beaches for Multiple Benefits,* CCW Science Report No. 974

[6] Natural Environment and Rural Communities Act 2006

70% of all the biotopes found in the case study areas are <u>at most</u> moderately affected by one or more of the 12 possible factors that beach nourishment may influence. There is no information available for 9 of the biotope types (16%) (see ***Table 5*** in ***Section 3.1.1*** for the results of the sensitivity assessment).

Only 8 of the 56 biotopes or species (14%) are highly / very highly sensitive to one or more of the effects that may be caused by beach nourishment (see ***Table 6*** in ***Section 3.1.1***) and only three of these biotopes are found on the case study beaches.

<u>Data and literature review</u>

The data search focussed on five sources of information

1. Management manuals, guides and text books (see ***Section 3.2***)
2. Reviews / overviews by other authors (see ***Section 3.3***)
3. Journal / peer reviewed articles (see ***Section 3.4***)
4. Environmental Impact Assessments (EIAs) (see ***Section 3.5***)
5. Known beach re-building projects in the UK and Europe (see ***Section 3.6***)

<u>The effects of beach nourishment</u>

It is possible to identify a number of potential sources of impact from beach nourishment from the various materials reviewed as part of this study (see ***Section 4.1***):

- Impacts associated with the presence of / disturbance from machinery and workers on the beach. This includes:
  - Impacts to birds (particularly during nesting)
  - Impacts to vegetated shingle
  - Compaction of the beach
  - Pollution impacts from machinery.
- Impacts associated with the nourishment activity. These impacts relate to:
  - How and where on the beach the nourishment activity takes place
  - The speed with which nourishment is applied
  - Where material is placed on the beach
- Impacts associated with the nourishment material. This includes:
  - Impacts from using material that is poorly matched to that already found on the beach
  - Pollution/contamination of the sediment
- Impacts associated with the design of the nourishment project. These impacts relate to:
  - The area / proportion of beach to be nourished
  - The timing of nourishment activity
  - The use of beach control structures in combination with beach nourishment

<u>Beneficial effects</u>

There is almost no evidence of ecological benefits of beach nourishment to the intertidal area except in relation to the provision of additional or safeguarded habitat for birds that nest on sandy or shingle beaches (see ***Section 4.2***).

In considering this, it should be recognised that the scope of this study is restricted to the ecological effects of beach nourishment on the intertidal area <u>only</u> and does not give the whole picture in terms of the potential effects of beach nourishment beyond the intertidal area or to other environmental receptors such as flooding and coastal erosion, tourism, or landscape effects. These wider effects are generally picked up well in Environmental Statements (ESs) (see ***Section***

3.5). The potential for beach nourishment to deliver wider benefits are explored in more detail in the Phase 2 project report (Winnard *et al*, 2011).

Monitoring

Many of the papers, books, articles, etc. reviewed state that there is inadequate monitoring post nourishment in general and specifically, monitoring of the effects of nourishment on the biology/ecology are limited (see ***Section 4.3*** for more information).

In addition to insufficient post nourishment monitoring, the lack of sufficient pre nourishment monitoring makes drawing conclusions on the ecological effects of beach nourishment more difficult.

Many ESs recommend ecological and/or physical monitoring post nourishment, however, there is a lack of publicly available information relating to post scheme monitoring to draw any conclusions on either the appropriateness of the monitoring or the effectiveness of any mitigation measures.

Recovery

Recovery post nourishment was identified as a key area of concern for CCW. The subject is only really covered by the academic literature and reported recovery times vary from days to weeks to several years (or not at all). There is general widespread agreement that 'good' schemes recover faster than 'bad' schemes, with the degree of matching to the existing beach sediment playing a significant role in the speed of recovery post nourishment.

The source of recovery is likely to be from a combination of larval recruitment and immigration from adjacent areas, although it is not clear which is most important and this may depend on the composition of the beach faunal communities (see ***Section 4.4*** for more detail).

Conclusions

In relation to the following conclusions and recommendations (***Section 5***), the reader is reminded that the scope of this study relates *only* to the potential *ecological effects* of beach nourishment on the *intertidal ecology* of Welsh beaches. It should also be recognised that beaches that require nourishment tend to already be in an unnatural state, being constrained from rolling back by human activity or development.

Beach nourishment is the most ecologically sound option – although beach nourishment can affect the ecology of beaches and surrounding areas, alternatives to nourishment are generally more damaging (e.g. Speybroek *et al,* 2006).

There are **few ecological benefits** of beach nourishment for the intertidal area and these tend to be confined to shingle beaches.

Most of the biotopes found on Welsh beaches **are not highly sensitive to beach nourishment operations** (see ***Section 3.1*** and ***Table 5*** in particular).

Eight biotopes have been identified as highly sensitive to some of the effects of beach nourishment. These are, however, only found in very specific local areas.

For most sandy beaches that **do not contain any particularly important habitat**, beach nourishment will **not have long term ecological impacts**, provided that some clear 'rules' are followed:

- Use sediment that is of a similar grain size composition and similar material as that already found on the beach.
- Restrict the amount of both fine material and coarse material, including shell fragments in the re-nourishment material

These conditions are already applied to many beach nourishment projects.

It cannot be stressed too heavily the importance of using well matched sediment to both reduce the impacts of nourishment and promote faster recovery.

The following measures could also be used to further reduce short term impacts and promote faster recovery:

- Apply nourishment slowly, in relatively thin layers (<1 m thick) – although it is not clear how practical this is
- Do not cover the whole beach / very large stretches of shoreline (<1 km) to enable adjacent areas to re-colonise nourished areas
- Undertake nourishment during winter months when numbers of organisms on the beach are at lower levels
- Do not allow nourishment activities to continue for protracted periods

For those beaches that are not sandy (i.e. shingle beaches) or where there are other habitat and/or species concerns additional measures are needed to reduce impacts to these more vulnerable areas of the beach. These **additional concerns and mitigation requirements are picked up through the EIA process**. The MarLIN biotope sensitivity information appears to be an underutilised resource that could provide a useful reference tool for EIA practitioners, whilst recognising that it is not without limitations (see ***Section 3.1***).

It is evident that **there is poor, if any, ecological monitoring of beaches pre or post-nourishment** or for coastal defence projects that include some degree of nourishment.

Overall, there seems little need for CCW to alter its current approach to giving advice in relation to most 'routine' coastal defence or beach nourishment projects. Additional consideration and a greater level of detail in EIAs are needed in relation to projects that:

- Are large scale (similar to Lincshore) or would affect the whole beach
- Will involve repeated nourishment / re-profiling on a regular basis (every 1 – 2 years)
- That include beach control structures as well as nourishment

<u>Recommendations</u>

1 - Increase ecological monitoring of beach nourishment projects both pre and post nourishment

2 - Access information on the ecological effects of beach nourishment elsewhere in the UK

3 - Further investigate the effect that beach control structures have on the ecological effects of beach nourishment

4 - Advocate the use of the MarLIN sensitivity assessment information in Environmental Impact Assessments for beach nourishment and coastal defence projects

1 INTRODUCTION

During 2009/2010 a Steering Group comprising The Countryside Council for Wales (CCW), The Crown Estate, British Marine Aggregates Producers Association (BMAPA), Welsh Government, and the Environment Agency Wales (EAW) commissioned a Pilot Study (McCue *et al*, 2010) to begin investigating the issues relating to the use of aggregates (sand, shingle, gravel, etc.) for beach nourishment in Wales, specifically in relation to the potential requirements for the quantity of material that may be needed to maintain Welsh beaches at current and future risk.

The work of the Pilot Study was built on in 2010/2011 and the outputs of the Pilot Study and the Phase 2 project are reported in Winnard, K; McCue, J; Pye, K., 2011. *Re-building Welsh Beaches for Multiple Benefits,* CCW Science Report No. 974.

The Phase 2 Study looked at a range of information regarding the practicalities of re-building beaches, including workshops with key stakeholders, a review of all Welsh Shoreline Management Plan reviews (SMP2s) and an investigation of the resource and economic constraints.

The Phase 2 Study report was written using non-technical language as it was intended to be made widely available and be easily accessible to a range of readers. The term 'beach re-building' was used in the report as it was found that other terms such as beach nourishment, beach re-nourishment, beach replenishment, beach feeding, beach recharge or beach fill were not widely understood by those not directly involved in the physical management of beaches. This report is aimed at a more technical audience with an understanding of the physical management of beaches, coastal processes and the ecology of beaches. The Phase 2 Study report provides more non-technical explanation of the terms used in beach management and the potential benefits and drawbacks of beach nourishment for a range of services.

The Phase 2 Study produced a number of recommendations for further work to answer key questions that remained outstanding regarding beach nourishment operations in Wales.

In 2012, CCW commissioned this study to examine one of the recommendations of the Phase 2 study, namely:

> *"The ecological effects (including potential benefits or adverse effects) of re-building beaches need to be investigated in more detail. This should consider the most appropriate places for beach re-building [in terms of the potential beneficial and adverse effects on the services provided by the beaches] such as, the methods used (including timing of works) and the suitability of different types of material."*

The study is, in essence, a short data and literature review to establish the current level of knowledge regarding the ecological impacts (both positive and negative) of beach nourishment on the intertidal ecology of Welsh beaches. The potential impacts of more 'traditional' hard engineering and the use beach control structures are relatively well understood by coastal engineers, while the potential impacts of beach nourishment are less well known by those responsible for all aspects of beach management (see Winnard *et al*, 2011).

The focus of the review is to understand the impacts and potential for recovery from adverse impacts of the intertidal ecology of Welsh beaches to beach nourishment operations. Welsh beaches are within the North East Atlantic biogeographic region in a temperate zone. The primary focus of the data study has therefore been on research in similar geographic and temperate areas of the world in order that the results can be more directly compared with Welsh beaches. Biotope types found on Welsh beaches have been identified and the sensitivity of these biotopes to different factors that may result from beach nourishment activities has been determined using an established peer reviewed source (MarLIN sensitivity analysis[7]).

[7]For more information see Section 3.1, Appendix 3 the MarLIN website http://www.marlin.ac.uk/index.php

The potential impacts of beach nourishment, as set out in a variety of literature types, has been examined. This includes information contained in beach management guidance, literature reviews carried out by other authors, peer reviewed papers, Environmental Statements for beach nourishment projects and data from other beach nourishment schemes in the UK. More details on the methodology used in the study are set out in ***Section 2*** of the report.

The study relates only to the ecological effects of beach nourishment on the intertidal ecology of Welsh beaches and does not consider other environmental effects, such as to landscape, geology or coastal processes. The study only considers the intertidal impacts and does not consider potential effects to the terrestrial or subtidal areas.

Beach nourishment schemes require the use of sediment, which may come from either a marine or terrestrial source. The impacts of dredging / removing marine aggregates and of mining terrestrial aggregate are well established and are not considered in this review. This study is not intended to be a life cycle impact assessment of the use of beach nourishment and does not consider less direct impacts such as carbon and energy use in winning, transporting and placing materials.

2 METHODS

2.1 Defining Welsh beach biotopes

The Re-building Welsh Beaches for Multiple Benefits study considered 10 case study beaches, chosen because they represent the range of issues around the coast of Wales and include sandy beaches, sand and shingle beaches, high and low tourist areas, different flood and erosion risks and a range of conservation issues.

CCW has carried out a Phase 1 habitat assessment for the whole intertidal area of Wales and mapped the assessment results. This data was used to identify the biotopes present within the case study areas.

2.1.1 Geographical coverage

The 10 case study beaches used in Winnard *et al* (2011) are:

- Talacre;
- Abergele - Pensarn;
- Traeth Crugan;
- Morfa Dyffryn;
- Broadwater - Tywyn – Aberdovey;
- Tenby North Beach;
- Port Eynon Bay;
- Northern Swansea Bay (Black Pill to Swansea Docks);
- Aberavon Sands (eastern Swansea Bay); and
- Porthcawl (Sandy Bay and Trecco Bay).

The Winnard *et al* (2011) work identified an area on each beach where beach nourishment might be carried out in order to calculate the quantity of sediment that would be needed. The area identified was reviewed and in most cases extended to identify the area over which sediment might be expected to move following nourishment. The biotopes in this search area where then identified using the CCW Phase 1 habitat information.

The initial maps produced were reviewed by the CCW project officer, CCW coastal geomorphology scientists and intertidal ecologists. Amendments to the search areas were made based on CCW staff comments (see ***Appendix 2*** for the full list of biotopes identified).

2.1.2 Additional species and biotopes

In addition to the biotopes identified in the case study search areas, key species and / or biotopes that might not appear within the search areas, but were considered important to include within the study were also identified, in consultation with CCW staff.

Additional species and biotopes identified were:

- Intertidal *Zostera* beds
- NERC[8] s42 species:
    - Bearded red seaweed - *Anotrichium barbatum*
    - Coral maerl - *Lithothamnion corallinoides*
    - Common maerl - *Phymatolithon calcareum*
    - Tentacled lagoon worm - *Alkmaria romijni*

[8] Natural Environment and Rural Communities Act 2006

- Red seaweed - *Dermocorynus montagnei*
- Peacock's tail - *Padina pavonica*

There are 56 marine species listed under s42 NERC Act, however, many of these are mobile or subtidal species and have not, therefore, been included within the search criteria. Other species are not known to occur in Wales (e.g. *Edwardsia timida*).

2.2 Data search

The literature search focussed initially on identifying studies that had examined the impact of beach nourishment on the environment. The search focussed primarily on similar geographic and temperate areas of the world to Wales. Literature relating to tropical or Mediterranean areas was not explored in any depth.

Searches for ecological information relating to known beach nourishment projects in the UK and northern Europe were undertaken, including Lincshore, Pevensey, Aberdeen and the EU Eurosion Project[9], and key literature on beach management was reviewed, such as the CIRIA Beach Management Manual, SNH Guidance and US Army Corps of Engineers manual. The UK Marine SAC publications[10] and the MarLIN website[11] were also included in the review. CCW staff also identified potential sources of information and reports known to them. A full list of all manuals reviewed is given in ***Section 3.2***.

Discussions with CCW staff indicated that recovery post nourishment is a key issue that needs to be explored through the project. Searches relating to recovery post beach nourishment, after smothering and following disturbance were carried out.

In addition, a search was carried out for Environmental Impact Assessments (EIAs) / Environmental Statements (ESs) in relation to beach nourishment projects or coastal defence schemes that included a beach nourishment element.

The biotopes identified on the case study beaches (see ***Appendix 2*** for list of biotopes) and those set out in ***Section 2.1.2*** were used to focus the results of searches to those most relevant to Welsh beaches and the potential impacts to species and habitats found on Welsh beaches.

Google and online journal sources were searched. No specific structured search methodology was used. Search terms included:

- 'Ecological effects of beach nourishment' - generally and with 'UK', 'Netherlands', 'Europe' applied)
- 'Beach nourishment EIA / Environmental Impact Assessment'
- 'Sand engine'
- 'Impacts of smothering'
- 'Intertidal'
- 'Benthic'

There was also some degree of 'snowball' searching, where papers mentioned in documents that were reviewed were actively sought, particularly if they were referenced by several authors.

All reports and data sources reviewed and referred to in the study are listed in the References (***Section 6***).

[9] http://www.eurosion.org/index.html
[10] Available from - http://www.ukmarinesac.org.uk/publications.htm
[11] http://www.marlin.ac.uk/index.php

3 RESULTS

This section sets out the findings of the study. The results have been presented under separate headings to help identify the type and level of detail of information available generally and in relation to specific types of information source.

3.1 Welsh beach biotopes

Maps showing the biotopes on each of the 10 case study beaches were produced based on the geographic boundaries set out in ***Table 1***. The descriptions provided of the biotopes have been taken from the corresponding MNCR Marine Habitat Classification on the JNCC website (http://www.jncc.gov.uk/marine/biotopes/hierarchy.aspx) using the 2004 classification. Maps can be found in ***Appendix 1***.

Table 1 – Boundaries used for case study beaches

Beach	**Limit**	**Limit**
Talacre	Lower Gronant	Headland where the A548 meets the coast
Abergele - Pensarn	Wern Road, west of the headland by Llanddulas	The estuary mouth at Rhyl
Traeth Crugan	Headland at Carreg y Defaid	Pwllheli golf club
Morfa Dyffryn	Shell Island	Tal-y-Bont
Broadwater - Tywyn – Aberdovey	Mouth of Broadwater	Mouth of Dyfi
Tenby North Beach	First point	2nd lifeboat ramp on Castle Mound
Port Eynon Bay	Port Eynon Point	Rocky headland to the east of Horton
Northern Swansea Bay (Black Pill to Swansea Docks)	Mumbles Head	West Pier
Aberavon Sands (eastern Swansea Bay)	Mouth of Neath Estuary	Dock / river mouth
Porthcawl (Sandy Bay and Trecco Bay)	Porthcawl Point	Newton Point

Biotopes were initially identified to EUNIS level 6 (or the most detailed level given in the CCW Phase 1 habitat data). A total of 68 biotope types were identified in the search areas (see ***Appendix 2*** for the full list).

The number of different biotopes on each beach is shown in ***Table 2***.

Table 2 – Number of different biotopes by beach

Beach	No. biotopes
Aberavon Sands (eastern Swansea Bay)	27
Abergele - Pensarn	16
Broadwater - Tywyn - Aberdovey	12
Morfa Dyffryn	11
Northern Swansea Bay (Black Pill to Swansea Docks)	55
Port Eynon Bay	30
Porthcawl (Sandy Bay and Trecco Bay)	28
Talacre	24
Tenby North Beach	26
Traeth Crugan	19

3.1.1 Biotope sensitivity

The biotopes identified on each of the 10 beaches were grouped to EUNIS level 5. The MarLIN sensitivity assessment was used to determine the sensitivity of each biotope to changes in environmental factors that beach nourishment activity could cause.

The MarLIN website enables the user to produce a list of species or biotopes that are sensitive to environmental changes caused by specified marine and coastal activities in the section on '*Effects of marine activities and natural events*' (http://www.marlin.ac.uk/human-activity.php). The list of biotopes identified as sensitive to the activity '*Coastal defence*' and sub-activity '*beach replenishment*' does not match the 2004 biotope classification codes and does not translate well using the correlation table available on the JNCC website. Furthermore, the hyperlinks on the MarLIN website for the biotopes listed do not appear to work any longer.

As a result, each of the EUNIS level 5 biotopes identified in the case study areas was searched individually on the MarLIN website and the sensitivity information for each of the above factors was recorded. Where no level 5 information was available, level 4 or level 6 information was used. ***Table 3*** sets out the biotopes and species that were used in the search for sensitivity information.

Table 3 – Biotopes and species used to search the MarLIN website

Description	Level 5 code	Level 4 / Level 6 code
Biotopes in case study areas		
Laminaria hyperborea forest with dense foliose red seaweeds on exposed upper infralittoral rock	IR.HIR.KFaR.LhypR	
Laminaria saccharina, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles	IR.HIR.KSed.LsacChoR	
Laminaria digitata on moderately exposed sublittoral fringe rock	IR.MIR.KR.Ldig	
Sponges, bryozoans and ascidians on deeply overhanging lower shore bedrock or caves	LR.FLR.CvOv.SpByAs	LR.FLR.CvOv
Verrucaria mucosa and/or *Hildenbrandia rubra* on upper to mid shore cave walls	LR.FLR.CvOv.VmucHil	LR.FLR.CvOv
Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata	LR.FLR.Eph.BLitX	
Enteromorpha spp. on freshwater-influenced and/or unstable upper eulittoral rock	LR.FLR.Eph.Ent	
Porphyra purpurea and *Enteromorpha* spp. on sand-scoured mid or lower eulittoral rock	LR.FLR.Eph.EntPor	
Ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata	LR.FLR.Eph.EphX	
Ulothrix flacca and *Urospora* spp. on freshwater-influenced vertical littoral fringe soft rock	LR.FLR.Lic.UloUro	
Verrucaria maura on littoral fringe rock	LR.FLR.Lic.Ver	
Yellow and grey lichens on supralittoral rock	LR.FLR.Lic.YG	
Coralline crust-dominated shallow eulittoral rockpools	LR.FLR.Rkp.Cor	
Fucoids and kelp in deep eulittoral rockpools	LR.FLR.Rkp.FK	
Green seaweeds (*Enteromorpha* spp. and *Cladophora* spp.) in shallow upper shore rockpools	LR.FLR.Rkp.G	
Hydroids, ephemeral seaweeds and *Littorina littorea* in shallow eulittoral mixed substrata pools	LR.FLR.Rkp.H	
Seaweeds in sediment-floored eulittoral rockpools	LR.FLR.Rkp.SwSed	
Ceramium sp. and piddocks on eulittoral fossilised peat	LR.HLR.FR.RPid	
Fucus serratus, sponges and ascidians on tide-swept lower eulittoral rock	LR.HLR.FT.FserT	
Chthamalus spp. on exposed eulittoral rock	LR.HLR.MusB.Cht	
Mytilus edulis and barnacles on very exposed eulittoral rock	LR.HLR.MusB.MytB	
Semibalanus balanoides on exposed to moderately exposed or vertical sheltered eulittoral rock	LR.HLR.MusB.Sem	
Ascophyllum nodosum on very sheltered mid eulittoral rock	LR.LLR.F.Asc	
Fucus serratus on sheltered lower eulittoral rock	LR.LLR.F.Fserr	
Fucus vesiculosus on moderately exposed to sheltered mid eulittoral rock	LR.LLR.F.Fves	
Pelvetia canaliculata on sheltered littoral fringe rock	LR.LLR.F.Pel	
Fucus spiralis on sheltered variable salinity upper eulittoral rock	LR.LLR.FVS.FspiVS	
Fucus vesiculosus on variable salinity mid eulittoral boulders and stable mixed substrata	LR.LLR.FVS.FvesVS	
Pelvetia canaliculata on sheltered variable salinity littoral fringe rock	LR.LLR.FVS.PelVS	
Fucus serratus on moderately exposed lower eulittoral rock	LR.MLR.BF.Fser	LR.MLR.BF
Fucus spiralis on exposed to moderately exposed upper eulittoral rock	LR.MLR.BF.FspiB	LR.MLR.BF

Description	Level 5 code	Level 4 / Level 6 code
Fucus vesiculosus and barnacle mosaics on moderately exposed mid eulittoral rock	LR.MLR.BF.FvesB	LR.MLR.BF
Pelvetia canaliculata and barnacles on moderately exposed littoral fringe rock	LR.MLR.BF.PelB	LR.MLR.BF
Rhodothamniella floridula on sand-scoured lower eulittoral rock	LR.MLR.BF.Rho	
Mytilus edulis, Fucus serratus and red seaweeds on moderately exposed lower eulittoral rock	LR.MLR.MusF.MytFR	
Mytilus edulis and *Fucus vesiculosus* on moderately exposed mid eulittoral rock	LR.MLR.MusF.MytFves	
Mytilus edulis and piddocks on eulittoral firm clay	LR.MLR.MusF.MytPid	
Mytilus edulis beds on littoral sediments	LS.LBR.LMus.Myt	
Sabellaria alveolata reefs on sand-abraded eulittoral rock	LS.LBR.Sab.Salv	
Pectenogammarus planicrurus in mid shore well-sorted gravel or coarse sand	LS.LCS.Sh.Pec	
Saltmarsh	LS.LMp.Sm	
Hediste diversicolor and *Macoma balthica* in littoral sandy mud	LS.LMu.MEst.HedMac	
Hediste diversicolor, *Macoma balthica* and *Scrobicularia plana* in littoral sandy mud shores	LS.LMu.MEst.HedMacScr	
Polychaetes in littoral fine sand	LS.LSa.FiSa.Po	
Eurydice pulchra in littoral mobile sand	LS.LSa.MoSa.AmSco	LS.LSa.MoSa.AmSco.Eur
Bathyporeia pilosa and *Corophium arenarium* in littoral muddy sand	LS.LSa.MuSa.BatCare	LS.Lsa.MuSa
Cerastoderma edule and polychaetes in littoral muddy sand	LS.LSa.MuSa.CerPo	LS.Lsa.MuSa
Hediste diversicolor, *Macoma balthica* and *Eteone longa* in littoral muddy sand	LS.LSa.MuSa.HedMacEte	
Lanice conchilega in littoral sand	LS.LSa.MuSa.Lan	
Macoma balthica and *Arenicola marina* in littoral muddy sand	LS.LSa.MuSa.MacAre	LS.Lsa.MuSa
Talitrids on the upper shore and strand-line	LS.LSa.St.Tal	
Venerupis senegalensis, *Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment	SS.SMx.IMx.VsenAsquAps	
Crepidula fornicata and *Mediomastus fragilis* in variable salinity infralittoral mixed sediment	SS.SMx.SMxVS.CreMed	
Echinocardium cordatum and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand	SS.SSa.IMuSa.EcorEns	
Additional species / habitats identified by CCW		
Infralittoral muddy sand		LS.LMS.MS
Coral maerl - *Lithothamnion corallinoides*		
Common eelgrass - *Zostera marina*		
Common maerl - *Phymatolithon calcareum*		
Tentacled lagoon worm - *Alkmaria romijni*		
Red seaweed - *Dermocorynus montagnei*		
Peacock's tail - *Padina pavonica*		
Bearded red seaweed - *Anotrichium barbatum*		

The factors listed by MarLIN as likely to change under beach nourishment and the assumptions made in collating sensitivity information in each of the case study areas is set out in ***Table 4***.

Table 4 – Sensitivity factors recorded

Factor	Assumption / definition used
Smothering	As listed
Suspended sediment	Increase in suspended sediment
Desiccation	As listed
Change in emergence regime	Increase or decrease – the greatest effect was noted
Change in water flow rate	Increase or decrease – the greatest effect was noted
Change in turbidity	Increase or decrease – the greatest effect was noted
Change in wave exposure	Increase or decrease – the greatest effect was noted
Noise disturbance	As listed
Abrasion or physical disturbance	As listed
Displacement	As listed
Change in nutrient level	As listed
Change in oxygenation	As listed

In addition to the biotopes identified in the case study areas, the MarLIN website was also searched for sensitivity information for the additional species and habitats identified in ***Section 2.1.2***.

The results of the sensitivity information search are set out in ***Table 5*** **-** only the information presented in the '*sensitivity'* column is presented. The final column of ***Table 5*** records the highest sensitivity value noted for each biotope / species.

Where information on sensitivity is recorded as '*not listed'*, '*insufficient information*' or '*no information*', this is taken directly from the MarLIN assessment (i.e. MarLIN have assessed the information as being lacking). If ***Table 5*** records the result as '*no information'* it means that no information relating to the biotope sensitivity is given on the MarLIN website (i.e. MarLIN have not made an assessment).

Where MarLIN provided no information in relation to sensitivity, '*no information'* has been recorded. All other definitions are taken from the MarLIN sensitivity assessment and are set out in ***Appendix 3***. More information on the assessment rationale and definitions are available on the MarLIN website at http://www.marlin.ac.uk/sensitivityrationale.php#table1. MarLIN sensitivity assessments have been used as published at the time of writing this report (April 2012) with no amendments.

The sensitivity levels have been colour coded using the following colours:

	Sensitivity level
(red)	Very high / high
(orange)	Moderate
(yellow)	Low / Very low
(blue)	Not sensitive
(grey)	Not relevant
	Not listed / Insufficient information / No information

Table 5 – Sensitivity of biotopes to beach nourishment

Biotope code / species	Smothering	Suspended sediment increase	Desiccation	Change in emergence regime	Change in water flow rate	Change in turbidity	Change in wave exposure	Noise disturbance	Abrasion / physical disturbance	Displacement	Change in nutrient level	Change in oxygenation	Highest level
Biotopes in case study areas													
IR.HIR.KFaR.LhypR	low	low	moderate	moderate	moderate	moderate	moderate	not sensitive	moderate	moderate	moderate	low	moderate
IR.HIR.KSed.LsacChoR	low	not sensitive	low	moderate	very low	low	low	not relevant	low	moderate	low	low	moderate
IR.MIR.KR.Ldig	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	
LR.FLR.CvOv	moderate	low	low	low	low	low	low	not relevant	moderate	moderate	not sensitive	moderate	moderate
LR.FLR.Eph.BLitX	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	
LR.FLR.Eph.Ent	low	not sensitive	very low	moderate	not sensitive	not sensitive	low	not sensitive	low	low	not sensitive	insufficient info	moderate
LR.FLR.Eph.EntPor	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	
LR.FLR.Eph.EphX	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	
LR.FLR.Lic.UloUro	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	
LR.FLR.Lic.Ver	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	
LR.FLR.Lic.YG	very low	not relevant	high	high	not relevant	not relevant	high	not sensitive	high	very high	high	not relevant	very high
LR.FLR.Rkp.Cor	low	low	low	moderate	not relevant	not sensitive	very low	not sensitive	low	moderate	very low	very low	moderate
LR.FLR.Rkp.FK	moderate	low	low	moderate	not relevant	low	moderate	not sensitive	low	moderate	low	not sensitive	moderate
LR.FLR.Rkp.G	low	not relevant	low	moderate	not relevant	not sensitive	very low	not sensitive	low	low	not sensitive	not sensitive	moderate
LR.FLR.Rkp.H	low	not sensitive	low	low	low	not sensitive	low	not sensitive	low	low	low	not sensitive	low
LR.FLR.Rkp.SwSed	low	moderate	low	moderate	not relevant	very low	moderate	not sensitive	low	moderate	low	not sensitive	moderate
LR.HLR.FR.RPid	low	not sensitive	low	very low	low	not sensitive	low	not sensitive	low	moderate	not sensitive	insuffic. info	moderate
LR.HLR.FT.FserT	not sensitive	low	low	low	low	not sensitive	moderate	not sensitive	low	moderate	very low	very low	moderate
LR.HLR.MusB.Cht	moderate	low	low	low	low	not sensitive	moderate	not sensitive	moderate	moderate	low	not sensitive	moderate

Biotope code / species	Smothering	Suspended sediment increase	Desiccation	Change in emergence regime	Change in water flow rate	Change in turbidity	Change in wave exposure	Noise disturbance	Abrasion / physical disturbance	Displacement	Change in nutrient level	Change in oxygenation	Highest level
LR.HLR.MusB.MytB	moderate	very low	low	low	not sensitive	very low	moderate	not sensitive	low	moderate	low	not relevant	moderate
LR.HLR.MusB.Sem	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	
LR.LLR.F.Asc	low	very low	moderate	moderate	very low	not sensitive	high	not sensitive	high	high	moderate	low	high
LR.LLR.F.Fserr	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	
LR.LLR.F.Fves	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	
LR.LLR.F.Pel	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	
LR.LLR.FVS.FspiVS	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	
LR.LLR.FVS.FvesVS	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	
LR.LLR.FVS.PelVS	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	
LR.MLR.BF	low	low	low	low	low	low	moderate	not sensitive	moderate	moderate	low	low	moderate
LR.MLR.BF.Rho	moderate	moderate	low	low	not sensitive	low	moderate	not sensitive	low	moderate	low	low	moderate
LR.MLR.MusF.MytFR	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	
LR.MLR.MusF.MytFves	moderate	very low	low	low	very low	very low	moderate	not sensitive	low	moderate	low	not relevant	moderate
LR.MLR.MusF.MytPid	moderate	very low	low	low	very low	very low	moderate	not sensitive	moderate	moderate	low	no info	moderate
LS.LBR.LMus.Myt	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	
LS.LBR.Sab.Salv	low	low	moderate	moderate	low	very low	moderate	not relevant	low	moderate	very low	low	moderate
LS.LCS.Sh.Pec	low	not relevant	not relevant	not sensitive	not sensitive	not relevant	low	not sensitive	not sensitive	not relevant	not sensitive	not relevant	low
LS.LMp.Sm	low	moderate	low	moderate	moderate	not sensitive	moderate	low	low	moderate	low	very low	moderate
LS.LMu.MEst.HedMac	very low	very low	very low	very low	low	very low	low	not sensitive	low	low	low	very low	low
LS.LMu.MEst.HedMacScr	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	
LS.LSa.FiSa.Po	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	not listed	
LS.LSa.MoSa.AmSco.Eur	very low	not sensitive	low	low	moderate	not sensitive	moderate	not sensitive	very low	not sensitive	moderate	moderate	moderate
LS.Lsa.MuSa	low	very low	very low	moderate	moderate	not	high	very low	low	low	moderate	moderate	high

Biotope code / species	Smothering	Suspended sediment increase	Desiccation	Change in emergence regime	Change in water flow rate	Change in turbidity	Change in wave exposure	Noise disturbance	Abrasion / physical disturbance	Displacement	Change in nutrient level	Change in oxygenation	Highest level
						sensitive							
LS.LSa.MuSa.HedMacEte	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	
LS.LSa.MuSa.Lan	low	very low	low	low	moderate	very low	moderate	not sensitive	low	very low	moderate	low	moderate
LS.LSa.St.Tal	not sensitive	not relevant	not relevant	not sensitive	not relevant	not relevant	very low	not sensitive	not sensitive	not sensitive	not relevant	not relevant	very low
SS.SMx.IMx.VsenAsquAps	low	very low	very low	low	low	very low	moderate	not sensitive	low	low	low	low	moderate
SS.SMx.SMxVS.CreMed	very low	very low	very low	low	low	low	moderate	not sensitive	low	low	low	low	moderate
SS.SSa.IMuSa.EcorEns	not sensitive	low	low	low	moderate	very low	low	not sensitive	moderate	low	low	moderate	moderate
LS.LMS.MS	low	very low	very low	moderate	moderate	not sensitive	high	very low	low	low	moderate	moderate	high
Additional species / habitats identified by CCW													
Lithothamnion corallinoides	very high	very high	very high	very high	moderate	moderate	moderate	not sensitive	very high	not sensitive	very low	not sensitive	very high
Zostera marina	very high	moderate	low	low	moderate	very high	very high	not sensitive	moderate	high	very high	very low	very high
Phymatolithon calcareum	very high	very high	very high	very high	moderate	moderate	moderate	not sensitive	very high	not sensitive	very low	not sensitive	very high
Alkmaria romijni	high	low	low	low	high	not sensitive	high	insuffic. info	high	high	insuffic. info	low	high
Dermocorynus montagnei	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	
Padina pavonica	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	
Anotrichium barbatum	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	no info	

Table 5 shows that very few of the biotopes / species are highly or very highly sensitive to environmental changes caused by beach nourishment.

The last column in ***Table 5*** shows the highest sensitivity value noted for each biotope / species for any of the 12 factors. 23 of the biotopes (41%) are recorded as being, at most, moderately affected by any of the factors that may result from beach nourishment. A further 16 biotopes (29%) are recorded as having, at most, only a low or very low sensitivity or are not listed under any importance categories ('*not listed*'). There is no information available for 9 of the biotope types (16%) - four of these relate to fucoids on low energy littoral rock (LR.LLR.F) and a further three are species listed in s42 of NERC with limited distribution (*Dermocorynus montagnei*[12], *Padina pavonica*[13], *Anotrichium barbatum*[14]).

Although sensitivities for the ephemeral algal biotopes (LR.FLR.Eph.EntPor, LR.FLR.Eph.EphX and LR.FLR.Eph.BLitX) are not listed, CCW intertidal ecologists suggest that these biotopes are not sensitive to factors such as scour and sand cover and may actually be actively increased by these factors.

In total, therefore, 70% of all the biotopes found in the case study areas are *at most* moderately affected by one or more of the 12 possible factors that beach nourishment may influence.

Only 8 of the 56 biotopes or species (14%) are highly / very highly sensitive to one or more of the effects that may be caused by beach nourishment (see ***Table 6***) and only three of these biotopes are found on the case study beaches. Of these biotopes, the lichen (LR.FLR.Lic.YG) may be considered unlikely to be affected by beach nourishment as any placed sediment would be lower on the shore than this biotope is found. The other lichen biotopes (LR.FLR.Lic.UloUro and LR.FLR.Lic.Ver) can also be assumed to be of similar sensitivity as LR.FLR.Lic.YG.

LS.LSa.St.Tal is a strandline biotope and its location on the shore will alter as the height of the tide does. It is possible that it could be adversely affected by beach nourishment activities, such as smothering or physical damage from plant on the shore, depending on where sediment is applied to the beach. Several of the US papers refer to impacts to strandline species such as *Ocypode* (ghost crabs). Talitrids occupy a similar ecological niche on Welsh beaches, although they do not burrow like ghost crab.

The polychaete/bivalve biotope (LS.Lsa.MuSa) is much more likely to be found in areas where nourishment may be placed, however, it is the change in wave exposure that is the potential cause of adverse effects, rather than more direct impacts such as smothering or increase in turbidity. Arguably the aim of beach nourishment projects is to alter the wave climate affecting the beach, however, the potential for all beach nourishment projects to sufficiently alter wave climate to the extent that it poses a high risk to the LS.Lsa.MuSa biotope or others sensitive to alterations in wave climate is likely to be low. The degree to which any beach nourishment project may affect wave exposure and, therefore, adversely affect this biotope will very much depend on the specifics of the beach and the beach nourishment project, as well as the degree to which change in wave exposure persists after nourishment. Such changes should be determined through the design and modelling of a beach nourishment scheme and the associated EIA.

[12] Only recorded on the Llyn Peninsula at two sites – NBN gateway - http://data.nbn.org.uk/
[13] Isolated records between Pwllheli and Abersoch – MarLIN
[14] Only found in Pembroke in Wales – MarLIN

Table 6 – Biotopes / species that are highly / very highly sensitive to beach nourishment

Biotope code	Description	Sensitive factor	Beaches
LR.FLR.Lic.YG	Yellow and grey lichens on supralittoral rock	• Desiccation • Change in emergence regime • Change in wave exposure • Abrasion / physical disturbance • Displacement • Change in nutrient level	• Aberavon Sands • Abergele • Northern Swansea Bay • Port Eynon • Porthcawl • Talacre • Tenby North Beach • Traeth Crugan
LR.LLR.F.Asc	*Ascophyllum nodosum* on very sheltered mid eulittoral rock	• Change in wave exposure • Abrasion / physical disturbance • Displacement	• Northern Swansea Bay • Port Eynon • Porthcawl
LS.Lsa.MuSa	Polychaete / bivalve dominated muddy sand shores	• Change in wave exposure	• Aberavon Sands • Abergele • Northern Swansea Bay • Talacre • Tenby North Beach • Traeth Crugan
LS.LMS.MS	Infralittoral muddy sand	• Change in wave exposure	
	Lithothamnion corallinoides	• Smothering • Suspended sediment increase • Desiccation • Change in emergence regime • Abrasion / physical disturbance	
	Zostera marina	• Smothering • Change in turbidity • Change in wave exposure • Displacement • Change in nutrient level	
	Phymatolithon calcareum	• Smothering • Suspended sediment increase • Desiccation • Change in emergence regime • Abrasion / physical disturbance	
	Alkmaria romijni	• Smothering • Change in water flow rate • Change in wave exposure • Abrasion / physical disturbance • Displacement	

In terms of the factor which causes most effects, a change in wave exposure is the factor that the greatest number of biotopes are very highly/highly sensitive to, with 6 biotopes listed as being most sensitive to this change (see ***Table 6***).

Noise disturbance is the factor that the greatest number of biotopes have no sensitivity to, with 28 biotopes (50%) listed as being '*not sensitive*' to noise disturbance.

Nine other factors also seem to be of relatively minimal concern, with at least 25% of biotopes (at least 14 different biotopes) showing low/very low sensitivity to the following factors:

- Smothering (21 biotopes; 37%)
- Suspended sediment increase (20 biotopes; 36%)
- Desiccation (27 biotopes; 48%)
- Change in emergence regime (18 biotopes; 32%)

- Change in water flow rate (14 biotopes; 25%)
- Change in turbidity (15 biotopes, 27%)
- Abrasion / physical disturbance (21 biotopes; 37%)
- Change in nutrient level (20 biotopes; 36%)
- Change in oxygenation (15 biotopes, 27%)

Table 7 shows the number and percentage of biotopes / species at least moderately affected by each factor.

Table 7 – Biotopes / species that affected by each factor

Factor	**No. biotopes / species that are *at least* moderately affected**	**% biotopes / species that are *at least* moderately affected**	**No. biotopes / species that are *less than* moderately affected**	**% biotopes / species that are *less than* moderately affected**
Smothering	11	20	36	64
Suspended sediment increase	6	11	41	73
Desiccation	6	11	41	73
Change in emergence regime	15	27	32	57
Change in water flow rate	11	20	36	64
Change in turbidity	4	7	43	77
Change in wave exposure	24	43	23	41
Noise disturbance	0	0	46	82
Abrasion / physical disturbance	12	21	35	63
Displacement	20	36	27	48
Change in nutrient level	8	14	38	68
Change in oxygenation	5	9	39	70

The MarLIN biotope sensitivity information shows that in general, most of the biotopes found on Welsh beaches are not highly sensitive to beach nourishment operations, with most of the factors that beach nourishment is likely to generate affecting less than half of the biotopes found on Welsh beaches. It should, however, be remembered that this result relates only to the biotopes found on the areas shown on the maps in ***Appendix 1*** for the 10 case study beaches selected. Wales has over 200 individual beaches, each of which contains many different biotopes. The case study beaches were selected because they because they represent the range of issues around the coast of Wales and include sandy beaches, sand and shingle beaches, high and low tourist areas, different flood and erosion risks and a range of conservation issues (see McCue *et al*, 2010 for information on the selection of case study beaches).

As ***Table 2*** and the maps in ***Appendix 1*** show, Welsh beaches are highly heterogeneous, containing a number of different biotopes, with different sensitivities to beach nourishment operations. The biotope sensitivity information could, therefore, prove useful in identifying the particular areas of the beach where beach nourishment may have the greatest impacts and where care may need to be taken in the design and implementation of beach nourishment projects.

It should be remembered, however, that the biotope sensitivity does not capture all of the possible effects that beach nourishment operations might have. Noise sensitivity is a good illustration of a potential source of adverse effect that is not captured well by considering biotopes alone. Noise is a potential source of impact to species such as birds (particularly when nesting), marine mammals or fish, which is not captured by the biotope typologies. However, disturbance from machinery, plant and beach nourishment works may be an important factor to take into account when considering if beach nourishment is appropriate or when such operations can be carried out to reduce potential impacts.

Furthermore, the sensitivity assessment alone does not give an indication of the likelihood of beach nourishment exerting sufficient change in the factor to reach the 'benchmark' level that has been used in the sensitivity assessment. The degree of change in relation to smothering is "*All of the population of a species or an area of a biotope is smothered by sediment to a depth of 5 cm above the substratum for one month*". This may be quite likely to occur in many beach nourishment schemes. The definition of 'high' sensitivity, however, is that recover takes more than 25 years, or does not occur at all. It is much less likely that the duration of a smothering impact would persist for such a long period for many biotopes as it could be expected that re-colonisation would occur (see ***Sections 3.2, 3.3, 3.4 and 4.4*** for information on recovery from literature sources). The MarLIN sensitivity assessment applies to a wide range of possible impacts from a variety of factors so that these can be applied to almost any potential situation. Given this, there may be merit in CCW revisiting the MarLIN sensitivity assessment as it applies to beach nourishment.

It is also likely that different beach nourishment projects will exert different degrees of change, depending on the specifics of the beach and the aims and design of the project. As such, the sensitivity assessment gives a good guide to which biotopes may be more likely to be affected by beach nourishment but should not be taken as the definitive result without referring to the benchmarks for each factor and the specifics of the project in question.

3.2 Beach management manuals, guides and text books

There are several text books, guides and manuals that address beach nourishment as part of wider beach management issues and approaches. These were reviewed for their discussion of the ecological effects of beach nourishment. Texts included in the review were:

- CIRIA Beach Management Manual (Second edition), 2010
- Scottish Natural Heritage (SNH) Guide to Managing Coastal Erosion in Beach / Dune Systems, 2000
- US Army Corps of Engineers manual
- Beach Nourishment Theory and Practice, Advanced Series on Ocean Engineering, 2002
- US National Research Council, Beach Nourishment and Protection, 1995
- Practical aspects of executing re-nourishment schemes on mixed beaches, Defra/EA Science Report, 2008
- Beach Nourishment: MassDEP's Guide to Best Management Practices for Projects in Massachusetts, 2007

The management manuals consider a variety of beach types and locations and range from relatively short, non-technical guidance (MassDEP's Guide) to much more in-depth, highly technical guidance (CIRIA Beach Management Manual).

The manuals and guidance are designed for use by beach managers i.e. those seeking to undertake coastal protection works, including beach nourishment and recycling. As such, they tend to focus on the physical aspects of beach management and the physical monitoring of beaches post-construction works. They do also recognise the potential for beach management to have an effect on the environment and they each, to some degree, consider the potential ecological effects of beach nourishment and the monitoring of potential effects. Wider impacts to other environmental receptors or to the site that is the source of nourishment material are considered by some of the manuals, however, these issues are not discussed here as they are not the focus of this project.

The dynamic nature of beaches and the specialised character of the species that inhabit them are highlighted in the guidance documents:

- "*Beaches are dynamic structures*" - Beach Management Manual
- "*The harsh and dynamic nature of shingle and sand beaches means that only a specialist range of invertebrate species can survive these habitats*." –Beach Management Manual
- "*Most beaches in Scotland are inherently dynamic in character and are subject to periodic coastal erosion*" – SNH guide
- "*The plant and animal species existing in littoral areas are adapted to survive in the dynamic environment created by the natural cycle of sand erosion and accretion*" – US Army Corps of Engineers
- "*… the area of interest is one of substantial natural rapid changes and the animals which reside in this region tend to be well-adapted to highly dynamic conditions*" - Beach Nourishment Theory and Practice
- "*Natural forces change beaches considerably; they change seasonally in response to storms and over long time scales*" - Beach Nourishment and Protection
- "*The indigenous fauna of a sandy beach are primarily burrowing species that are well adapted to this constantly changing and relatively stressful environment*" - Beach Nourishment and Protection

Beach nourishment activity is likened to the naturally occurring movement of water and sediment on the beach. It is recognised that deliberate nourishment may be of a greater scale than natural movements but also may be considerably less than that experienced during storms, which may affect a much larger area of coast as well as involving greater volumes of sediment. Deliberate nourishment can also occur in areas that would not be hit by natural processes, such as muddy / depositional areas between headlands or fixed structures.

3.2.1 Categories of impact

Several of the management manuals divide the potential impacts of beach nourishment into different categories or types, based on either the cause of impact or area of beach affected (see ***Table 8***).

Table 8 – Types of effect identified by different guidance documents

Guidance document	Category / area of impact
CIRIA	• Impacts of the sediment on existing habitats • Impacts of management of recharge on flora and fauna • Related impacts from changes to geomorphological processes
US Army Corps of Engineers manual	• Subaerial • Subtidal • Borrow site (not considered in this study)
Beach Nourishment Theory and Practice	• Short term • Long term

The *Beach Management Manual* and the SNH guide make reference to the role of EIA in establishing the potential impacts of any beach management project.

3.2.2 Potential impacts

The *Beach Management Manual* (Rogers, *et al*, 2010) includes a table of common impacts of beach recycling, which are also relevant to beach nourishment (see ***Figure 1***) and are covered by the other guidance documents.

Potential effect	Nature of effect + positive X negative	Effect on donor or deposit site
Natural environment		
Disruption/damage to habitats due to smothering	X	Donor
Destruction of habitat	X	Donor/deposit
Human environment		
Disruption of informal and formal recreational use	X	Donor/deposit
Restrictions on access	X	Donor/deposit
Public hazard because of recycling	X	Donor/deposit
Disruption to commercial works and land-use	X	Donor/deposit
Disturbance to archaeological sites	X	Donor/deposit
Disturbance to infrastructure facilities	X	Haulage route (unless beach used)
Physical environment		
Disruption/destruction of geomorphological or geological features because of construction works	X	Donor/deposit

Figure 1 – Typical potential effects of beach recycling / nourishment, from CIRIA Beach Management Manual (Rogers, *et al*, 2010)

The *Beach Management Manual* also makes reference to several studies that consider the potential environmental impacts of beach nourishment (see ***Table 9***). Some of these studies have been reviewed as part of this project.

Table 9 – Summary of studies referred to in the CIRIA Beach Management Manual (Rogers, *et al*, 2010)

Author	Date	Location	Paper title / subject	Findings / conclusions
Petersen, C.H., Bishop, M.J., Johnson, G.A., D'Anna, L.M., Manning, L.M	2006	North Carolina, USA	Exploiting beach filling as an unaffordable experiment: benthic intertidal impacts propagating upwards to shorebirds	• Works done during winter • Used courser sediment than present on the beach • Dramatic suppression of macroinvertebrates (<10% previous) • Shorebird use dropped (by 70 - 90%) • Impacts lasted at least one season
Grippo, M.A., Cooper, S. and Massey, A.G	2007	North Carolina, USA	Impacts of beach replenishment projects on waterbird and shorebird communities	• Insignificant changes to bird abundance • Inconsistent changes to species richness. • Decline in feeding activity of birds post nourishment but could not definitely link this to nourishment
Jones, A.R., Murray, A., Lasiak, T.,A., and Marsh, R.E	2008	New South Wales, Australia	The effects of beach nourishment on the sandy beach amphipod *Exoediceros fossor*: impact and recovery in Botany Bay	• Large reduction in amphipod abundance • Recovery started within weeks • Recovery appeared complete within one year
Clarke & Burlas	2007	New Jersey, USA	Summary of 2nd Regional Workshop on dredging, beach nourishment and birds on the north Atlantic coast	• Benthic communities recovered within 5 – 6 months of nourishment • Invertebrate communities were similar to areas elsewhere on the same coast • Invertebrate abundance and biomass was not significantly lower in nourished areas
Speybroek, J., Bonte, D., Courtens, W., Geskiere, T., Grootaert, P., Maelfait, J-P., Mathys, M., Provoost, S., Sabbe, K., Stienen, E.W.M., Van Lancker, V., Vincx, M. and Degraer, S	2006	Various	Beach nourishment: an ecologically sound coastal defence alternative? A review	• Adverse ecosystem component-specific impacts predominate in short – medium term • Extent of impacts determined by scale of works, quality and quantity of nourishment material, timing, place and size of project, nourishment technique. • In the long term, speed and degree of recovery depends on physical characteristics of the beach – largely determined by sediment quality and quantity, recharge technique, volume of material, and physical environment before nourishment. • Suggests good practice

Smothering / burying on the beach

Guidance documents recognise that nourishment and / or recycling will bury and smother flora and fauna in the area of placement. Some only consider this in passing, almost 'taken as read', while others go into more detail.

The *Beach Management Manual* and SNH guide (Brampton *et al*, 2000) note that the placement and spreading of beach nourishment material can damage intertidal and dune communities by smothering.

The US Army Corps of Engineers manual cites studies that looked at the impacts of burying on burrowing intertidal fauna, which conclude that most benthic species die if covered by more than 0.5cm sediment but that recovery takes place over several weeks to months, with no long term impacts. Other studies, cited in *Beach Nourishment and Protection*, suggest that some species can deal with instantaneous burial by up to 10cm material, while others can burrow up through large overburdens of sand of 60-100cm. It also notes that larger, more mobile species are able to leave the area being nourished and return afterwards.

Beach Nourishment and Protection identifies that more important than the act of burying, which it says is expected and unavoidable, is the recovery rate post nourishment, which, according to the few studies carried out, is relatively quick with only temporary changes in abundance, diversity and species composition ranging from a few weeks to a few months. The guide does recognise that there were limitations to many of these studies, with most only involving limited sampling and in area south of 36 degrees in the USA. It concludes that more studies are warranted.

Impacts to water quality

Impacts to water quality arising from an increase in suspended sediment are often discussed in the same context as impacts resulting from smothering / burying as the large amounts of sand deposited on the beach can lead to increased sediment loads in the water column which in turn can lead to increased deposition and smothering.

Impacts to intertidal nearshore fisheries and benthic communities are made reference to in all the guidance documents reviewed, which go on to state that such impacts are likely to be localised and temporary (during and shortly after nourishment). *Beach Nourishment Theory and Practice* does, however, cite a study in North Carolina where turbidity was raised up to 1 km from the beach but this also concluded that as the area was one of high energy and variable turbidity, this was still within natural limits. *Beach Nourishment and Protection* mentions measurements taken at a beach nourishment project in North Carolina, USA which showed an increase in turbidity of up to 50 – 150 NTUs[15] above background levels up to 200 m away from the site. However, in this case background turbidity levels were measured during calm conditions and were unlikely to reflect naturally occurring maximum turbidity.

Beach Nourishment Theory and Practice also considers the potential impacts of smothering to nearby subtidal rock outcrops. Here, the magnitude of the impact is dependent on the normal conditions to which the rock is subject - if they are regularly covered by natural sediment movement, they are more likely to be better able to cope / recover from nourishment nearby, so long as they are not completely submerged by nourishment.

Near shore benthic communities that may be affected by increased suspended sediment are generally considered to be broadly similar to those of the intertidal area, although somewhat less adapted to extreme stress. Potential impacts to filter feeders, fish (gills, feeding), larval stages, photosynthesis, etc. are all mentioned. The US Army Corps of Engineers manual cites several studies that found no long term effects to near shore soft bottom communities, fish populations in the surfzone, food availability for fish in the nearshore area or fish larvae populations.

[15] nephelometric turbidity units

This is reiterated in *Beach Nourishment and Protection*, which goes on to clarify that those most likely to be most affected are sessile species in hard bottomed reefs or seagrass that are more sensitive to smothering or increased turbidity / sedimentation.

The *Beach Management Manual* considers impacts to water quality from contamination in the material to be low as materials are either uncontaminated (as the source is usually marine and such sources tend to be uncontaminated), or are required to be tested before use to ensure there is no contamination. Contamination from the operation of machinery to carry out the nourishment is also considered or relatively low importance as these risks are easily and normally managed through the use of specific guidance and codes of practice.

The *Beach Management Manual* also considers impacts to shingle beaches as well as to sandy beaches and dune systems, however, the ecology of shingle systems focuses mainly on the vegetation, with the understanding of shingle invertebrates restricted to only a few locations (Dungeness, Rye Harbour).

In terms of the impact of on-going management (re-cycling of sediment), the *Beach Management Manual* considers that these are unlikely to lead to a significant increase in impact over those occurring during nourishment but that there may be site-specific impacts which do need to be taken into account in developing beach management plans. It also notes that repeated management may prevent recovery leading to impoverished benthic communities compared with pre-nourishment, but that long delays between management activities could lead to impacts that are as great as the initial disturbance. The SNH guide considers the impacts of beach nourishment and beach recycling / re-profiling to be the same, with the same text used in both sections. It also refers the reader to the Beach Management Manual for more detail.

<u>Other impacts</u>

Other impacts that are made reference to in the guidance documents are:

- Disturbance and noise - *Beach Management Manual*
- Compaction / damage by machinery *Beach Management Manual*, SNH guide, US Army Corps of Engineers
- Knock on impacts to birds, fish, etc. that feed on species that may be directly impacted - *Beach Management Manual*, US Army Corps of Engineers, *Beach Nourishment and Protection*

<u>Beneficial effects</u>

The positive ecological effects of beach nourishment are not mentioned in any detail. American guidance highlights the potential benefits to turtle nesting, horseshoe crab spawning and plover nesting habitat (see ***Figure 2***). These benefits are not relevant to the Welsh or UK situation, with the exception of providing additional plover nesting habitat, which may be relevant to some shingle beaches.

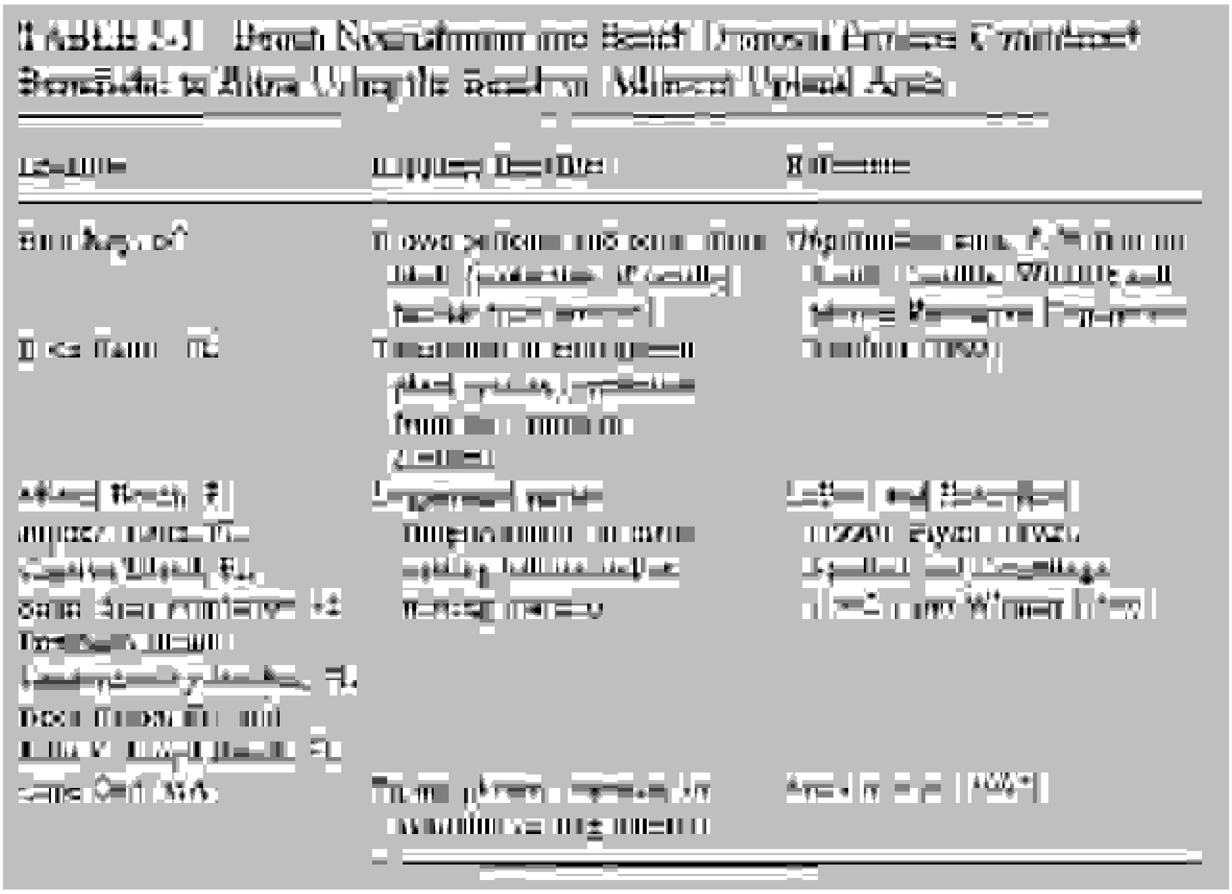

Figure 2 – Beneficial effects of beach nourishment, from *Beach Nourishment and Protection* (NRC, 1995)

3.2.3 The importance of using well matched sediment

All the manuals make reference to the need to use sediment that is as well matched as possible to that already on the beach.

The MassDEP guide (Haney *et al*, 2007) is the least detailed of all the documents reviewed, providing more of a checklist of steps that need to be considered in beach nourishment projects. However, it stresses that one of the most important factors for beach nourishment projects is grain size distribution of material compared to the native beach.

The CIRIA *Beach Management Manual* (Rogers, *et al*, 2010) considers that there is little potential for nourishment to affect the sediment quality of beaches as the specifications for material usually require sediment to be the same size as that already on the beach, with limited fines content.

The SNH guidance points out that too much coarse material can lead to an increase in the slope of the upper beach, while too much fine material can lead to an increased sediment load damaging fisheries and nearshore benthic communities, however it is not specific on the duration or recoverability impacts. The National Research Council in *Beach Nourishment and Protection* considers that material containing a high percentage of fines should be avoided not only from an ecological view but because it is not good material from a physical point of view to use for nourishment.

Beach Nourishment Theory and Practice states that infauna species recover more quickly if good quality sediment is used, illustrating this with the results of previous studies; one that concluded the use of material similar to native sand resulted in minimal impact and rapid recovery; another where recovery took up to 6 months because both finer and coarser material than the native sediment was used and a third where recovery was not complete up to 2 years following nourishment due to the introduction of silts and clays as part of the nourishment material.

Compaction

The CIRIA *Beach Management Manual* notes that recharged shingle beaches may become compacted and almost impermeable to water, leading to 'cliffing' and suggests that it may take up to 5 years for sediments below the beach surface to achieve the same structure as those on a natural beach.

From a coastal defence point of view, compaction and cliffing is not desirable as in making the beach more impermeable, it does not dissipate wave energy but reflects it. The Defra/EA R&D report (*Practical aspects of executing renourishment schemes on mixed beaches*, Clarke & Brooks, 2008) monitored two nourishment schemes on sand/shingle beaches in Kent. Newly replenished areas showed much reduced permeability than adjacent mature beach area, with cliffing occurring particularly in areas that had been nourished with material containing a larger proportion of fines. Over a 3 year monitoring period, erosion was more evident in areas that included more fine material, however, the majority of erosion occurred in the first winter season, after which the erosion rate dropped as the beach had worked itself into a stable bay (with steeper slope than initially profiled).

The National Research Council point out in *Beach Nourishment and Protection* that compaction can also occur naturally on beaches that have not been nourished.

Those guidance documents with an American focus highlight the potential negative impacts of compaction for turtle nesting (e.g. US Army Corps of Engineers). Although this is not relevant to Welsh beaches, there are potential negative impacts of compaction that are little discussed by the guidance documents, but are explored by some of the other documents reviewed (see ***Section 3.3.3***).

Attempts to reduce cliffing include mixing imported shingle with natural sediment as it is recharged (CIRIA Beach Management Manual), and using coarser sand, monitoring the degree of compaction and tilling to offset compaction (US Army Corps of Engineers). Tilling is also recommended in *Beach Nourishment Theory and Practice*. This recommends tilling to a depth of 18 inches (approx. 45cm) for beaches compacted to greater than 500 psi[16] (approx. 343 bar).

3.2.4 Monitoring

Most of the manuals focus on the physical monitoring of beaches and forcing conditions that affect beaches (waves, currents, tides, sea level etc.). The SNH guide does not include mention of ecological monitoring.

Beach Nourishment and Protection (NRC, 1995) identifies a lack of standardisation of environmental monitoring studies and the limited duration or scope of most environmental monitoring studies (see ***Figure 3***). It considers that biological monitoring objectives should:

- Determine the baseline that may be affected and suggest mitigation
- Determine the spatial and temporal variability in / near the proposed project – including natural seasonal variations, which could help identify best / worst times for nourishment
- Evaluate recovery post nourishment

However, it considers that in most cases, projects have failed to adequately address at least one of these objectives.

[16] Pounds per square inch

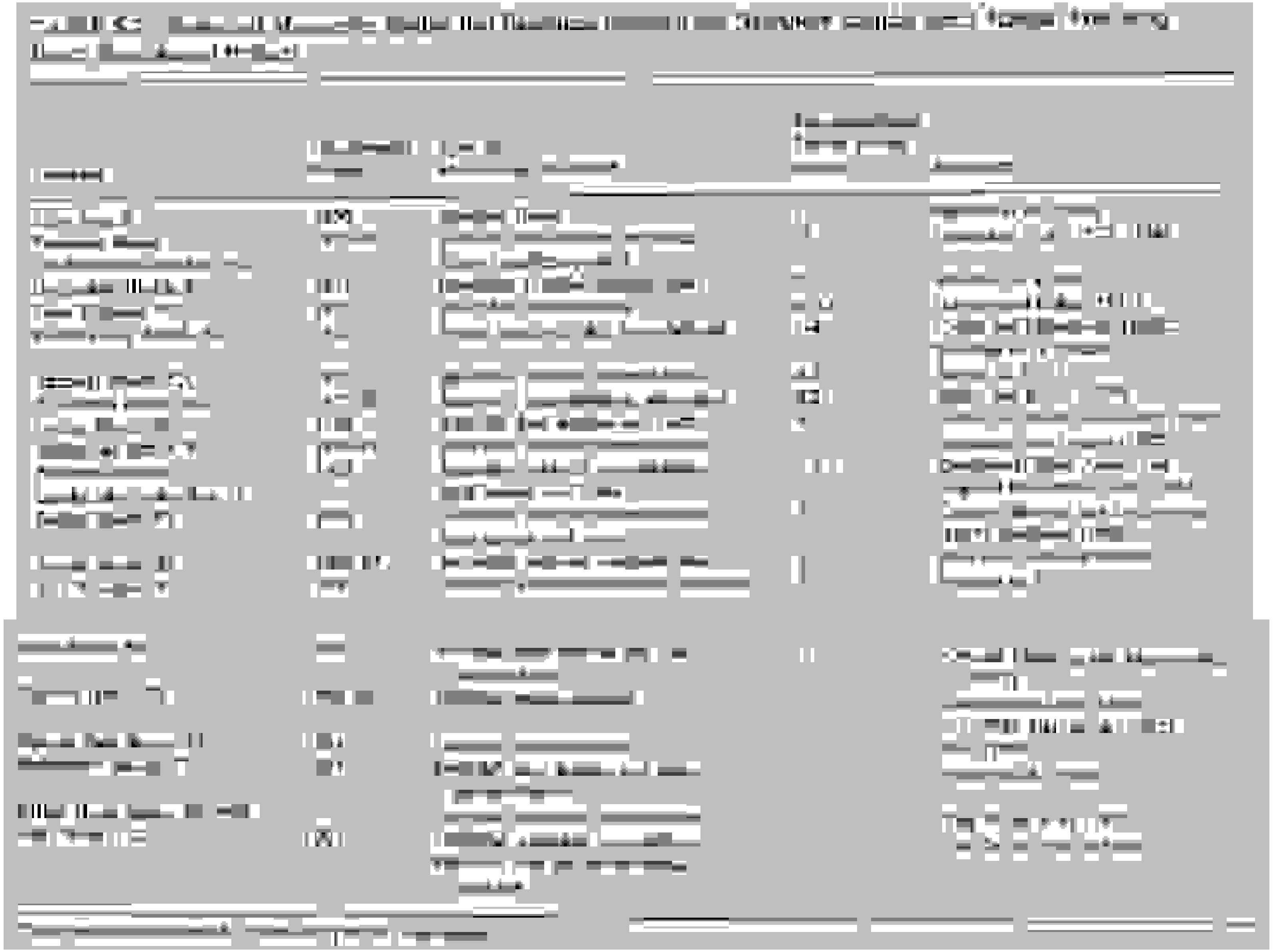

Figure 3 – Post-nourishment biological monitoring studies, from *Beach Nourishment and Protection* (NRC, 1995)

The emphasis of monitoring is normally placed on those species / habitats of greatest concern as there is rarely enough funding to monitor everything, although it points out that it is not necessary to include things that cannot be adequately quantified / identified, or if they are not good indicators of environmental quality. The importance of monitoring sensitive species is also mentioned by the MassDEP guide.

Many studies have focussed on species abundance and diversity rather than looking at any trends or changes in faunal communities with respect to trophic structure and function (NRC, 1995), however, it is necessary to understand the structure and function in order to monitor changes or determine the significance of change.

In considering the design of monitoring programmes, good monitoring programmes should also take account of statistical issues.

The *Beach Management Manual* notes that environmental, recreational and commercial use information and monitoring of beaches is less prevalent around UK than is physical monitoring to establish baseline conditions and that post project and/or long term monitoring is lacking. Indeed, this second edition notes that a significant change from the first is the inclusion of environmental and recreational aspects, suggesting that the consideration of these issues is a relatively new development.

The *Beach Management Manual* goes on the state that most monitoring is localised and focused on areas of management intervention with data relating to long term patterns of change at a strategic level not available. It continues that although several large scale monitoring programmes have been put in place in the last 10 years, they have not been running long enough to provide long term information as yet. The general perception is that monitoring data sets start to become useful at 10+ years duration, for both ecological and morphological change, however, "*There has been little monitoring conducted to evaluate the ecological effects of beach management*". When compared with comments made in *Beach Nourishment and Protection* it seems that this situation has not changed since the NRC publication some 15 years previously.

Detail is given of a range of beach monitoring methods and techniques and on how a monitoring programme should be established and recorded. The emphasis within the manual is that beach management is a cyclical process, with monitoring against performance criteria an integral part of that process to inform the need for and approach to intervention.

There is also a section on ecological monitoring, which emphasises that the basis for environmental monitoring (type and source of data) should be identified through the EIA process. A lack of baseline data may require survey work, ideally several years in advance of interventions, which should continue during and post-nourishment. The *Beach Management Manual* recognises the importance of monitoring to assess recovery post, any beneficial effects and to provide information to help predict future effects when more intervention needed at the same site or elsewhere. The review of ESs and the lack of information found in relation to ecological studies of beach nourishment projects in the UK suggests that this does not happen in practice.

3.3 Other literature reviews

A number of reviews of the impacts of beach nourishment by other authors were identified and reviewed:

- Beach Nourishment: A Review of Biological and Physical Impacts, 2002
- Ecological Effects of Offshore Dredging and Beach Nourishment: A Review, 1973
- Beach nourishment: an ecologically sound coastal defence alternative? A review, 2006
- Assessing the Environmental Impacts of Beach Nourishment, 2005
- Threats to sandy beach ecosystems: A review, 2009

- Beach and Dune Nourishment in the Netherlands, 1984

Many looked not only at the effects of nourishment but also of the extraction of the material used for nourishment and physical impacts. These aspects were not examined as they were not the focus of the current project.

As can be seen from the dates of the publications reviewed, authors have been concerned with the potential impacts of beach nourishment for nearly 40 years. The earliest review is that carried out by Thompson for the US Army Corps of Engineers in 1973. This paper states that at the time of writing, little work on the ecological effects of either offshore dredging or beach nourishment had been done and that ecology as a discipline was regarded as a relatively new science. Unlike the other reviews, Thompson also included interviews with scientists as well as a review of published literature, possibly due to the relative lack of published papers at the time of writing. Some of the underlying assumptions set out by Thompson are seen in all the other reviews – the harsh environment of the beach, the specialised nature of the species found on beaches, the importance of using sediment of a similar type and size to that already on the beach to minimise potential adverse effects. However, the differences in thinking between the date of publication and current approaches are also apparent – Thompson does not see beach nourishment (or dredging) as having any detrimental effects, although he recognises the need for more and specific research into the potential for adverse effects.

The most recent review (Defeo *et al*, 2009) considers all potential threats to sandy beach ecosystems, of which beach nourishment is just one of nine main anthropogenic pressures identified (the others being recreation, cleaning, pollution, exploitation/fishing, biological invasion, coastal development, mining/extraction and climate change).

All the reviews considered impacts to sandy beaches as this is the focus of most of the individual papers on beach nourishment (see ***Section 3.2.3*** below). Most also focussed on US beaches and studies as this is where the greatest number of beach nourishment operations have taken place and over the longest time period; in some places dating back to the early part of the 20th Century. In Europe, most projects have been carried out in Spain (>600 between 1997 and 2002), Netherlands (200), France, Italy, UK and Denmark (Speybroeck *et al*, 2006). The Dutch review (Roelse, 1984) unfortunately considers only engineering issues.

In an approach similar to the guidance documents, all of the reviews mention the naturally dynamic nature of sandy beaches and the adaptations of species that inhabit them to such dynamism. Defeo *et al* (2009) highlight this specialism in a different manner to the other authors pointing out that beach species are not found anywhere other than on beaches, They consider the unique adaptations for life in a dynamic environment to be mobility, burrowing ability, protective exoskeletons, rhythmic behaviour, orientation mechanisms and behavioural plasticity. Speybroek *et al* (2006) point out that beaches that require nourishment tend to already be in an unnatural state, being constrained from rolling back by human activity or development, thus making it difficult to assess the additional impact of nourishment on an already altered environment.

Greene (2002) states that impacts to benthic organisms at the nourishment site are generally considered to be less than those at the mine/dredge site because those species living in a high energy beach environment, especially in the intertidal are better adapted to disturbance than those at the dredge site. Speybroek *et al* (2006), however, qualify the ability of beach species to tolerate change by pointing out that tolerance is not unlimited. This is also echoed in several of the individual papers reviewed in ***Section 3.4***.

Many of the reviews that are based on US studies make reference to species that do not occur in Wales, however, there are similar species to those mentioned that are found on Welsh beaches and the findings of the US-based reviews should not be discounted.

Table 10 – US species referred to in review documents and similar Welsh species

US based species	Similar Welsh species
Ocypode (ghost crabs) - found in tropical/subtropical areas	Sandhoppers / talitrids - occupy similar ecological niche in temperate areas, high up on the beach in the strandline (although do not burrow)
Emerita talpoida (Sand crab / mole crab) – burrowing / swimming crabs	Burrowing invertebrates, small crustaceans – mole crab cannot walk and are important prey species for birds and fish
Donax – important prey species for birds and fish	Tellins and other burrowing bivalves

3.3.1 Categories of impact

Most of the reviews consider the impacts to organisms in particular areas of the beach and focus on benthic macrofauna, as these are the subjects of the papers they review. Peterson & Bishop (2005) comment that benthic invertebrates are the most frequent subject of beach nourishment ecological studies because they are relatively sessile, can be easily sampled and identified and can reveal ecologically important patterns.

Table 11 – Types of effect identified by different reviews

Guidance document	Category / area of impact
Beach Nourishment: A Review of Biological and Physical Impacts	• Upper beach • Midlittoral • Swash zone • Surf zone
Ecological Effects of Offshore Dredging and Beach Nourishment: A Review	• Upper zone • Mid zone • Lower zone
Beach nourishment: an ecologically sound coastal defence alternative? A review	5 beach ecosystem components: • Microphytobenthos – from strand line to subtidal • Vascular plants – dune foot + dry beach area • Terrestrial arthropods – insects and other spp on the strand line and dry parts of beach – strandline + dune foot + dry beach area • Marine zoobenthos - >1mm - from strand line to subtidal • Birds – whole beach 3 effect types: • Construction effects • Effects related to quality of sediment • Effects related to quantity of sediment

3.3.2 Potential impacts

Greene (2002) establishes that biological abundance and species diversity are not constant either geographically across the beach or throughout the year. Species diversity is lower in the upper reaches of the beach and increases as you progress down the shore towards the sea, with specific types of organism associated with different areas of the beach:

- Upper beach - talitrid amphipods, crabs, isopods and transient animals such as beetles
- Midlittoral - polychaetes, isopods, haustoriid amphipods and interstitial organisms
- Swash zone - polychaetes and clams; and the surf zone contains shellfish, forage fish and birds.

Biological abundance is also variable, being greatest in the summer and least in winter. These patterns in space and time can be used to help reduce the potential significance of impacts and increase the likelihood of recovery.

Speybroek *et al* (2006) have created an integrated network of the ecological effects of beach nourishment, based on their categorisation of the type of impact – construction effects, effects related to quality of sediment and effects related to quantity of sediment (see ***Table 11***). This also separates effects into 'habitat effects' and 'biological effects' (see ***Figure 4***). An earlier version of this network of effects is set out in Speybroek *et al* (2005).

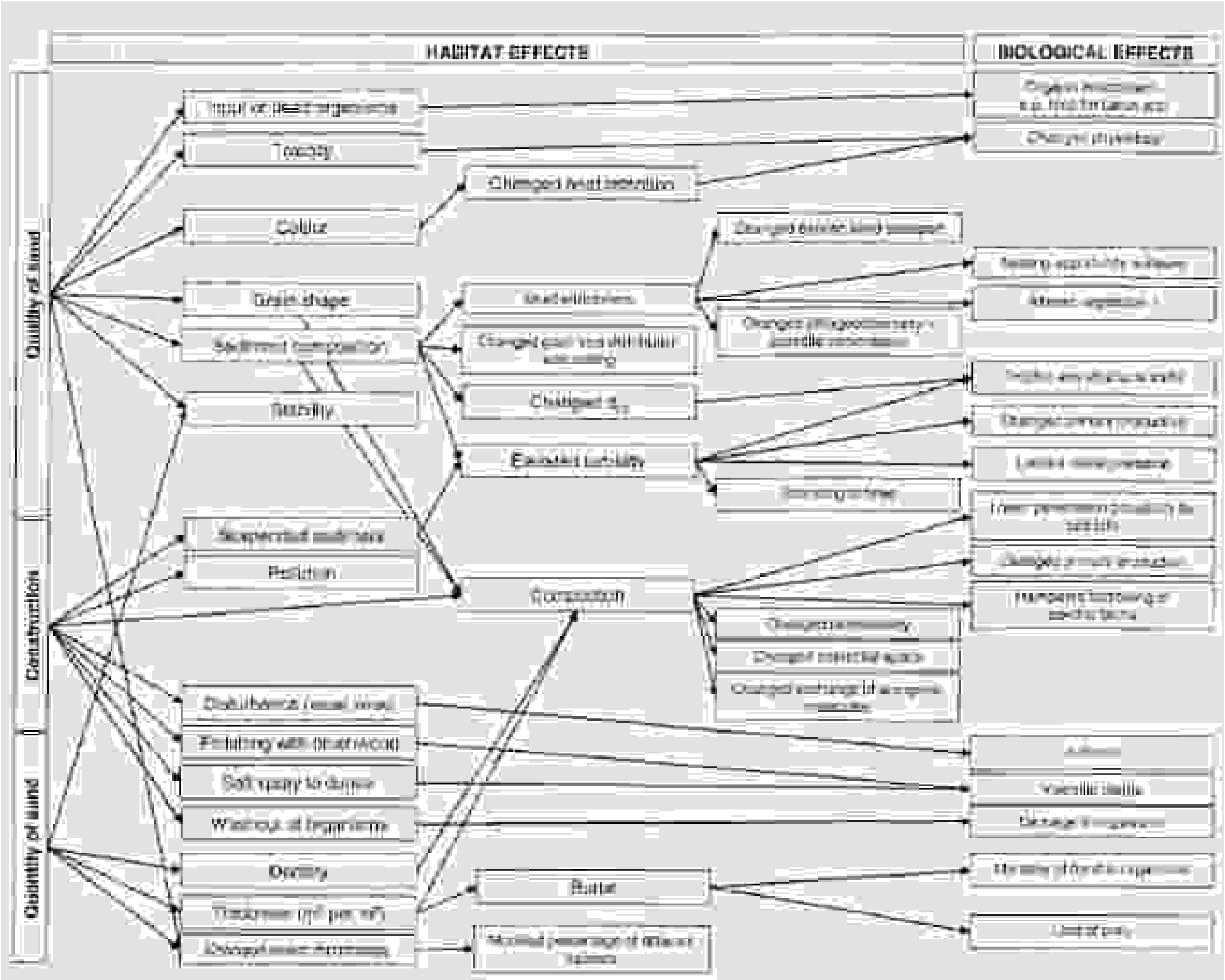

Figure 4 – Integrated network of the ecological effects of beach nourishment, from *Beach nourishment: an ecologically sound coastal defence alternative? A review* (Speybroek *et al*, 2006)

<u>Smothering / burying on the beach</u>

The review undertaken by Greene (2002) states that burial will lead to death unless the organisms can move away or burrow up through the sand. She points to reports that show some species capable of burrowing up through 60cm – 90cm sand. Speybroek *et al* (2006), however, point out that burying by 90cm sediment or more leads to mortality of polychaetes and that most of the nourishment projects they reviewed (in the US) places 1m – 2.5m depth sediment, which would lead to total mortality of infauna. They also point to the lack of information regarding the effects of burial on mircrophytobenthos – two experimental studies have shown upward migration of diatoms through 2.5mm – 4cm sand in between 5 and 7 days. However, these were both laboratory experiments with much lower levels of burying than occurs during nourishment and it can be concluded that nourishment will result in 100% mortality of mircrophytobenthos.

Defeo *et al* (2009) also consider the immediate effects of nourishment to be large, resulting from burying and emigration of organisms able to escape the burial / disturbance caused by nourishment activity.

Both Greene (2002) and Defeo *et al* (2009) consider a potential means of reducing the impact of burial to be a slower application of sediment to the beach. Greene suggests application in a sheeting spray of sand and water, however, Speybroek *et al* (2006) suggest that sediment pumped as a slurry can lead to increased compaction (up to 4 times higher than the original beach).

One study reviewed by Greene (2002) partially attributed rapid benthic recovery to the placement of sediment high up on the beach, which allowed a more gradual redistribution of material across the beach, giving organisms time to move away or burrow up through the added sediment.

<u>Impacts to water quality</u>

Several authors' reviews include comments in relation to impacts to water quality related to increased turbidity. Increased turbidity can reduce photosynthesis, kill suspension feeders, reduce the feeding ability of predators that rely on sight, smother sessile species, damage eggs or larvae and clog fish gills, leading to death, especially in juvenile/small fish (Greene, 2002).

Many authors also point out that the nearshore area is often subject to turbid conditions naturally, with storms leading to increase turbidity for several days and over a much larger area than even large nourishment project. Species inhabiting this area are, therefore, considered generally able to cope with increased turbidity (Speybroek *et al,* 2006).

Beaches that are not typically subject to storm activity or not in naturally turbid areas may suffer more from increases to turbidity than those that are in naturally turbid areas. Increased turbidity is exacerbated if there are high fines or clay levels in the nourished sediment (see ***Section 3.3.3***).

Greene (2002) notes a report on Delaware Bay, which resulted in reduced prevalence of Sabellariid worm reefs post nourishment due to smothering, and studies in North Carolina in which hard substrate was lost due to smothering. Other studies suggest that Sabellariid worms are reasonably tolerant to smothering, however, the tolerance is temperature sensitive (Main & Nelson, 1988 – see ***Section 3.4*** for more detail). MarLIN sensitivity assessments also suggest *Sabellaria alveolata* reefs are not highly sensitive to smothering, increased turbidity or changes in nutrients (see ***Table 5*** in ***Section 3.1***).

The geographic area of influence of changes in turbidity varies between reviews. Greene (2002) notes that increases in turbidity in areas nourished with pumped sediment usually disappears within hours of nourishment activity stopping and is confined to within several tens of metres of the pump site. She notes that studies conducted off the coast of New Jersey showed turbidity limited to within 500m of beach with peak levels being observed in the swash zone and beyond this turbidity being no higher than normal circumstances. However, she also points out that some studies have found turbidity to persist, with one showed reduced visibility up to 7 years post nourishment.

Increased turbidity may also affect species that use vision to find their prey (Greene, 2002).

<u>Impacts to fish</u>

There appears to be a lack of information relating to the potential effects of beach nourishment on fish species. Effects on fish are generally inferred from impacts to prey species or are derived from anecdotal evidence. A 1957 study reviewed by Greene (2002) showed fish kills have occurred post nourishment, however, this is an extremely old text. More up to date literature does not mention direct fish kills but focuses on impacts caused by increased turbidity and knock on effects through altered availability of prey or burial of refugia and nursery/spawning areas.

Fish that live in the nearshore area tend to be opportunistic, suggesting that they are able to adapt to changes to prey that may be caused by beach nourishment. Fish are also highly mobile, able to leave areas subject to nourishment and potential impacts. Fish have been observed leaving shallow coastal waters to avoid turbidity during storms, however, migratory fish may travel parallel to the shore in the nearshore area and are potentially at greater risk of disturbance by nourishment, although there is no evidence to support this theory (Greene, 2002).

The Army Corps of Engineers study of the impacts of beach nourishment in New Jersey (reviewed by Greene, 2002) showed no long term impacts to surf zone fish distribution or abundance and could find no indicator that could tell nourished from control beaches when looking at fish species. It is recognised, however that it is difficult to detect impacts to fisheries that are not dramatic, with the Army Corps of Engineers report stating that "*interannual variation in fish population are large, therefore it is unlikely that anything other than catastrophic effects would be detected*".

Petersen & Bishop (2005) comment that only a few of the 46 ecological studies they reviewed looked at the effects of beach nourishment on fish (and even fewer at the effects on birds).

<u>Other impacts</u>

Other impacts that are made reference to in the reviews but not discussed in any detail are:

- Disturbance and noise – impacts to nesting / foraging birds - Speybroek *et al* (2006), Defeo *et al* (2009)
- Compaction / damage by machinery - Speybroek *et al* (2006), Defeo et al (2009)
- Colour of sediment – this could affect heat retention / temperature on the beach, but lack of data available - Speybroek *et al* (2006)[17]
- Change in beach morphology / wave climate – can lead to reduced diversity and abundance of species, slow recovery or a permanent shift in community structure, with the suggestion that the effects of morphological change are greater than those of direct burying - Speybroek *et al* (2006), Defeo *et al* (2009). The MarLIN sensitivity assessment in ***Section 3.1*** and ***Table 5*** show that some biotopes found on Welsh beaches are sensitive to changes in wave exposure.
- Presence of toxins / high organic matter content - Speybroek *et al* (2006)
- Knock on / indirect effects to predators / other species – Greene (2002) - suggests that impacts affecting the abundance of prey species may have an impact on predators, particularly with reference to *Emerita talpoida* and *Donax*, which are important food species for birds and fish on US beaches
- Cumulative effects of several projects in one area / repeated nourishment
    - Greene (2002), Defeo *et al* (2009)
    - Speybroek *et al* (2006) – effects are little known, but could lead to a gradual change in grain size, increased compaction, long term increased turbidity. Considers several short projects are preferred to larger, long lasting ones.

[17] Sediment colour may also have effects on other environmental receptors, such as visual impact and landscape, however as this is not the focus of this review, they are not considered in detail.

Speybroek *et al* (2006) also discuss the way in which nourishment is applied - across the whole intertidal area, backshore nourishment or foreshore nourishment. They were unable to distinguish which method was best overall but concluded that the technique used could have potentially significant effects depending on the particular beach and the vulnerability of organisms in different areas to burying. A Dutch study which compared the traditional whole beach nourishment approach with backshore nourishment found that recovery of macrobenthos was faster on the backshore nourished beach.

Beneficial effects

There is very little information relating to the benefits of beach nourishment in any of the reviews, although Speybroek *et al*, 2006 consider beach nourishment to be less environmentally damaging / more ecologically sound than the alternatives, but this cannot be said to be a beneficial effect.

3.3.3 The importance of using well matched sediment

Using sediment that closely matches the receiving beach is considered vital to minimise impacts to beach fauna.

Speybroek *et at* (2006) consider the potential impacts of using poorly matched sediment in detail, with reference to the five beach ecosystem components they identify (see ***Table 6***). This goes beyond the consideration of most authors, who focus on macroinfaunal impacts. They state that grain size distribution has been shown to strongly influence the structure and function of benthic community structure, with changes in grain size distribution affecting both microphytobenthos and benthic macrofauna community structure, but there is little information relating to how change affects vascular plants, or terrestrial arthropods although there is some indication that some burrowing beetles show definite grain size preferences and some burrowing amphipods having a clear preference for low levels of fines (<1 or 2%).

One study reviewed by Greene (2002) attributed rapid benthic recovery to good matching of fill. Greene (2002) states that recovery times are usually take longer if silts/clays are introduced as part of the nourishment. Work by Charles Petersen, reviewed by Greene (2002) showed that repeated nourishments with sediment containing higher levels of fines, less than one year apart resulted in no active recovery following nourishment. Speybroek *et al* (2006) also comment on the potential adverse effects caused by too much fine material in beach nourishment sediment, which can lead to increased turbidity and lead to a slower rate of recovery of macrobenthos. They also point out that fine material may also contain higher levels of organic material, leading to reduced oxygen levels.

The use of material with a high shell content or that is too coarse can create difficulties for birds that feed on burrowing organisms both directly (by making it more difficult to insert their beaks into the beach sediment) and indirectly (by reducing the availability of species on which they feed). However, the presence of shell / coarser sediment is beneficial for the nesting success of some birds. Speybroek *et al* (2006) also note that sediment containing high shell content can undergo cementation caused by chemicals leeching from the shell fragments.

Compaction

Compaction is considered in less detail than in the guidance documents, which tend to be more concerned with the physical properties of the beach and how it functions as a defence.

Changes in sediment compaction can lead to changes in the permeability of the sediment to water and gases, impacting on burrowing species and infauna. Greene and Speybroek *et al* (2006) mention the impacts of increased compaction on burrowing organisms and to birds' ability to penetrate heavily compacted beaches to search for food. Greene (2002) also suggests that cliffing as a result of compaction can inhibit or prevent the movement of species between the lower and upper areas of the beach.

In Speybroek *et al* (2005), which seems to be a precursor of the wider Speybroek *et al* (2006) review discussed here, the authors suggest that compaction can be reduced by tilling but that it is mainly a short term problem as wave action, especially during storms, will soften the beach naturally over time.

3.3.4 Monitoring

The issues highlighted by the reviews are very similar to those identified in the guidance documents reviewed in ***Section 3.2*** – a lack of adequate baseline data, insufficient post nourishment biological sampling and lack of long term monitoring. This is also picked up in the paper by Roelse *et al* from the Netherlands in 1991, indicating that this is a long standing problem in all areas where beach nourishment takes place that remains to be resolved / improved.

Most of the reviews comment on the lack of monitoring data in relation to beach nourishment activities. Greene (2002), Speybroek *et al* (2006) and Peterson & Bishop (2005) point to the reactive nature of many of the studies which they review, which focus on recording what happens at a particular site after nourishment activity has taken place. This makes it difficult to interpret the results obtained due to the number of uncontrolled factors. Few studies consider the amount of replication needed to show meaningful variation or consider statistical analysis.

The review undertaken by Peterson & Bishop (2005) takes a different approach to the others and looks specifically at the sampling designs and analyses done to assess the ecological impacts of beach nourishment across 46 projects in the USA. They highlight that assessments of beach nourishment are dominated by reports required by monitoring agencies as a condition of permits and are, therefore, focussed on local conditions, not subject to peer review and often unpublished.

Peterson & Bishop (2005) also suggest that most studies do not take sufficient account of either the natural variation between sites when comparing nourished and control sites or seasonal variation when comparing the same beach before and after nourishment. Speybroek *et al* (2006) also consider poor choice of control sites to be a flaw in many of the studies they reviewed.

Speybroek *et al* (2006) identify several imperfections often found in the studies they reviewed that relate to monitoring and survey design:

- Lack of pre-nourishment / baseline information
- Lack of control sites / poorly chosen control sites
- Lack of replication
- Lack of detailed sampling over time
- Lack of distance between impact and control sites
- Lack of long term monitoring
- Lack of physicochemical monitoring

Greene (2002) suggests that monitoring is most needed in areas that have never been sampled and for indirect effects such as to trophic interactions, rather than the focus on the presence and abundance of individual species. This is echoed by Speybroek *et al* (2006) who point out that most of the studies they reviewed only looked at one ecosystem component and described the effects, rather than considering the overall ecological effects or biological processes that result in observed effects. Peterson & Bishop (2005) found only one of the 46 they reviewed measured biological processes such as burrowing or predation, with most considering species diversity and / or richness.

The focus on individual species or a single type of beach organism (usually macroinfauna) was picked up in the US National Research Council publication *Beach Nourishment and Protection* (1995). This point is still being made by publications 20 years later.

Insufficient pre and post nourishment monitoring is also highlighted by Speybroek *et al* (2006), with Peterson & Bishop (2005) stating that sampling before nourishment was often not sufficient to determine differences between pre and post nourishment – the studies did not sufficiently anticipate the project and permitting agencies did not delay start of project to ensure more pre nourishment sampling could take place. They also point out that the majority (87%) of monitoring studies lasted only 1.5 years and monitoring was terminated before recovery was demonstrated.

Peterson & Bishop (2005) conclude that flaws in the design, analysis and interpretation of the results of monitoring studies suggests a lack of understanding of how to design appropriate monitoring programmes by those granting permits, leading to poor monitoring programmes and the reason why there remains so much uncertainty about the effects of beach nourishment. This assessment seems a somewhat harsh and inconsiderate of 'real world' constraints on the monitoring of beaches, permitting and post nourishment monitoring. In an ideal world, several years of both pre and post scheme monitoring of physical and ecological conditions would be the norm, however, from experience in Wales/UK, coastal defence and/or beach nourishment projects are constrained by funding deadlines and both pre and post monitoring is restricted by the financial and resource constraints of local authorities.

3.3.5 Recovery

The issue of recovery following impact is explored in most of the review papers. Greene (2002) identifies three possible recovery routes / mechanisms:

- Deposition of 'new' species on the beach through the pipelines discharging sediment or in the sediment itself. The studies reviewed by Greene however found that most macroscopic species are killed by entrainment through pumping pipelines and that newly placed sand did not contain any living macroinfauna. The conclusion, therefore is that animals surviving entrainment or sand placement do not play a major role in re-colonisation of the beach.
- Existing species migrating up through the newly placed sand. The impacts of burying are considered in ***Section 3.3.2*** above, which suggests that vertical migration up through the sediment could be a substantial source of re-colonisation if the impacts of burial are reduced. Suggestions include applying the sediment more slowly to enable burrowing organisms to keep pace with sediment placement.
- Recruitment from adjacent areas by larvae, juveniles and adults. Studies show the polychaete *Scolelepis squamata* (which is also found in the UK) is an effective coloniser post nourishment – one study showed it was the only living species on the beach during nourishment and was also found one day after nourishment with numbers increasing over the following three months.

Greene (2002) also reviewed earlier literature reviews by other authors from 1985, 1993 and 1996, which show impacts to beach infauna result in a short term decline in biomass, abundance, and species richness, with recovery in 2 – 7 months. Other studies reviewed by Greene (2002) from 1999 and 2001 saw a much faster recovery time, with one reporting infaunal re-colonisation two weeks post nourishment. A 2001 study included in Greene's review showed infaunal abundance dropped quickly following nourishment, but also recovered quickly attributing this to the affected species high reproductive rates and wide dispersal capability. The same study also suggested that stopping nourishment activity before the normal seasonal drop in abundance promoted faster recovery - areas where nourishment continued into the winter recovered more slowly.

Defeo et al (2009) consider beach nourishment to be a short term 'pulse' disturbance from which recovery should be expected in months, rather than years but can be influenced by factors such as poor sediment quality/matching (see above) or dramatic changes in beach morphology.

However, several studies by Charles Petersen which were reviewed by Greene (2002) suggest much longer recovery times with effects being seen for two years or more. Such effects included a decrease in the abundance of *Emerita talpoida* and *Donax* by up to 90% and a decrease in body size of these species being observed for at least two years following nourishment. Petersen concluded that nourishment resulted in a reduction in the value of the habitat on nourished beaches for most surf fish and shorebirds due to reduced prey abundance and body size.

Peterson & Bishop's (2005) review of 46 projects in the USA determined that most studies were terminated before recovery was demonstrated (average duration of 1.5 years post nourishment monitoring). This could indicate that if re-nourishment occurred annually or before recovery is demonstrated, cumulative adverse effects could result. Over a period of several re-nourishments this could have serious consequences for the intertidal ecology. Speybroeck et al (2006) note that hardly anything is known of the cumulative effects of repeated nourishments on same beach, or several projects in one area and any synergistic effects that may result

3.4 Journal articles

This section examines peer reviewed papers published regarding beach nourishment. It is distinguished from the above type of publication in that it considers only one or a few beaches or situations. It is much more difficult to make generalisations about the effects of beach nourishment described by individual papers than those presented by guidance documents or literature reviews as they tend to focus on much more specific aspect of the effects, a specific beach, a specific group of organisms (generally macrofauna) or a specific species.

One of the earliest studies found as part of this project is that carried out by the US Army Corps of Engineers, following a seven month beach nourishment project (December 1977 – June 1978) over 1,600m intertidal coastline at Fort Macon beach, Bogue Banks in North Carolina (Reilly & Bellis, 1983). Monitoring was carried out in the six months prior to the nourishment beginning, throughout the nourishment works and post nourishment for over 12 months. The beach at Fort Macon was compared with an unnourished beach 20km away at Emerald Isle, also on Bogue Banks. The study found that prior to nourishment, both beaches had similar community structures and diversities of organisms. Nourishment resulted in the loss of all organisms from the beach (due to burial under approx. 2m sand). Recovery by larval recruitment did not begin until all nourishment activity had ceased, leading the authors to suggest that the increased turbidity in the water column during nourishment works blocked larval recruitment. They also found that organisms that were not recruited via larvae took longer to recover, however this could be due to the large area of beach being nourished and the works going on for several months, limiting recruitment from adjacent areas. The authors conclude that recovery should occur within one or two seasons of nourishment ceasing and that smaller nourishment projects of less than 800m should recover faster than larger ones, as recovery from adjacent areas would be greater. The time taken for recovery is very variable as reported in the literature reviewed for this project, ranging from days to weeks to months, with factors such as sediment matching having a significant role in determining the speed of recovery (see ***Sections 3.3.5, 3.3.3 and 3.2.3*** in particular).

In common with the reviews, the naturally dynamic nature of the beach environment and the specialised nature of the organisms found on beaches is referenced. Harris *et al* (2011) looked at the impact of natural storm events in 2008 and 2009 on the ecology of two sandy beach sites in Sardinia Bay, South Africa. Following large storms, both beaches became more reflective and showed changes in macrofauna community structure. One of the beaches was so altered by a storm event that even two years after the event it had not reverted to its original sandy beach state but has become a mixed sediment beach with more permanent areas of exposed bedrock present and much less sediment, supporting a much lower abundance of macrofauna. The second site did not show such radical change in either beach structure or macrofauna community structure. The authors postulate that the second beach is more stable and, therefore, more resilient to storm disturbance due to the presence of backshore dunes which were able to release sediment onto the beach in response to the storm action. The site that experienced greater change was backed by concrete retaining walls and other hard structures. Although the authors cannot specifically link modification of the backshore to the vulnerability of the site, it is likely that removal and/or stabilisation of backshore dunes had an impact on the resilience of the beach to storms.

Most of the articles related to beach nourishment consider the potential impacts to sandy shores. This is to be expected as sandy beaches are much more widespread than shingle shores, which are mainly limited to areas of extreme latitude and others that experienced Pleistocene glaciation (north west Europe, Japan, New Zealand) (Smith, 2009). McFarland *et al* (1994), however, provide some observations following shingle nourishment at Hayling Island and Whitstable in Kent during the 1980s. Unfortunately, they concentrate on the physical aspects of the effects, particularly the compaction and cliffing (between 25 cm and 1 m high) observed at both locations with the beaches becoming much more reflective in nature. Defeo *et al* (2009) in their review assert that species composition and abundance is controlled mainly by the physical environment, with more species being found on dissipative beaches than on reflective beaches, which are harsher, higher energy environments. Greene (2002) also suggests that the cliffing can result in the creation of physical barriers to beach organisms inhibiting or preventing the movement of species between the lower and upper areas of the beach. So, although McFarland *et al* do not comment on the potential ecological impacts of the observed physical changes, it is clear from other authors that ecological effects will be experienced as a result of such changes.

Eelgrass (*Zostera marina*) was identified by CCW as one of the habitats/species of concern in relation to the effects that beach nourishment might have. None of the guidance documents or literature reviews included makes any mention of the potential effects of beach nourishment on eelgrass, however, a few papers were found that may be of relevance.

González-Correa *et al* (2008) investigated the recovery of two areas of seagrass (*Posidonia oceanica*) that had been degraded by beach nourishment 18 years previously. Their study found that it was still possible to see the impacts even after so many years, with the meadows having a significantly lower covering of seagrass and measures of productivity (leaf production, net total rhizomes recruitment and starch concentration) being much lower than in control areas. Sediments at impacted localities contained higher silt/clay and higher organic matter load suggesting the impact may be related to changes in the sediment. Although the authors do not state so, such changes may be as a result of poorly matched sediment, with too high fines/clay content in the nourishment material. This theory is in agreement with another of the authors' papers (González-Correa *et al,* 2009), which looked at the short term effects of beach nourishment on *P. oceanica*. This found significant effects as a result of higher silt/clay deposition, resulting in a decrease of filter feeding epiphytes, starch reserves, shoot surface and shoot biomass. As a result the authors recommended avoiding any dumping or sediment movement in the vicinity of *P. oceanica* meadows.

Posidonia oceanica is, however, a Mediterranean seagrass species and results may not be directly relevant to eelgrass (*Zostera marina*) beds found in Wales. Boese *et al* (2009) however, considered the recovery of *Z. marina* beds following physical disturbance by experimentally removing shoots and observing recovery. Both lower intertidal perennial meadows and higher intertidal eelgrass patches were subject to the experiment. In addition, some areas where *Z.marina* had been removed were sown with seeds to determine evaluate the importance of seedlings in the recovery process. It was found that recovery in both low and high intertidal plots was due exclusively to rhizome growth from adjacent perennial eelgrass. Natural seedling production appeared to play no part in recovery and where seeds were planted, only a few produced seedlings and none survived 12 months. In permanent eelgrass meadows, where recovery took place from adjacent areas, it began immediately and was complete within 2 years. Recovery in transitional areas took almost twice as long to recover to pre-disturbance levels.

These two papers suggest that seagrass/eelgrass is particularly sensitive to disturbance from smothering and physical disturbance, both of which may result from beach nourishment activity. The importance of well matched sediment with minimal fines/clay content is again highlighted and the impact of increased fines on recovery rate is shown (see ***Section 3.4.1*** for more information on findings related to the importance of using well matched sediment). Boese *et al* (2009) also show the importance of limiting the area of disturbance in order to speed recovery.

Sabellaria reefs and other biogenic reefs are often considered to be at particular risk from the effects of beach nourishment as require a supply of sediment to form and grow, but too much sediment can smother them. The paper by Main & Nelson (1988) presents the results of a series of experiments on the Sabellarid reef building worm *Phragmatopoma lapidosa* Kinberg[18] to test its tolerance to burial, silt and exposure to hydrogen sulphide, all of which can result from beach nourishment. They found that *P. lapidosa* Kinberg more tolerant to burial at winter temperatures (for up to 3 days) than at summer temperatures (up to. 25 hours) and that burial by finer sediments resulted in higher mortality than coarse sediments. They also found that *P. lapidosa* Kinberg could tolerate exposure to silt levels 100 times normal levels for 4 days without increased mortality, but could only tolerate exposure to increased hydrogen sulphide for 24 hours.

Although not a UK species, *P. lapidosa* Kinberg is a tube building polychaete worm that is very similar to *Sabellaria alveolata*, being found on exposed beaches subject to high wave action in the intertidal and shallow subtidal areas and along channels and inlets with high tidal currents (Zale & Merrifield, 1989). The findings of Main & Nelson (1988) appear to agree with the sensitivity assessment for the *S. alveolata* biogenic reef biotope (LS.LBR.Sab.Salv) (see ***Table 5*** in ***Section 3.1***) which indicate that *S. alveolata* reefs are not sensitive to most of the potential effects of beach nourishment, having a '*low*' sensitivity to smothering, increased suspended sediment and abrasion/physical disturbance and a '*very low*' sensitivity to changes in turbidity. The MarLIN sensitivity assessment does not give details for increased hydrogen sulphide, but suggests *S. alveolata* reefs also has '*low*' and '*very low*' sensitivity to changes in oxygenation and nutrient levels respectively.

Petersen *et al* (2006), continues with themes picked in others of his papers – the need to establish the cause or mechanism of change following nourishment, not just the correlation between change and impact that is described in many of the studies of beach nourishment and the need for studies to be designed to show statistically relevant results in order to establish the cause of change. This 2006 study, which looked at sediment size composition, benthic macroinvertebrate density and shorebird use on an 11km stretch of beach at Bogue Banks in North Carolina, found:

- Sediment samples collected from nourished beaches were more similar to each other than to samples collected either pre nourishment or to control beaches
- Significant difference in sediment post nourishment was driven mainly by increased coarse sediment but also increased proportion of fines
- *Donax* and amphipod abundance was much lower on nourished beaches – at least as low or lower than normally experienced seasonal lows on control beaches. This was due to

[18] Now re-classified as *Phragmatopoma caudate* – World Register of Marine Species - http://www.marinespecies.org/aphia.php?p=taxdetails&id=330550

decreased habitat area and reduced density of organisms per m^2 with density reductions being the greatest contributor to the difference

- Dramatic detectable differences in the number of shorebirds using nourished compared with control beaches, with counts up to 7 times higher on control beaches. Reduced numbers persisted for up to 7 month. Between 7 and 12 months post nourishment, differences reduced to a level where there was no significant difference between the numbers on nourished and control beaches

The differences in shorebird numbers are potentially relevant to Welsh projects. The birds in question were mainly sanderling (*Calidris alba*), which overwinter in and migrate to and from the Arctic via the UK, including all round Wales. Petersen *et al* propose that the reduced foraging activity of sanderling on nourished beaches implies that the value of the habitat has decreased for birds as a result of nourishment due to one or more of the following reasons:

- Reduced foraging area (intertidal / shallow subtidal) caused by a change in beach profile
- Reduced prey species density
- The presence of coarse / shell material making it harder for them to penetrate the sediment to find food

Any change in habitat value for sanderling may also imply change in value for surf fish which forage in the same area of the beach.

Convertino *et al* (2011) also considered the potential impact of beach nourishment on shorebirds, this time in relation to its use as a wintering or breeding ground for Snowy Plover (*Charadrius alexandrinus*), Piping Plover (*Charadrius melodus*) and Red Knot (*Calidris canutus*) by examining bird count data and timings of beach nourishment activity. They found that beach nourishment made it more likely that the beach was not used for overwintering the following year for Snowy Plover and Piping Plover, and it was also more likely not to be used by Snowy Plover for nesting either. They also found that the habitat used by Snowy Plover for breeding and overwintering was very similar, thus providing an explanation as to why nourishment influenced both overwintering and breeding beach choice.

Another paper which considered the potential impact of beach nourishment on birds is that of Baptist & Leopold (2009), which investigated the relationship between the change from direct placement of beach nourishment to the use of shoreface nourishment and a reduction in the number of common scoter (*Melanitta nigra*) in the Netherlands.

Shoreface nourishment is the placing of sand in nearshore areas (5m – 8m depth) that naturally feed the beach and using the natural action of waves to move the sand gradually towards the coast. A study of a 1993 shoreface nourishment concluded that it resulted mainly in short term effects as a result of burial of benthic species with recovery after 2 years (except for long lived species of mollusc, echinoderm, etc.). Shoreface nourishment has been used increasingly and regularly in the Netherlands since 1997 and there have been concerns about the ecological effects of this practice its increased use has coincided with a decrease in *Spisula subtruncata* and common scoter. *S. subtruncata* is a staple food for common scoter in the Netherlands.

Spisula was very abundant in the 1990s along large parts of the coast. Numbers dropped in the period 2000 – 2005, which coincided with a time of increased shoreface nourishment. Numbers of overwintering scoter also decreased over the same time period. Baptist & Leopold (2009) re-examined data on shoreface nourishments and *S. subtruncata* survey information. Although on the whole, there seems to be a correlation between the increased use of shoreface nourishment and a decline in both *Spisula* and scoter, when examined in detail, the declines do not seem to be correlated with the nourishments that took place locally. In some places, *Spisula* was found after nourishments took place, while in others there seems a more direct link.

The authors conclude that there is a definite causal relationship between shoreface nourishment and *Spisula* decline and that other causes may have played an additional role such as fishing, poor settlement, predation and climate change - declines appear to have happened first in the south and last in the north, which could indicate climate change has an influence.

In relation to scoter, the decline is attributed to the decline in food source, namely *Spisula*. Similar declines in scoter were seen in Belgium, where *Spisula* is also the main food source, but numbers did not decline in France where *Spisula* is less important in the birds' diet. However, since shoreface nourishment cannot be directly attributed to *Spisula* numbers, it cannot also not be linked to the decline in scoter numbers.

Although there is limited research on the impacts of beach nourishment on birds, these studies indicate that generalisations cannot be made regarding the effects but instead depend not only on the species involved, but the relative importance of the impacted beach/habitat for the local bird populations (breeding, feeding, overwintering, etc).

In common with the papers reviewed by other authors and described in ***Section 3.3***, most of the journal articles reviewed are not experiments but are studies of the changes to a particular location(s) following nourishment. This is considered a failing of many of the beach nourishment papers reviewed by Petersen & Bishop (2005) (see ***Section 3.3***). One of the few experimental studies reviewed is that of Schratzberger *et al* (2004), which investigated the effect of adding sediment similar to that which might be dredged from a harbor or navigation channel on the benthos of an intertidal mudflat. While not directly relevant to sandy or shingle beaches, intertidal mudflats are often found near to beaches subject to nourishment. The study found that re-colonisation was strongly influenced by patch size and isolation, with smaller and/or less isolated patches re-colonised faster than larger and/or more isolated ones. Colonization of plots nourished with sediment with a higher organic content was also slower and the community structure was altered, with fewer large sized species and more small-sized species present.

Many of the coastal defence projects in Wales involve the use of beach control structures as well as nourishment. Most of the papers reviewed for this study looked only at the impacts of beach nourishment alone, however, the paper by Martin *et al* (2005) considered the use of detached shore parallel breakwaters designed to keep sediment in place on beach, which they term 'low crested structures' (LCS). This paper is also of interest in that it also attempts to predict how beach biotopes will change as a result of the predicted changes to the physical environment predicted by modelling software typically used in the design of coastal defence schemes. The authors examined several beaches in Europe with LCS to investigate the effect of structures on soft bottom macroinvertebrate fauna by comparing areas with structures to those without and develop a model to forecast change where new LCS are proposed.

They found that LCS definitely have an impact on the surrounding habitat, creating a mosaic of habitats and leading to an increase in diversity in the vicinity of the structures, with the localised nature of changes being more pronounced at UK sites, which have a greater tidal range than the sites in either Italy or Spain. Changes were caused mostly by changes to sediment and water movement rather than increased elevation in tidal regime caused by sediment raising beach levels. At UK sites, they also found that the presence of *Corophium* was an indicator of modified conditions in the sediments, being found on the landward side of LCS, but rare on the seaward side and absent from control beaches with no LCS.

In predicting change, Martin *et al* (2005) found that the accuracy was sufficient as a broad brush predictive tool that seems useful in designing structures to minimise changes to beach habitats. They were able to make some general predictions regarding the changes that LCS could cause and provide a list of design considerations.

General predictions:

- On an exposed coarse sandy shore an impoverished amphipod / isopod / polychaete dominated community is likely to be altered by a structure
- The coarser the sand and steeper the beach, the less likely there will be an effect
- Dissipative beaches tend to be more strongly affected
- Where there is also source of fine sediment this will tend to build up behind structures leading to a different macroinvertebrate community structure on landward side of the structure
- The furthest away from the beach that the structure can be built (without compromising wave breaking function), the better from an ecological point of view
- The more the wave and water regimes are altered by the structure, the greater the changes will be on the biota
- Structures will increase diversity by changing a uniformly exposed beach to one with a mosaic of habitats
- Badly designed structures can lead to extensive areas of anoxia and stagnation. They may also lead to an increased accumulation of seaweed on beaches creating perception problems by users, although this may be more relevant to European microtidal or less exposed UK beaches

Design considerations:

- Keep the degree of change to minimum
- Maximise overtopping and porosity
- Maximise gaps between structures
- Minimise structure length and number
- Avoid beach nourishment
- Minimise enclosure of the area and avoid the use of lateral goynes

It is interesting to note that Martin *et al* (2005) consider that beach nourishment should be avoided in combination with LCS. Recent Welsh coastal defence projects have included beach nourishment as well as beach control structures similar to those examined by Martin *et al* (2005) in an effort to reduce the amount of sediment that the structures draw in from the surrounding area, potentially affecting coastal processes.

There are a number of published papers and articles on the effects of coastal defence structures on beach ecology. These were not included within this study as the focus was on beach nourishment. However, this may be an area for further investigation as most UK projects involve a combination of hard engineering and beach nourishment. CCW may wish to consider how they advise on this matter for future coastal defence projects.

3.4.1 The importance of using well matched sediment

The importance of using well matched sediment is highlighted in several of the papers reviewed, which concurs with both the literature reviews and the guidance documents. Speybroek *et al* (2005), in their study of 11 sandy beaches in Belgium, reference the important role sediment characteristics play in affecting beach morphology and ecosystem composition and point out that geologists as well as biologists (and probably beach managers) will want to retain the original beach grain size distribution, to prevent a shift in the beach from dissipative to reflective.

Petersen *et al* (2005) also highlight the vital importance of the need for nourished sediment to be as closely matched to the original sediment as possible. They point to several other studies that show an increase in fine material as a result of nourishment leads to a depression of macroinfauna lasting at least 7 to 12 months. Conversely, in four previous studies where beach fill better matched natural grain size and composition, recovery was in days to weeks. Furthermore, other studies that have shown no long-lasting effects of beach nourishment have used very similar sediment to that already on the beach and appear to be on beaches with high rates of longshore sediment transport. The authors postulate that such transport can carry 'unnatural' sediment away and bring re-colonising organisms in, leading to greater potential to speed recovery. As a result of their findings, the authors suggest that nourishment permits should demand matching of sediment at both fine and coarse levels. They also point out that one of the potential consequences of nourishing such a long stretch of beach (nearly 11 km) in one go limits the potential for recovery from adjacent areas. This is of less relevance to Wales as most beach nourishment schemes cover a much shorter length of coast, however, this should be borne in mind if larger scale projects are considered or proposed in the future.

Bergquist (unknown date) looked at the impacts of beach nourishment in South Carolina, finding that although the initial placement of sand partially / fully buries macrobenthic communities, recovery can be rapid and that minimum impacts were dependent on a good sediment match.

3.5 EIA studies

The Environmental Statements (ESs) for the following projects, which involve or include beach nourishment to some extent, were reviewed to determine the types of impacts identified, the degree of significance applied to them and proposed mitigation measures:

- Poole Harbour Approach Channel Deepening and Beneficial Use Scheme EIA, Environmental Statement, Royal Haskoning, 2004
- Eastoke Beach Re-nourishment Scheme Environmental Statement, Halcrow, 2005
- Heacham South Beach and Snettisham Beach Re-nourishment Works, Addendum to Environmental Statement, Babtie Brown & Root, 2005
- East Sussex Vegetated Shingle Management Plan, East Sussex Vegetated Shingle Project, 2009 – although this is not an EIA, it does contain information relating to how the impacts of managing shingle beaches should be dealt with
- West Sands Coast Protection Scheme, Atkins, 2009
- Tywyn Coastal Defence Scheme, Atkins, 2009
- Borth Coast Defence Scheme, Atkins 2010

Only those impacts to ecology were considered when reviewing the ESs as impacts to other receptors are not the focus of this study.

A summary of the details of the schemes, potential impacts and proposed mitigation measures are set out in ***Table 12***.

Table 12 – Summary of Environmental Statements reviewed

Scheme name	**Scheme proposals**	**Summary of ecology**	**Potential impacts**	**Proposed mitigation measures**
Poole Harbour Approach Channel Deepening and Beneficial Use Scheme EIA	Material dredged from navigation channel capital dredging proposed to be used as nourishment in several areas around Poole Harbour Estuary		• Sediment quality • Pollution – from sediment contaminants • Smothering of intertidal communities • Increased turbidity – 'wash out of fines'	• Match nourished sediment to original sediment • Testing for contamination – below guideline levels • Species are on wave exposed sandy beaches, so therefore tolerant of mobile sediment. Locations not considered important in terms of biological communities and not important wildfowl feeding areas • Small quantity of fines+ rapid dispersal – increase will be indistinguishable from background levels of sediment
Eastoke Beach Re-nourishment Scheme	Shingle nourishment around existing beach control structures with 80,000 – 150,000m3 shingle – from offshore aggregate source and Chichester harbour dredging	• SPA, SAC, Ramsar site – shingle is supporting habitat for birds • Shingle vegetation • Beach control structures – support limited fauna • Sand and shingle - little evidence of fauna due to its mobility – exposure to wave action is most important factor influencing variety and abundance of invertebrates on the beach • *Sabellaria spinulosa* around harbour • Shallow subtidal *Zostera*	• Disturbance - to bird feeding from construction activity • Destruction of vegetated shingle • Pollution – from machinery / vehicles • Sediment release - increased turbidity: o *S.spinulosa* o Shellfish / fish • Pollution – from machinery / vehicles	• Works not near feeding sites • Sensitive areas are above areas of re-nourishment. Plant to avoid sensitive areas • Pollution control measures – use of codes of practice and relevant guidance • Environment is naturally turbid - effects of storms are considered greater – *S.spinulosa* and shellfish areas considered sufficiently distant to not be affected • Pollution control measures to safeguard aquatic flora

Scheme name	Scheme proposals	Summary of ecology	Potential impacts	Proposed mitigation measures
Heacham South Beach and Snettisham Beach Re-nourishment Works	Sand and shingle nourishment at the two sites– 230,000m3 material total • 160,000m^3 @ Heacham over 1.4km • 70,000m^3 @ Snettisham over 900m Dredgers will place material on lower shore that will then be moved / re-profiled with land based plant Ongoing re-profiling	• Birds – ringer plover nesting and overwintering • Shingle vegetation • Dunes • Invertebrates • Cockle fishery	• Disturbance - to bird nesting and feeding from construction activity • Loss of vegetated shingle during nourishment • Impacts to dunes from wind-blown sediment • Smothering - impacts to invertebrates • Sediment release - increased turbidity – impacts to cockles • Pollution	• Timing of works to avoid main nesting season as this is considered most important period to avoid disturbance. Overwintering disturbance reduced through use of buffer zones and limiting works during feeding times • Pre-nourishment survey + translocation / removal of vegetation – replaced post nourishment. Avoidance of sensitive areas • Minimise fines in nourishment material – monitoring of earlier schemes suggests low impacts • Assessed to be minor / negligible • No plant allowed in cockle/mussel fishery area. Cefas report suggests no link between re-nourishment and decline in shellfish • Use of biodegradable diesel

Scheme name	Scheme proposals	Summary of ecology	Potential impacts	Proposed mitigation measures
East Sussex Vegetated Shingle Management Plan	East Sussex Vegetated Shingle Project – established to gather info to help evaluation and monitoring of shingle sites in Sussex	Range of species, habitats and protected sites around the coast of East Sussex	• Aggregate extraction • Development • Sea defences • Enrichment – through litter, dog fouling, garden waste • Invasive species • Public access / recreation • Vehicle access – can lead to compaction, pollution/enrichment	• No specific measures proposed • No specific measures proposed • Management of coastal defence projects including nourishment / re-profiling : o Guidelines for good practice when working on beaches with vegetated shingle o Cab cards for construction workers to keep in vehicles to recognise important species o Remove and store top 30cm and replace afterwards – helps to retain local seeds in the shingle and then replace o Mark sensitive areas to avoid o Restoration • Education of the public, provision of bins • Invasive species removal programme, public education, restoration • Limit / control access, fencing, boardwalks, education, restoration • Restrict vehicle access unless necessary – fencing, gates, temporary trackways, public education, restoration

Scheme name	Scheme proposals	Summary of ecology	Potential impacts	Proposed mitigation measures
West Sands Coast Protection Scheme	L shaped detached breakwaters + shingle recharge 450,000m^3 shingle. Recycling (every 3 – 4 years / as and when required) Recharge approx every 10 years	• SSSI • Shingle beach - survey show very little vegetated shingle actually present • Saltmarsh • Area of seasonally flooded grassland • Birds – low ecological value of the beach and shingle ridge for birds	• Disturbance - presence of machinery on beach / in water o Impacts to beach - neutral due to absence of vegetated shingle in the area of works o Impacts to marine species o Noise / vibration – o Birds - temp displacement o Intertidal species • Increased turbidity o Possible smothering of lobster grounds further away – deemed too far away to be impacted o Reduction in photosynthesis o Clogging of fish gills • Pollution • Impacts post construction o Benefits to hinterland from protection of scheme o Benefits to shingle beach – increased beach width provides a larger and more stable area for vegetation o Benefits from new structures – providing additional habitat and roosting areas o Benefits - reduction in recycling / re-profiling from current situation - less disturbance	• No anchoring of boats in nearshore area – reduce sediment suspension Avoid areas of vegetated shingle • <5% fines (0.06mm) in shingle nourishment Strong waves and currents in the area mean there is already high levels of suspended sediment • Various actions to reduce risk of pollution – no re-fuelling on the beach, use well maintained machinery, emergency response plan in place, storage of potentially polluting materials in bunded area, compound, machinery and materials to be stored in secure area (locked)

Scheme name	Scheme proposals	Summary of ecology	Potential impacts	Proposed mitigation measures

Tywyn Coastal Defence Scheme	Rock armour breakwater, rock groynes, replace timber groynes, beach nourishment 16,500 m^3 mixed sand, shingle, cobbles	• SAC, SSSIs, SPA
		• Important species on the beach including piddock on clay exposures
		• Low number of species and low abundance – likely due to exposed nature and high energy
		• Zonation of the shore
		  o Upper shore - large cobbles - no apparent marcrofauna
		  o Mid shore – sand – burrowing amphipods, isopods, bivalves and polychaetes
		  o Lower shore – muddy sand – *Echinocardium*, polychaetes, small burrowing bivalves – nos. polychates increase as move down shore
		• Rocky shore species associated with hard substrate structures – outfall pipes, timber groynes
		• Low bird value
		• *Sabellaria* on boulders in mid shore areas
			• Changes to sediment transport and coastal processes – neutral / beneficial from nourishment
			• Damage / disturbance from plant/machinery in intertidal
			  o Species considered common, in low nos. and re-colonisation is likely
			  o *Sabellaria* patches
			  o Bird disturbance / temp displacement
			  o Noise / vibration
			• Sediment release / turbidity / smothering – mitigation measures to reduce sediment release
			  o Impacts to fish that feed on organisms that may be smothered
			  o Decrease in photosynthesis
			• Removal of habitat – artificial structures
			• Pollution
			• Post construction – mostly neutral
				• Recharge material should closely match that on the beach
				• Agreed routes across the beach, avoid sensitive areas
				Not all the beach will be used / impacted by the construction – areas adjacent for ecology
				• Various actions to reduce turbidity / release of sediment – use of mats, agreed working routes, minimise working within water, excavation works only at low tide, use of geotextile layer under rock structures, nourishment to take place at low water
				• Structures will be replaced by others and re-colonised
				• Various actions to reduce risk of pollution – no re-fuelling on the beach, use well maintained machinery, emergency response plan in place, storage of potentially polluting materials in bunded area, compound, machinery and materials to be stored in secure area (locked)

Scheme name	Scheme proposals	Summary of ecology	Potential impacts	Proposed mitigation measures

Borth Coast Defence Scheme	Multi phase scheme – only phase 1 considered in detail – future phases require separate EIAs
	Offshore reef + rock groynes + shingle nourishment – 5,000m^3 sand + 5,000m^3 shingle
		• SSSIs, SACs, SPA, Ramsar
		• Dunes – important for plant, invertebrate, reptile and birds
		• Shingle ridge – some vegetated shingle
		• Beach – piddock, rocky shore species associated with hard structures e.g. groynes
		• Rock platform – *Sabellaria*
		• Subtidal – *Sabellaria* / sandbanks (not in the vicinity of the beach), piddock
		• Birds – beach not important for birds but areas around are e.g. bog, cliffs – high recreational use of the beach makes it poor habitat for nesting birds
			• Changes to sediment transport and coastal processes – neutral
			• Disturbance / damage from machinery etc.
			  o Noise – birds, marine mammals, fish
			• Sediment release / turbidity / smothering
			  o Impacts to fish that feed on organisms that may be smothered
			  o Decrease in photosynthesis
			• Smothering of species from stockpiling and from nourishment
			• Removal of habitat – artificial structures
			• Pollution
				• Recharge material should closely match that on the beach
				• Avoidance of areas of high importance – agree routes / sites, etc.
				Minimise noise impacts (mainly in relation to marine mammals) – marine mammal observer, use same vessel routes, briefing vessel operators re marine mammal presence, limit underwater sound generation
				• Minimise activities that will release sediment – minimise working in water, excavation works only at low tide, use of geotextile layer under rock structures, nourishment to take place at low water, protective mats to spread load of heavy plant on beach
				• Not all the beach will be used / impacted – areas adjacent still available for ecology
				• Structures will be replaced by others and re-colonised
				• Various actions to reduce risk of pollution – no re-fuelling on the beach, use well maintained machinery, emergency response plan in place, storage of potentially polluting materials in bunded area, compound, machinery and materials to be stored in secure area (locked)

Impacts to sandy intertidal communities are discussed but tend to be considered as of low significance because the existing communities are considered to be of low biological significance either in their own right or as a source of food for protected or important species (normally birds).

Other issues are considered of relatively greater importance and the assessment of impacts and development of mitigation focuses on these other issues, which may be either in relation to other ecological element or other environmental receptors. For example receptors of geological, historical and landscape importance were a particular focus of the EIA for Borth, while recreation and traffic issues were significant issues in the ES for Tywyn. While ecological issues were of particular concern at both sites, due to the presence of numerous local, national and European protected sites, the features for which the sites were designated were not related to the intertidal ecology of the beach but to subtidal features or the geology and coastal processes of the beach and shoreline. The intertidal *Sabellaria* reef at Borth does form part of the SAC designation and potential impacts from a range of sources (e.g. smothering, physical damage from machinery) were a concern. These were picked up by the ES and mitigation measures were proposed. The consent, when granted for the Borth scheme, included a condition that the *Sabellaria* reef was monitored throughout construction. Construction of the scheme is not yet complete, and there is no published information on the monitoring of the *Sabellaria* reef, however, informal discussion with CCW staff suggest that no impacts to the reef have been observed (Sue Byrne, pers. comm.).

Where there are particularly sensitive habitats or species present on the beach itself e.g. at West Sands or Heacham and Snettisham, the EIA process considers these receptors in appropriate detail and proposes relevant specific mitigation measures to reduce the significance of these impacts. The ESs also suggest post-scheme monitoring – in the case of Heacham and Snettisham the ES recommends that ecological monitoring continue for at least three years after the nourishment takes place.

Impacts identified as potentially resulting from beach nourishment, that are identified in management guides, reviews and journal articles that do not appear in the ESs reviewed are:

- Compaction from placement of sediment – although the ESs do identify the mortality of species and temporary loss of habitat from placement of nourishment and/or stockpiling of materials
- Impacts associated with the speed and technique of nourishment or where on the beach nourishment takes place
- Sediment size composition – although impacts associated with sediment size are not identified, all recommend that sediment of a similar size composition to that already on the beach, with a minimum amount of fines is used for nourishment, in accordance with standard guidance
- Timing of nourishment – is only mentioned if particularly sensitive species are present e.g. birds. The timing of nourishment operations is often constrained by cost and engineering concerns or potential impacts to other environmental receptors (usually tourism/recreation), which are of more concern, unless particularly sensitive species are present
- Design of the beach – beach morphology, profile and width post nourishment

The benefits of the project/beach nourishment are generally well identified in the ESs, however, they are not, in the main, in relation to the intertidal ecology of the beach. The over-riding driver for and benefits from projects accrue to other environmental receptors. These benefits are generally associated with decreased flooding and coastal erosion impacts, which is usually the driver for the project (except in relation to the Poole Harbour Scheme). Ecological benefits to terrestrial or freshwater habitats and species may, however, be delivered through decreased flooding and coastal erosion impacts, while benefits to dune habitats may accrue through increased or safeguarded sediment supply. Additional benefits may also be delivered for tourism and recreation.

The exceptions to this are the West Sands Coast Protection Scheme and the East Sussex Vegetated Shingle Management Plan. Both of these focus on shingle beaches, with potential ecological benefits delivered by beach nourishment by providing increased beach width, providing a larger and more stable area for vegetation and additional habitat for nesting birds.

3.6 Other beach nourishment / coastal defence schemes

Although the author and CCW project manager are aware of several beach nourishment projects in Wales and the UK, the search for information relating to these projects specifically, and more generally for information relating to actual beach nourishment projects, has proved relatively fruitless.

The Lincshore project from Mablethorpe to Skegness is one of the largest and well know beach nourishment projects in the UK. It began in 1994, covers approximately 20km coast and is still an active project managed by the Environment Agency (EA).

There is some publicly available information on the Lincshore project, however, this seems to be mainly a description of the nourishment activities, the costs and financing arrangements (PPP). References to various reports and reviews that have been produced have been identified but these have been produced for the EA and do not appear to be publicly available. Environmental monitoring has been undertaken by the Institute of Estuarine and Coastal Studies (IECS) at the University of Hull for Halcrow/EA, but reports could not be found online.

Most consents for beach nourishment projects will have included conditions relating to the monitoring of the beach post nourishment. From experience, these conditions relate to the physical aspects of the beach and its ability to function as a defence. They rarely relate to monitoring the ecology of the beach. Where conditions do relate to ecological monitoring, they are concerned with potentially sensitive habitats or species such as the *Sabellaria* reefs present on the beach at Borth, which have been monitored throughout the construction of the coastal defence project in accordance consent conditions. The ES for Heacham and Snettisham recommends that ecological monitoring continue for at least three years after the nourishment takes place, however, no published information relating to post scheme monitoring was found during this study.

As Petersen & Bishop (2005) point out in their review of 46 projects in the USA, most studies that are required by monitoring agencies as a condition of permits are not well designed and suffer from a lack of appropriate pre nourishment monitoring. Without access to similar monitoring projects for Welsh/UK beach nourishment projects, it is difficult to determine if ecological monitoring studies in the UK/Wales suffer from the same flaws. However, it is fairly clear from Environmental Statements that ecological monitoring of beaches before nourishment or coastal defence construction is limited and certainly not as detailed or over as long a time period as physical monitoring. There is a lack of publicly available information relating to post scheme monitoring to draw any conclusions on either the appropriateness of the monitoring or the effectiveness of any mitigation measures.

4 DISCUSSION

4.1 Impacts of beach nourishment

It is possible to identify a number of potential sources of impact from beach nourishment from the various materials reviewed as part of this study. These are discussed in the following sections. Different literature sources focus on some of these impacts more than others and this is also discussed.

4.1.1 Impacts associated with the presence of / disturbance from machinery and workers on the beach

Impacts associated with the presence of or disturbance from machinery and workers on the beach mainly relate to **impacts to birds** at important times, predominantly during nesting but also (less so) during overwintering feeding. Most studies consider potential impacts to nesting birds to be greater than those to overwintering birds, if both are considered likely to result from the same project. This is reflected in the Heacham South Beach and Snettisham Beach Re-nourishment Works ES, which recommends timing of works to avoid the main nesting season, while mitigation to reduce disturbance to overwintering birds is proposed through use of buffer zones and limiting works during active feeding times.

More indirect impacts to birds from changes in food species abundance, size and other factors that affect the value of the beach for birds are more difficult to identify, quantify and to draw general conclusions about. EIAs seem to cover potential disturbance impacts relatively well, with appropriate mitigation measures proposed. However, more indirect impacts are less well considered. This may be due to a lack of information on the precise features of the beach that are important to the birds. If a beach is known to be important for birds, the potential impacts of beach nourishment, beyond those associated with works-related disturbance should be considered.

Impacts to vegetated shingle are only covered in that literature that specifically considers shingle beaches – most of the literature in concerned with impacts to sandy beaches. In the main, impacts relate to the damage or destruction of plants. Mitigation is generally proposed by the use of avoidance measures; directing activity away from areas where vegetated shingle is found, through the use of agreed routes, working practices and fencing. The East Sussex Vegetated Shingle Management Plan (Smith, 2009) also advocates the use of habitat restoration, including:

- Collection of seed prior to works taking place that can then be scattered after the completion of work
- Removal and storage of the top 30cm shingle, which is then replaced after works have finished. This helps to retain local seeds in the shingle which are then replaced.

Smith (2009) states that seed scattering has proved effective at a restoration project in East Stream, West Sussex where seed scattered following completion of works resulted in several species re-establishing successfully within one year.

Compaction of the beach is possible due to the presence of large plant and vehicles across potentially large areas of the beach, however, this is generally considered minor when compared with the potential for compaction resulting from the amount of nourishment material or the use of poorly matched sediment.

Compaction is not much covered by either management guides or Environmental Statements. It is considered in more depth by both peer reviewed papers and review documents. The issue seems to be of much greater concern for specific areas of the USA, where sandy beaches are important nesting grounds for turtles and compaction can have significant detrimental effects turtle nesting. Outside the US, compaction is an issue in that it will reduce the effectiveness of the beach to act as a defence. Ecological impacts are less well understood, although it is clear that they could be wide ranging from slowing/preventing recovery of burrowing macrofauna, inhibiting foraging by birds or creating physical barriers to organisms through cliffing. Quantifying these impacts is, however, difficult. The effects of using poorly matched sediment are clear and discussed below.

Pollution impacts from machinery are generally not covered by peer reviewed articles or review papers, however, they are generally mentioned by management guides / manuals and always covered by EIAs. Potential impacts arising from spills or leaks from machinery can be (and indeed should be) reduced by management measures. As such, these impacts are routinely mentioned in both management guides and EIAs/ESs. They may be less mentioned in journals and reviews because they are well understood and managed.

4.1.2 Impacts associated with the nourishment activity

These impacts relate to **how and where on the beach the nourishment activity takes place**. Impacts from the machinery used to place nourishment material are considered in ***Section 4.1.1*** above.

These impacts are considered in the review papers and in several of the peer reviewed papers, however, they do not appear in any of the management guides or ESs. The use of different techniques to apply nourishment material is covered in some of the management guides, from a practical ‘how to’ point of view, but the relative ecological effects are not considered in these publications or many of the others reviewed.

It is perhaps expected that they are not considered in ESs, as the method of placement may not have been decided at the time of writing the ES and may be determined by an, as yet, un-appointed contractor. Other factors, most significantly cost, drive the consideration of how beach nourishment is applied. It is less easy to explain why these factors, which could influence the degree of impact, are not discussed in management guides.

The **speed with which nourishment is applied** is also not considered in either management guides or ESs. Nourishment is generally applied in quantities and at rates too great for burrowing organisms to keep pace with and some authors suggest that the impact of burial by sediment could be reduced if nourishment was applied more slowly. Academic articles do not consider the cost consequences of such action and it may be this that precludes the adoption of slower application techniques in practical terms. This could explain its absence from both management guides and Environmental Statements.

Where material is placed on the beach may have an influence on the effects of a project, but again this is not considered by many authors - Speybroek *et al* (2006) being one of the exceptions. However, even here the authors were unable to distinguish which method was best overall but concluded that it should be assessed depending on the particular beach and the vulnerability of organisms in different areas to burying.

Most beach nourishment projects appear to follow the traditional approach of applying material across the whole of the beach to create a desired profile. The increasing use of shoreface nourishment in the Netherlands has caused some concern as it seems to be linked to a decrease in common scoter as a result of the effect of the nourishment on their main food source (*Spisula subtruncata*), however, the link is not proven and no conclusions can be drawn on the relative magnitude of effects from shoreface nourishment as compared to traditional methods.

4.1.3 Impacts associated with the nourishment material

The majority of the literature reviewed from the four different types of publication all stress the **importance of using material that is well matched to that already found on the beach**. This seems to be the over-riding message from all sources, all geographic areas and across the whole range of dates of publications which were reviewed. Impacts resulting from using poorly matched sediment include increased compaction, increased turbidity, increased nutrient enrichment/decreased oxygen content, reduced rate of recovery of beach fauna and knock-on impacts to birds and fish species.

Pollution/contamination of the sediment used is covered in a similar manner to pollution impacts from machinery (see above). This potential impact is well understood and can be managed so is not mentioned in peer reviewed articles or reviews, but is covered by both EIAs and guidance documents.

4.1.4 Impacts associated with the design of the nourishment project

A few authors consider the potential effects associated with the **area / proportion of beach to be nourished**. Covering a very large area or the whole beach with sediment may reduce the speed with which organisms from adjacent areas re-colonise the beach. This was recognised over 25years ago in the study of the Bogue Banks nourishment project carried out by the US Army Corps of Engineers (Reilly & Bellis, 1983), which suggested that projects covering less than 800m would recover more quickly than larger projects.

This is not generally an issue for Welsh projects, which have so far tended to be on a much smaller scale to some of those studied in the US - the review by Defeo *et al* (2009) suggests that nourishment projects are typically on a scale of 1km – 10km, which even at the lower end is larger than most UK beach nourishment projects. Should larger scale schemes such as those in the USA, the Netherlands or similar to Lincshore be considered in Wales, the potential for larger impacts and slower recovery rates should be carefully considered and assessed before they go ahead. Even on a smaller scale, the potential effects of covering a whole beach (e.g. within an enclosed bay or closed sediment cell) should be considered carefully before proceeding as they could potentially be greater than the impacts of nourishment on a similar scale, but more open frontage.

The **timing of nourishment activity** is discussed by a number of American authors who propose that nourishment is carried out over winter. As most of the information relates to US beach nourishment projects it may not be directly relevant to Welsh projects and the issue is not well covered by UK literature or guidance. From experience, most UK projects try to avoid the main tourist season over the spring and summer months, as this reduces impacts to other environmental receptors (recreation, tourism, etc.). As such, the timing of works is usually well covered in EIA documents, however, the natural seasonal variability of beaches is not well covered by Environmental Statements (possibly due to lack of ecological data prior to project development). Unless particularly sensitive ecological features are present (e.g. nesting birds) practical constraints such as when funding is available, health and safety of workers, availability of plant and machinery, etc. may over-ride possible ecological concerns in relation to Welsh/UK beaches.

The **use of beach control structures** in addition to beach nourishment is not the focus of this project and was not researched in great detail, however, it may be of relevance to Welsh beaches as many of the recent coastal defence projects in Wales have involved the use of beach control structures as well as nourishment, rather than nourishment alone.

4.2 Benefits of beach nourishment

Information on the beneficial effects of beach nourishment in generally absent, except in relation to erosion and/or flood risk management. There is almost no evidence of ecological benefits of beach nourishment to the intertidal area, except in the provision of turtle or piping plover nesting habitat or spawning grounds for horseshoe crab in several US sources.

Although the turtle and horseshoe crab references are not relevant, the provision of additional or safeguarded habitat for birds that nest on sandy or shingle beaches is potentially relevant to some Welsh beaches as the shingle habitat is under threat in Wales. The provision of additional habitat for nesting birds is cited as a potential benefit in the ES for West Sands Coast Protection Scheme and the East Sussex Vegetated Shingle Management Plan (see ***Section 3.5***).

It should be recognised that the scope of this study is restricted to the ecological effects of beach nourishment on the intertidal area and does not give the whole picture in terms of potential effects of beach nourishment. Ecological effects to areas beyond the intertidal area are not included e.g. protection of terrestrial / freshwater habitats and species behind the beach, increased or safeguarded sediment supply to dunes, detrimental effects to sediment supply areas. Nor does it consider beneficial or adverse effects to other environmental receptors such as decreased flooding and coastal erosion impacts to people and property, tourism benefits, or landscape effects. These wider effects are generally picked up well in ESs (see see ***Section 3.5***) or guidance in relation to the impacts of coastal defence (e.g. ECUS, 2003, *Guidance for Coastal Defence in relation to their Landscape and Visual Impacts*). The potential for beach nourishment to deliver wider benefits are explored in more detail in the Phase 2 project report (Winnard *et al*, 2011).

4.3 Monitoring

Many of the papers, books, articles, etc. reviewed state that there is inadequate monitoring post nourishment in general and specifically, monitoring of the effects of nourishment on the biology/ecology are limited.

Post nourishment studies tend to focus on the topography and physical characteristics of the beach – what has happened to the sediment placed on the beach, how it has moved, graded/re-graded, what has happened to the nearshore wave environment, etc. This seems to be from either a coastal process point of view to see how they may have altered post nourishment or from the point of view of the beach manager to ensure that beach nourishment has had the desired effect; normally flood and/or erosion protection or amenity improvement.

In addition to insufficient post nourishment monitoring, lack of sufficient pre nourishment monitoring makes drawing conclusions on the ecological effects of beach nourishment more difficult. EIA studies in particular seem to suffer from a lack of pre nourishment ecological monitoring. As for post nourishment monitoring, the focus tends to be on monitoring the physical characteristics of the beach to determine when intervention (nourishment) is needed again. Many ESs recommend ecological and/or physical monitoring post nourishment, however, there is a lack of publicly available information relating to post scheme monitoring to draw any conclusions on either appropriateness of the monitoring or the effectiveness of any mitigation measures.

Models are often used to predict how beaches will perform or behave post nourishment, particularly in EIAs. There seems to be little published information on how well models have performed in predicting actual changes post nourishment, however, as this was not the focus of the review it could be that this is not a true reflection of the state of information available. There are fewer attempts still to link predicted physical changes with potential ecological change, although the paper by Martin *et al* (2005) does seek to link these, with some success which they suggest could be useful in designing structures to minimise changes to beach habitats.

4.4 Recovery

Recovery post nourishment was identified as a key area of concern for CCW. The subject is only really covered by the academic literature (journal articles and other literature reviews). There is a wide range of variability in terms of the timing of recovery post nourishment in the papers included in this study ranging from days to weeks to several years (or not at all).

The source of recovery is likely to be from a combination of larval recruitment and immigration from adjacent areas, although it is not clear which is most important and this may depend on the composition of the beach faunal communities.

There is little agreement on how long recovery is likely to take, although there is general widespread agreement that 'good' schemes recover faster than 'bad' schemes with the degree of matching to the existing beach sediment playing a significant role in the speed of recovery post nourishment.

4.5 Summary of mitigation measures for sensitive intertidal Welsh biotopes

Table 13 on the following page summarises the mitigation measures that could be used to reduce the potential impacts to the intertidal ecology of beach nourishment schemes in Wales, based on the biotopes identified as being sensitive to such schemes (see ***Table 6*** in ***Section 3.1.1***). The mitigation measures are based on findings from the literature sources and professional judgement. The effectiveness of the proposed mitigation measures is difficult to establish given the lack of published information on post scheme monitoring of other beach nourishment schemes (see ***Section 3.2.4, 3.3.4, 3.6*** and ***4.3*** in relation to monitoring).

Table 13 – Biotopes / species that are highly / very highly sensitive to beach nourishment and suggested mitigation measures

Biotope code	Description	Beaches	Sensitive factor	Possible mitigation
LR.FLR.Lic.YG	Yellow and grey lichens on supralittoral rock	• Aberavon Sands • Abergele • Northern Swansea Bay • Port Eynon • Porthcawl • Talacre • Tenby North Beach • Traeth Crugan	• Desiccation • Change in emergence regime • Change in wave exposure • Abrasion / physical disturbance • Change in nutrient level • Displacement	• Design of beach nourishment scheme to avoid / reduce change in wave exposure in areas where biotope is located • Modelling to predict / determine change in wave exposure in areas where biotope is located • Avoid placement of sediment in areas where biotope is located • Exclude plant, works, storage, etc. from areas where biotope is located • Testing of sediment for nutrient content prior to use + pollution control measures • Post scheme monitoring
LR.LLR.F.Asc	*Ascophyllum nodosum* on very sheltered mid eulittoral rock	• Northern Swansea Bay • Port Eynon • Porthcawl	• Change in wave exposure • Abrasion / physical disturbance • Displacement	• Design of beach nourishment scheme to avoid / reduce change in wave exposure in areas where biotope is located • Modelling to predict / determine change in wave exposure in areas where biotope is located • Avoid placement of sediment in areas where biotope is located • Exclude plant, works, storage, etc. from areas where biotope is located • Post scheme monitoring
LS.Lsa.MuSa	Polychaete / bivalve dominated muddy sand shores	• Aberavon Sands • Abergele • Northern Swansea Bay • Talacre • Tenby North Beach • Traeth Crugan	• Change in wave exposure	• Design of beach nourishment scheme to avoid / reduce change in wave exposure in areas where biotope is located • Modelling to predict / determine change in wave exposure in areas where biotope is located • Post scheme monitoring
LS.LMS.MS	Infralittoral muddy sand	Not found on any of the case study beaches	• Change in wave exposure	• Design of beach nourishment scheme to avoid / reduce change in wave exposure in areas where biotope is located • Modelling to predict / determine change in wave exposure in areas where biotope is located • Post scheme monitoring

Biotope code	Description	Beaches	Sensitive factor	Possible mitigation
-	*Lithothamnion corallinoides*	Not found on any of the case study beaches	• Smothering • Abrasion / physical disturbance • Suspended sediment increase • Desiccation • Change in emergence regime	• Avoid placement of sediment in areas where biotope is located • Exclude plant, works, storage, etc. from areas where biotope is located • Use well matched sediment with minimum fines content. Minimise works within water • Design of beach nourishment scheme to avoid / reduce change in wave exposure in areas where biotope is located • Modelling to predict / determine change in wave exposure in areas where biotope is located • Post scheme monitoring
-	*Zostera marina*	Not found on any of the case study beaches	• Smothering • Change in turbidity • Change in wave exposure • Change in nutrient level • Displacement	• Avoid placement of sediment in areas where biotope is located • Avoid covering the whole where the biotope is located • Use well matched sediment with minimum fines content. Minimise works within water • Design of beach nourishment scheme to avoid / reduce change in wave exposure in areas where biotope is located • Modelling to predict / determine change in wave exposure in areas where biotope is located • Testing of sediment for nutrient content prior to use + pollution control measures • Post scheme monitoring
-	*Phymatolithon calcareum*	Not found on any of the case study beaches	• Smothering • Suspended sediment increase • Abrasion / physical disturbance • Desiccation • Change in emergence regime	• Avoid placement of sediment in areas where biotope is located • Avoid covering the whole where the biotope is located • Use well matched sediment with minimum fines content. Minimise works within water • Avoid placement of sediment in areas where biotope is located • Design of beach nourishment scheme to avoid / reduce change in wave exposure in areas where biotope is located • Modelling to predict / determine change in wave exposure in areas where biotope is located

Biotope code	Description	Beaches	Sensitive factor	Possible mitigation
-	*Alkmaria romijni*	Not found on any of the case study beaches	• Smothering • Change in water flow rate • Change in wave exposure • Abrasion / physical disturbance • Displacement	• Avoid placement of sediment in areas where biotope is located • Avoid rainbowing of sediment or other processes which require large water quantities • Design of beach nourishment scheme to avoid / reduce change in wave exposure in areas where biotope is located • Modelling to predict / determine change in wave exposure in areas where biotope is located • Avoid placement of sediment in areas where biotope is located + exclude plant, works, storage, etc. from areas where biotope is located • Post scheme monitoring

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In relation to the following conclusions and recommendations, the reader is reminded that the scope of this study relates only to the potential ecological effects of beach nourishment on the intertidal ecology of Welsh beaches and does not consider other environmental effects, such as to landscape, geology or coastal processes. The study only considers the intertidal impacts and does not consider potential effects to the terrestrial or subtidal areas, nor does it consider less direct impacts such as carbon and energy use in winning, transporting and placing materials.

Most of the reviews, papers and guidance conclude that although beach nourishment can affect the ecology of beaches and surrounding areas, alternatives to nourishment are generally be more damaging to shoreline ecology and that **beach nourishment is the most ecologically sound option** (e.g. Speybroek *et al,* 2006).

There are, however, **few ecological benefits** of beach nourishment for the intertidal area and these tend to be confined to shingle beaches. It should, however, be recognised that beaches that require nourishment tend to **already be in an unnatural state**, being constrained from rolling back by human activity or development.

The biotope data for Welsh beaches show that although they are highly heterogeneous, containing a number of different biotopes, with different sensitivities to beach nourishment operations, **most of the biotopes found on Welsh beaches are not highly sensitive to beach nourishment operations** (see ***Section 3.1*** and ***Table 5*** in particular).

The sensitivity assessment does, however, identify **8 biotopes or species that are highly sensitive** to some of the effects of beach nourishment (see ***Table 6*** in ***Section 3.1***). In the main, however, these are only found in very specific local areas.

For most sandy beaches that **do not contain any particularly important habitat**, beach nourishment will **not have long term ecological impacts**, provided that some clear 'rules' are followed:

- Use sediment that is of a similar grain size composition and similar material as that already found on the beach.
- Restrict the amount of both fine material and coarse material, including shell fragments in the re-nourishment material

These conditions are already applied to many beach nourishment projects. **It cannot be stressed too heavily the importance of using well matched sediment to both reduce the impacts of nourishment and promote faster recovery.**

In addition, the following measures could be used to further reduce any short term impacts and promote a faster recovery:

- Apply nourishment slowly, in relatively thin layers (<1m thick) – although it is not clear how practical this is
- Do not cover the whole beach / very large stretches of shoreline (<1km) to enable adjacent areas to re-colonise nourished areas
- Undertake nourishment during winter months when numbers of organisms on the beach are at lower levels
- Do not allow nourishment activities to continue for protracted periods

For those beaches that are not sandy (i.e. shingle beaches) or where there are other habitat and/or species concerns (e.g. important bird species, eelgrass or other biotopes vulnerable to smothering or impacts from nourishment), additional measures are needed to reduce impacts to these more vulnerable areas of the beach. It is difficult to generalise about what additional measures are needed as they will very much depend on the specific beach in question and the project proposals. In the main, however, these **additional concerns and mitigation requirements are picked up through the EIA process**. The MarLIN biotope sensitivity information could provide a useful reference tool for EIA practitioners to help identify areas of the beach where nourishment could have the greatest impacts and where care may need to be taken in the design and implementation of beach nourishment projects. This seems to be an underutilised resource at the moment and is not without its limitations (see ***Section 3.1***). Its usefulness is, however, dependent on good baseline ecological information for the beaches.

It is evident that **there is poor, if any, ecological monitoring of beaches pre or post-nourishment** or for coastal defence projects that include some degree of nourishment.

Overall, there seems little need for CCW to alter its current approach to giving advice in relation to most ‘routine’ coastal defence or beach nourishment projects. Additional consideration and a greater level of detail in Environmental Impact Assessments are needed in relation to projects that:

- Are large scale (similar to Lincshore) or would affect the whole beach
- Will involve repeated nourishment / re-profiling on a regular basis (every 1 – 2 years)
- That include beach control structures as well as nourishment

5.2 Recommendations

1 - Increase ecological monitoring of beach nourishment projects both pre and post nourishment

The weight of evidence seems to support the conclusion that most beach nourishment projects have little ecological effect, but this is based on the monitoring of beach nourishment projects outside of Wales and the UK. CCW may wish to ensure that this conclusion is relevant to Wales by increasing the amount of ecological monitoring associated with beach nourishment and coastal defence projects that involve an element of nourishment.

This requires both pre and post nourishment surveys to be carried out for **ecological** as well as physical changes.

Where beach nourishment has been carried out recently (e.g. last 2 – 5 years), CCW should consider implementing ecological surveys of these areas to determine if there has been any change in the ecology or biotope types found when compared to the baselines given in the Environmental Statements to support the projects and the CCW Phase 1 intertidal habitat surveys. Surveys should include the area where nourishment has taken place and adjacent / control areas.

Where beach nourishment is proposed in the future, CCW should consider requiring post nourishment surveys in their responses to consenting and EIA consultations for these projects. In requiring such surveys, CCW should consider the cost implications to the applicant.

To ensure that the results are useful to CCW and not onerous or disproportionately costly to the applicant (in most cases a local authority), CCW should provide guidance on how these surveys should be carried out e.g. how often, for how long post nourishment, etc.

Ideally, local authorities should be able to carry out these surveys themselves. CCW could consider providing training for local authority staff to enable them to undertake the surveys, if they do not have the in-house capability.

The lack of publicly available post scheme monitoring makes it difficult to draw any conclusions on either the appropriateness of the monitoring or the effectiveness of mitigation measures. If consenting conditions require post scheme monitoring to take place, the results of this monitoring should, ideally be made publicly available. If not, they should at least, be made available to CCW so that the effectiveness of the scheme and of mitigation measures can be determined to inform future decisions.

2 - Access information on the ecological effects of beach nourishment elsewhere in the UK

It is clear that ecological monitoring has been carried out for some beach nourishment projects as references to reports produced as a result of this work have been found, however, it was not possible to locate publicly available sources of this information. This is particularly so for the Lincshore project. CCW should request access to relevant information regarding the ecological impacts of the project from the Environment Agency. This links to recommendation 1 above concerning making post scheme monitoring information available to CCW.

Lessons that can be learned from larger scale beach nourishment projects are particularly pertinent at this time as large scale nourishment is being actively considered for some areas of Wales.

3 - Further investigate the effect that beach control structures have on the ecological effects of beach nourishment

As it was not a primary focus of this project, the wider issue of beach control structures used in conjunction with beach nourishment was not investigated in any depth. Most of the recent coastal defence projects in Wales have included a mix of hard engineering and beach nourishment. It is possible that the use of both could have more complex ecological effects than either alone, which could affect large areas of beach if several structures are proposed.

4 - Advocate the use of the MarLIN sensitivity assessment information in Environmental Impact Assessments for beach nourishment and coastal defence projects

None of the EIAs reviewed made reference to the MarLIN sensitivity assessment information. There is relatively good coverage of information for biotopes and species and this additional reference could provide additional relevant data to inform EIAs.

Advice from CCW on the increased use of the MarLIN sensitivity assessment should point out that the sensitivity assessment alone does not capture all of the possible effects that beach nourishment operations might have, particularly in relation to more mobile species. Any guidance on the use of the sensitivity assessment should also include reference to the need to relate the specific likely changes associated with the project to the benchmarks used for the assessment to ensure that it is used appropriately and does not over or underestimate the impact of a project.

Given that the MarLIN sensitivity assessment applies to a wide range of possible impacts from a variety of factors, there may be merit in CCW revisiting / reviewing the sensitivity assessment as it applies to beach nourishment specifically if it were to include the use of the sensitivity assessment in any guidance on the use of beach nourishment schemes.

6 REFERENCES

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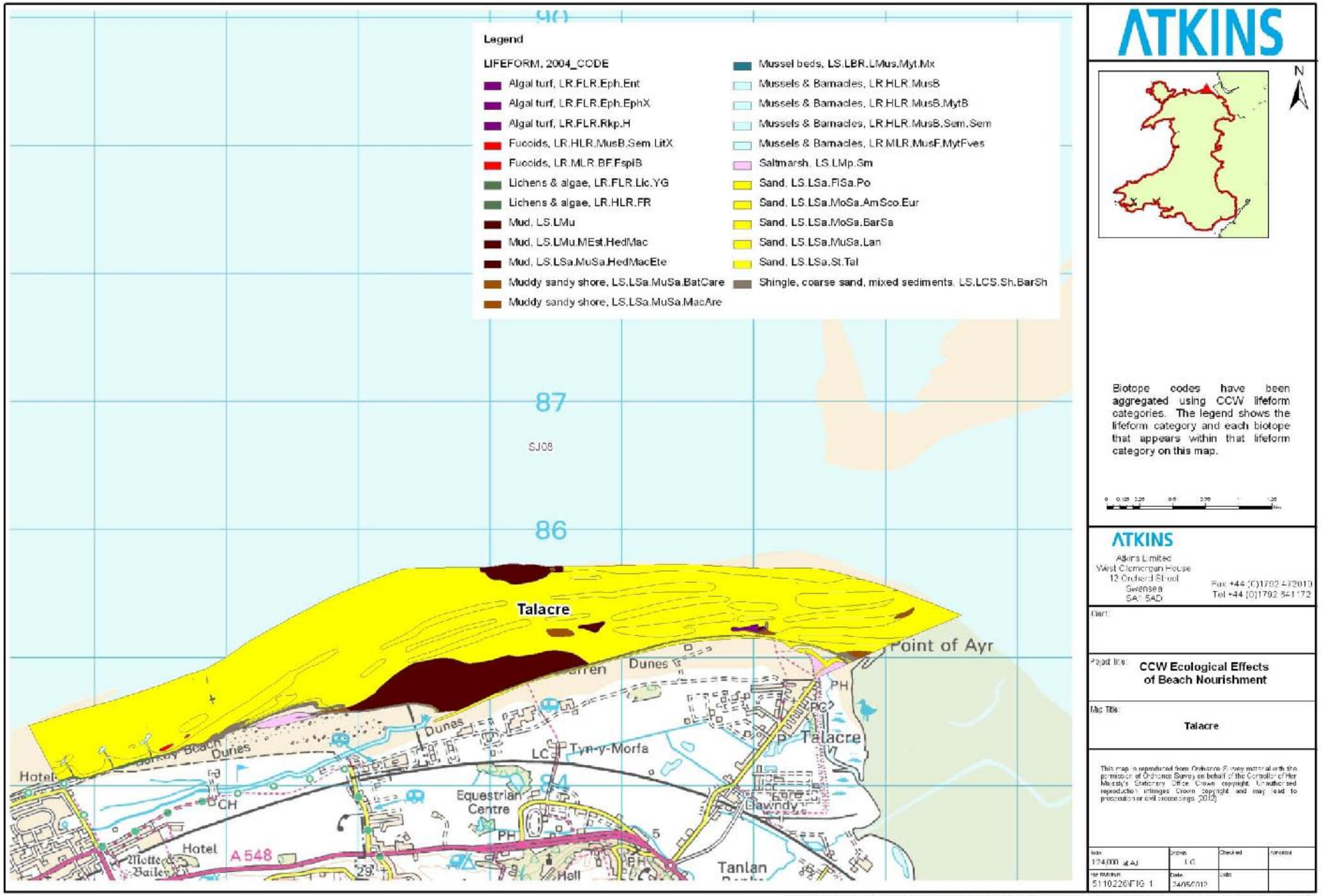
APPENDIX 1: BIOTOPE MAPS

The following biotope maps have been produced using data from CCW's Phase 1 habitat survey of the whole intertidal area of Wales (see ***Appendix 4*** for information on the datasets used).

Biotopes are identified to EUNIS level 6 (or the most detailed level given in the CCW Phase 1 habitat data). Biotope codes have been aggregated using the following CCW lifeform categories:

- Lichens & algae
- Fucoids
- Kelp
- Algal turf
- Mussels & barnacles
- Short faunal turf, crusts & cushions
- Faunal & algal turf
- Mussel beds
- Biogenic sand reefs
- Saltmarsh
- Seagrass beds
- Shingle, coarse sand & mixed sediment
- Sand
- Muddy sandy shore
- Mud

The legend for each map shows the lifeform category and each of the biotopes that appear within that lifeform category on the map in question. It does not show all the biotope types that could be within the lifeform category, only those appearing on the map. See ***Appendix 2*** for the list of biotopes identified on all the case study beaches.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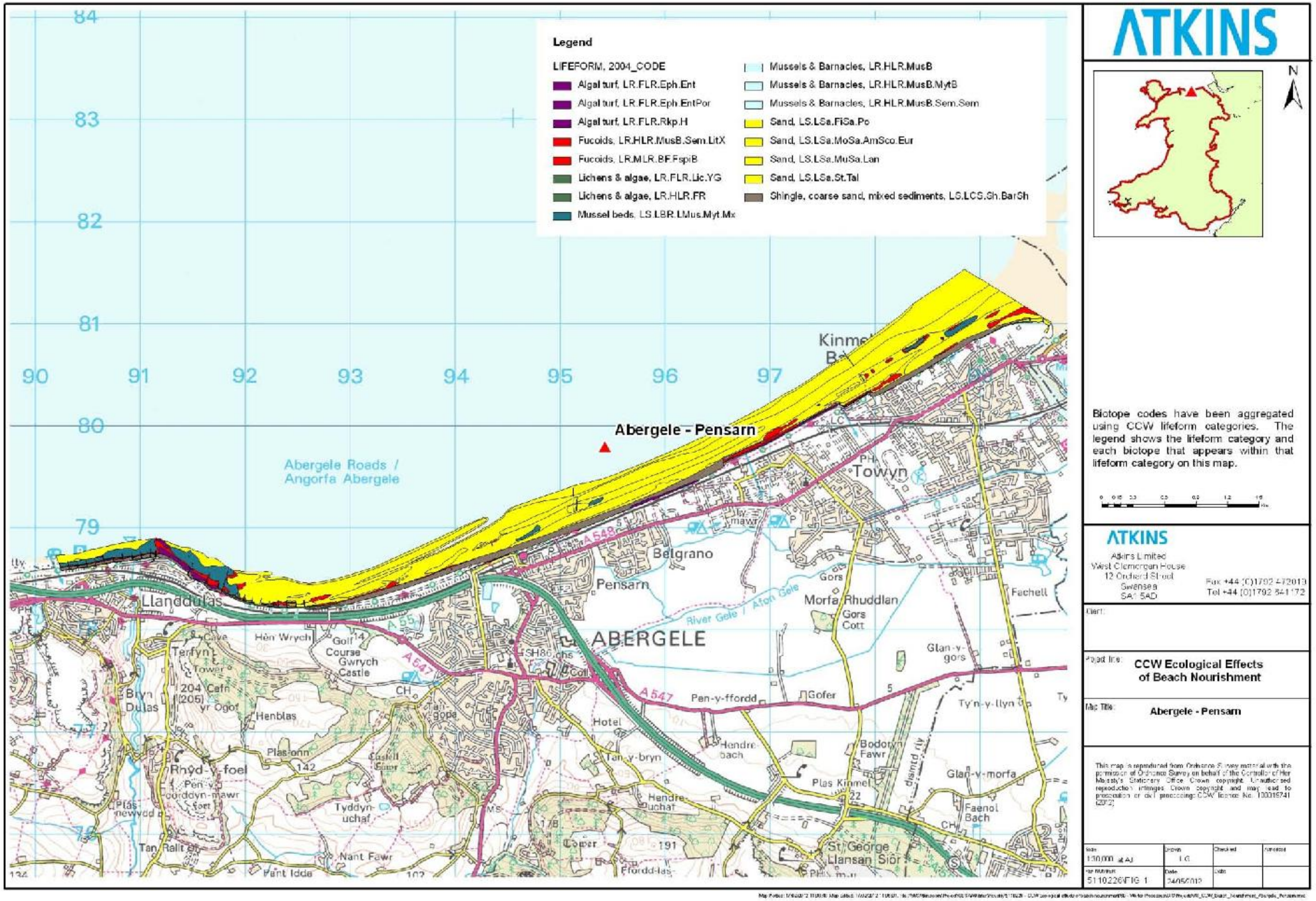
Algal turf, LR.FLR.Eph.Ent
Algal turf, LR.FLR.Eph.EphX
Algal turf, LR.FLR.Rkp.H
Fucoids, LR.HLR.MusB.Sem.LitX
Fucoids, LR.MLR.BF.FspiB
Lichens & algae, LR.FLR.Lic.YG
Lichens & algae, LR.HLR.FR
Mud, LS.LMu
Mud, LS.LMu.MEst.HedMac
Mud, LS.LSa.MuSa.HedMacEte
Muddy sandy shore, LS.LSa.MuSa.BatCare
Muddy sandy shore, LS.LSa.MuSa.MacAre
Mussel beds, LS.LBR.LMus.Myt.Mx
Mussels & Barnacles, LR.HLR.MusB
Mussels & Barnacles, LR.HLR.MusB.MytB
Mussels & Barnacles, LR.HLR.MusB.Sem.Sem
Mussels & Barnacles, LR.MLR.MusF.MytFves
Saltmarsh, LS.LMp.Sm
Sand, LS.LSa.FlSa.Po
Sand, LS.LSa.MoSa.AmSco.Eur
Sand, LS.LSa.MoSa.BarSa
Sand, LS.LSa.MuSa.Lan
Sand, LS.LSa.St.Tal
Shingle, coarse sand, mixed sediments, LS.LCS.Sh.BarSh
87
SJ08
86
Talacre
Point of Ayr
Dunes
Tyn-y-Morfa
Equestrian Centre
Hotel
A548
Tanlan
ATKINS
N
Biotope codes have been aggregated using CCW lifeform categories. The legend shows the lifeform category and each biotope that appears within that lifeform category on this map.
ATKINS
Atkins Limited
West Glamorgan House
12 Orchard Street
Swansea
SA1 5AD
Client:
Project Title:
CCW Ecological Effects of Beach Nourishment
Map Title:
Talacre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Algal turf, LR.FLR.Eph.EntPor
Algal turf, LR.FLR.Rkp.H
Fucoids, LR.HLR.MusB.Sem.LitX
Fucoids, LR.MLR.BF.FspiB
Lichens & algae, LR.FLR.Lic.YG
Lichens & algae, LR.HLR.FR
Mussel beds, LS.LBR.LMus.Myt.Mx
Mussels & Barnacles, LR.HLR.MusB
Mussels & Barnacles, LR.HLR.MusB.MytB
Mussels & Barnacles, LR.HLR.MusB.Sem.Sem
Sand, LS.LSa.FiSa.Po
Sand, LS.LSa.MoSa.AmSco.Eur
Sand, LS.LSa.MuSa.Lan
Sand, LS.LSa.St.Tal
Shingle, coarse sand, mixed sediments, LS.LCS.Sh.BarSh
Abergele - Pensarn
Abergele Roads / Angorfa Abergele
ABERGELE
Towyn
Belgrano
Pensarn
Llanddulas
Morfa Rhuddlan
ATKINS
Biotope codes have been aggregated using CCW lifeform categories. The legend shows the lifeform category and each biotope that appears within that lifeform category on this map.
ATKINS
Atkins Limited
West Glamorgan House
12 Orchard Street
Swansea
SA1 5AD
Fax +44 (0)1792 472013
Tel +44 (0)1792 841172
Client:
Project Title: CCW Ecological Effects of Beach Nourishment
Map Title: Abergele - Pensarn
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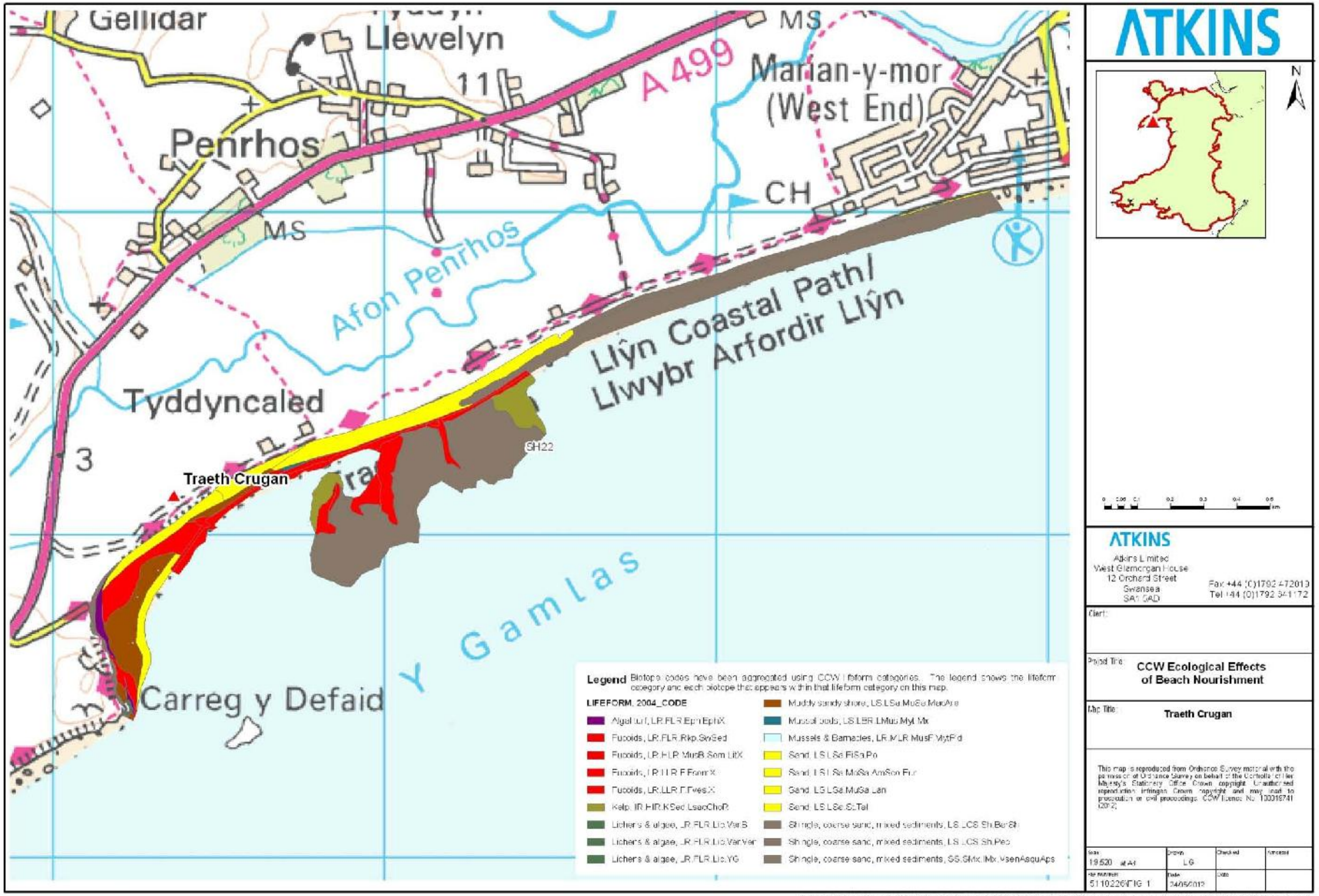
Checked
Approved
Fig number 5110226\FIG 1
Date 24/05/2012
Date



Gellidar
Llewelyn
Penrhos
Marian-y-mor
(West End)
A 499
MS
CH
Afon Penrhos
Llŷn Coastal Path/
Llwybr Arfordir Llŷn
Tyddyncaled
Traeth Crugan
SH22
Y Gamlas
Carreg y Defaid
Legend Biotope codes have been aggregated using CCW lifeform categories. The legend shows the lifeform category and each biotope that appears within that lifeform category on this map.
LIFEFORM_2004_CODE
Algal turf, LR.FLR.Eph.EphX
Fucoids, LR.FLR.Rkp.SwSed
Fucoids, LR.HLR.MusB.Sem.LitX
Fucoids, LR.LLR.F.Fserr.X
Fucoids, LR.LLR.F.Fves.X
Kelp, IR.HIR.KSed.LsacChoR
Lichens & algae, LR.FLR.Lic.Ver.B
Lichens & algae, LR.FLR.Lic.Ver.Ver
Lichens & algae, LR.FLR.Lic.YG
Muddy sandy shore, LS.LSa.MuSa.MacAre
Mussel beds, LS.LBR.LMus.Myt.Mx
Mussels & Barnacles, LR.MLR.MusF.MytFR
Sand, LS.LSa.FiSa.Po
Sand, LS.LSa.MuSa.AmSon.Fur
Sand, LS.LSa.MuSa.Lan
Sand, LS.LSa.St.Tal
Shingle, coarse sand, mixed sediments, LS.LCS.Sh.BarSh
Shingle, coarse sand, mixed sediments, LS.LCS.Sh.Pec
Shingle, coarse sand, mixed sediments, SS.SMx.IMx.VsenAsquAps
ATKINS
N
0 0.05 0.1 0.2 0.3 0.4 0.5 km
ATKINS
Atkins Limited
West Glamorgan House
12 Orchard Street
Swansea
SA1 5AD
Fax +44 (0)1792 472019
Tel +44 (0)1792 641172
Client:
Project Title: CCW Ecological Effects of Beach Nourishment
Map Title: Traeth Crugan
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Approved
Ref Number 5110226\FIG 1
Date 24/05/2012
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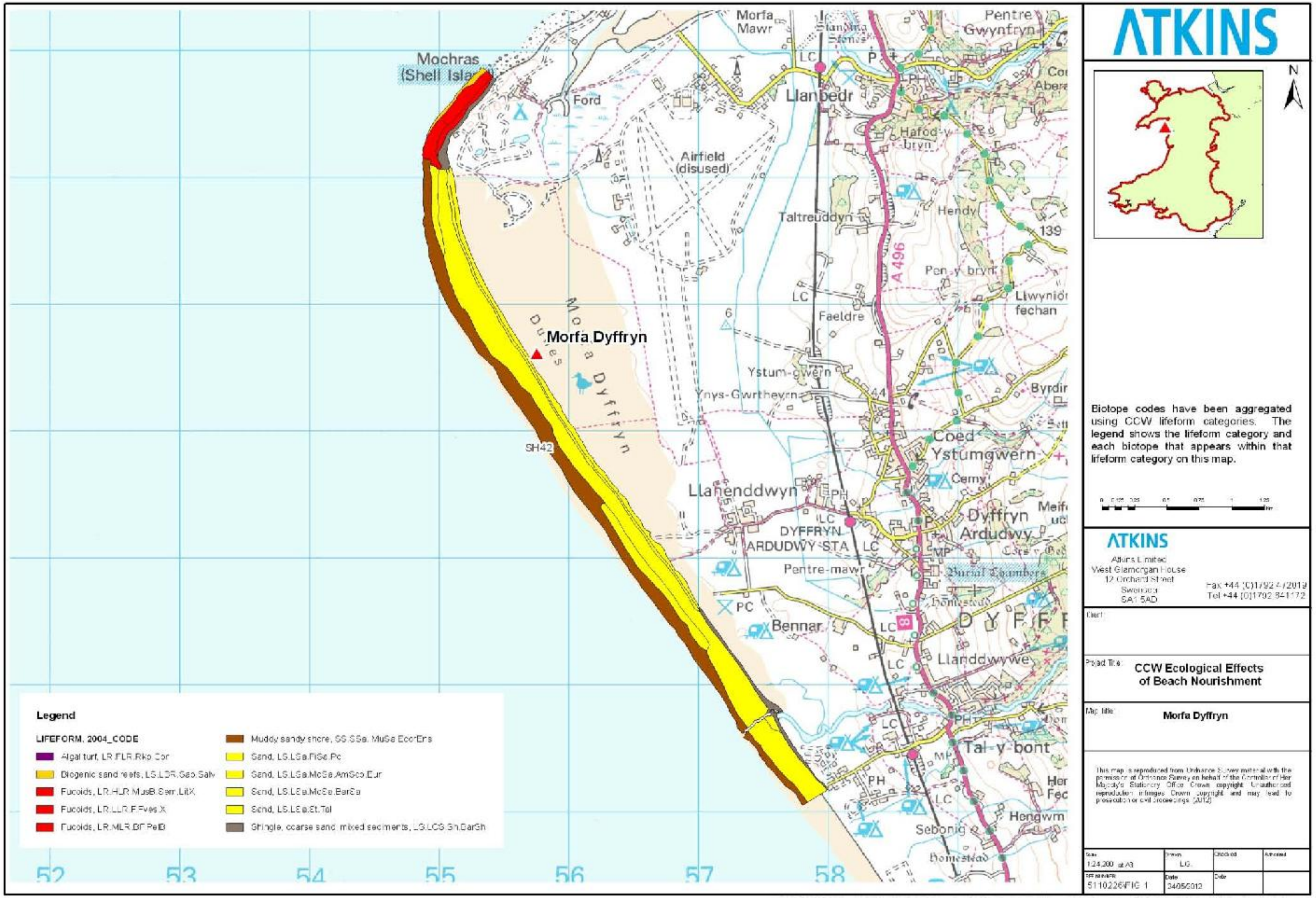

Mochras (Shell Island)
Morfa Dyffryn
Legend
LIFEFORM, 2004_CODE
Algal turf, LR.FLR.Rkp.Cor
Biogenic sand reefs, LS.LBR.Sab.Salv
Fucoids, LR.HLR.MusB.Sem.LitX
Fucoids, LR.LLR.F.Fves.X
Fucoids, LR.MLR.BF.PelB
Muddy sandy shore, SS.SSa.MuSa.EcorEns
Sand, LS.LSa.FiSa.Po
Sand, LS.LSa.MoSa.AmSco.Eur
Sand, LS.LSa.MoSa.BarSa
Sand, LS.LSa.St.Tal
Shingle, coarse sand mixed sediments, LS.LCS.Sh.BarSh
ATKINS
Biotope codes have been aggregated using CCW lifeform categories. The legend shows the lifeform category and each biotope that appears within that lifeform category on this map.
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Atkins Limited
West Glamorgan House
12 Orchard Street
Swansea
SA1 5AD
Client:
Project Title:
CCW Ecological Effects of Beach Nourishment
Map title:
Morfa Dyffryn
Scale
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Drawn
LG
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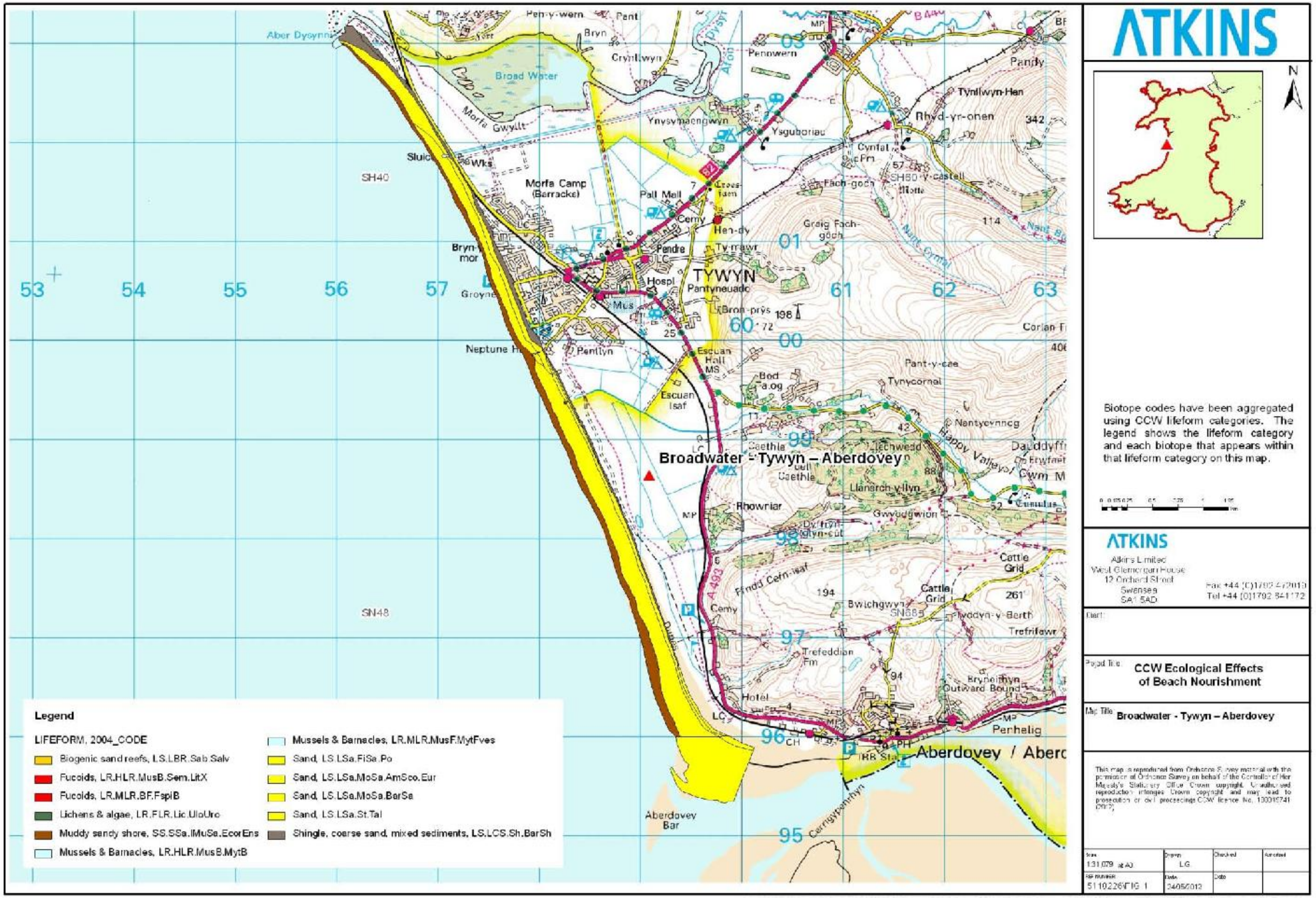
Authorised
Date
24/05/2012
Date
5110226/FIG 1


ATKINS
Broadwater - Tywyn – Aberdovey
TYWYN
Aberdovey / Aberd
Broad Water
Morfa Gwyllt
Morfa Camp (Barracks)
Aber Dysynni
Aberdovey Bar
SH40
SN48
53
54
55
56
57
61
62
63
Legend
LIFEFORM, 2004_CODE
Biogenic sand reefs, LS.LBR.Sab.Salv
Fucoids, LR.HLR.MusB.Sem.LitX
Fucoids, LR.MLR.BF.FspiB
Lichens & algae, LR.FLR.Lic.UloUro
Muddy sandy shore, SS.SSa.IMuSa.EcorEns
Mussels & Barnacles, LR.HLR.MusB.MytB
Mussels & Barnacles, LR.MLR.MusF.MytFves
Sand, LS.LSa.FiSa.Po
Sand, LS.LSa.MoSa.AmSco.Eur
Sand, LS.LSa.MoSa.BarSa
Sand, LS.LSa.St.Tal
Shingle, coarse sand, mixed sediments, LS.LCS.Sh.BarSh
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ATKINS
Atkins Limited
West Glamorgan House
12 Orchard Street
Swansea
SA1 5AD
Client:
Project Title: CCW Ecological Effects of Beach Nourishment
Map Title: Broadwater - Tywyn – Aberdovey
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Checked
Authorised
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Date 24/05/2012
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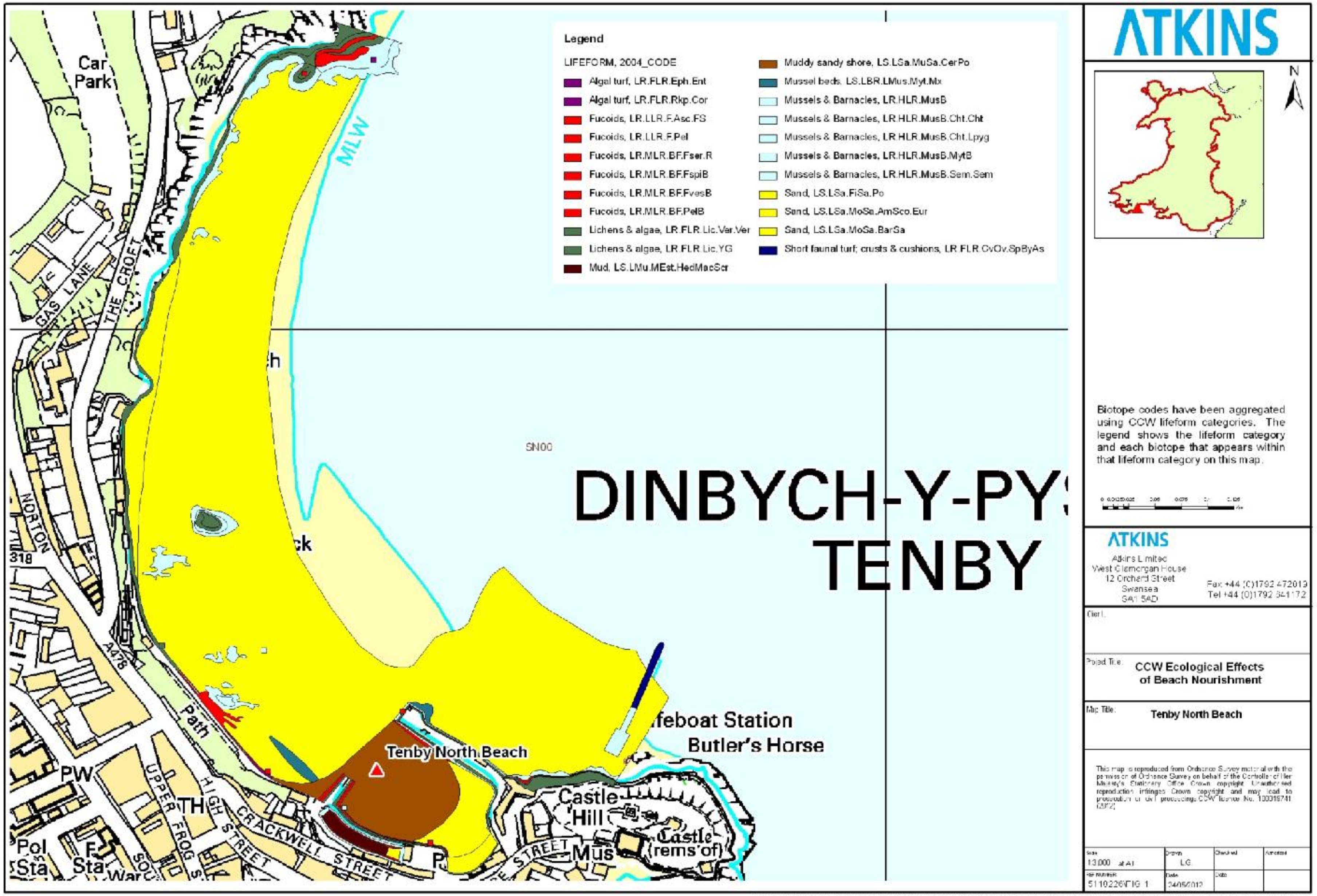
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Algal turf, LR.FLR.Rkp.Cor
Fucoids, LR.LLR.F.Asc.FS
Fucoids, LR.LLR.F.Pel
Fucoids, LR.MLR.BF.Fser.R
Fucoids, LR.MLR.BF.FspiB
Fucoids, LR.MLR.BF.FvesB
Fucoids, LR.MLR.BF.PelB
Lichens & algae, LR.FLR.Lic.Ver.Ver
Lichens & algae, LR.FLR.Lic.YG
Mud, LS.LMu.MEst.HedMacScr
Muddy sandy shore, LS.LSa.MuSa.CerPo
Mussel beds, LS.LBR.LMus.Myt.Mx
Mussels & Barnacles, LR.HLR.MusB
Mussels & Barnacles, LR.HLR.MusB.Cht.Cht
Mussels & Barnacles, LR.HLR.MusB.Cht.Lpyg
Mussels & Barnacles, LR.HLR.MusB.MytB
Mussels & Barnacles, LR.HLR.MusB.Sem.Sem
Sand, LS.LSa.FiSa.Po
Sand, LS.LSa.MoSa.AmSco.Eur
Sand, LS.LSa.MoSa.BarSa
Short faunal turf; crusts & cushions, LR.FLR.CvOv.SpByAs
Car Park
MLW
GAS LANE
THE CROFT
NORTON
A478
Path
SN00
DINBYCH-Y-PYS
TENBY
Tenby North Beach
Lifeboat Station
Butler's Horse
Castle Hill
Castle (rems of)
Mus
UPPER FROG
HIGH STREET
CRACKWELL STREET
ATKINS
N
Biotope codes have been aggregated using CCW lifeform categories. The legend shows the lifeform category and each biotope that appears within that lifeform category on this map.
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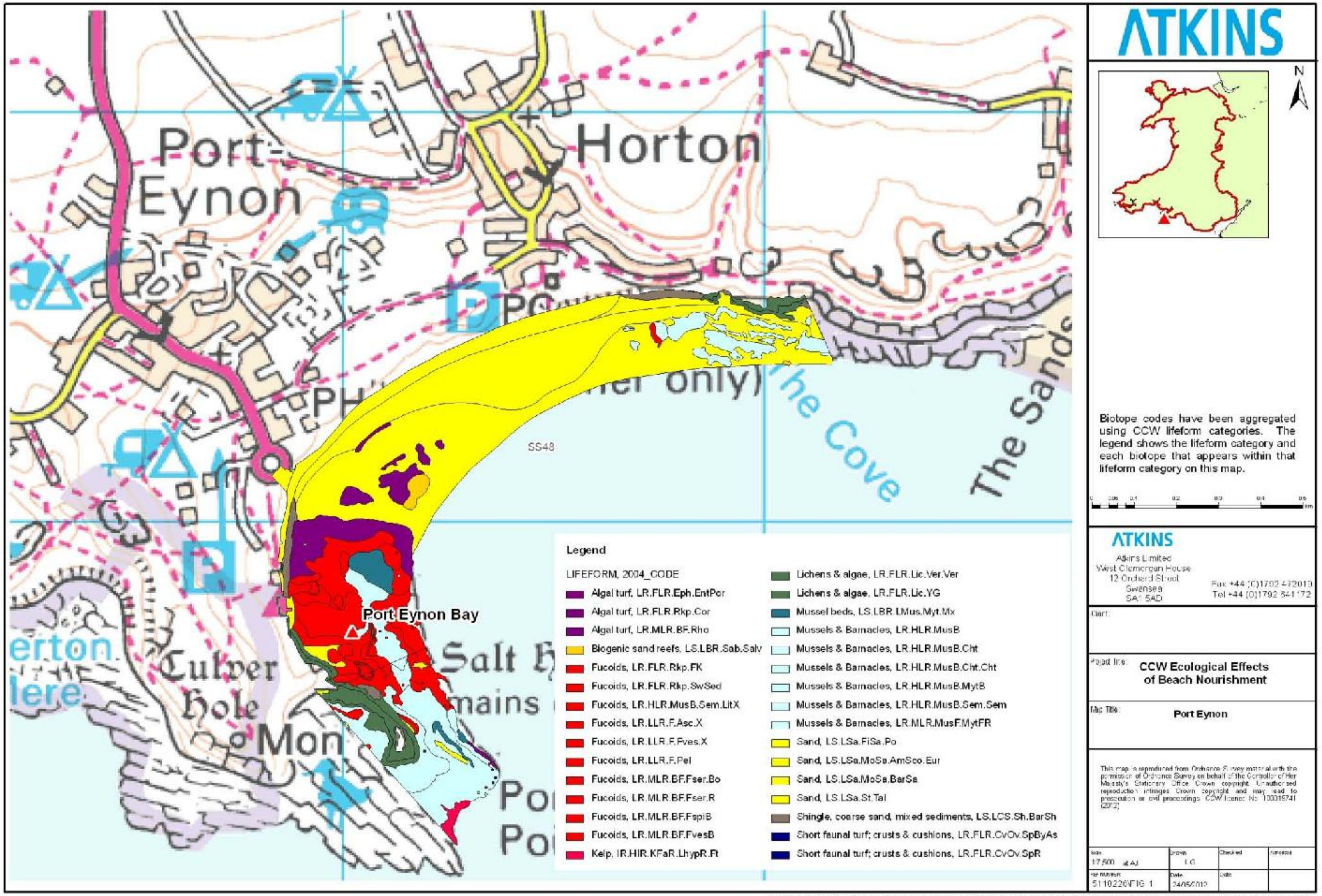

Port Eynon
Horton
The Cove
The Sands
SS48
Port Eynon Bay
Culver Hole
Legend
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Algal turf, LR.FLR.Rkp.Cor
Algal turf, LR.MLR.BF.Rho
Biogenic sand reefs, LS.LBR.Sab.Salv
Fucoids, LR.FLR.Rkp.FK
Fucoids, LR.FLR.Rkp.SwSed
Fucoids, LR.HLR.MusB.Sem.LitX
Fucoids, LR.LLR.F.Asc.X
Fucoids, LR.LLR.F.Fves.X
Fucoids, LR.LLR.F.Pel
Fucoids, LR.MLR.BF.Fser.Bo
Fucoids, LR.MLR.BF.Fser.R
Fucoids, LR.MLR.BF.FspiB
Fucoids, LR.MLR.BF.FvesB
Kelp, IR.HIR.KFaR.LhypR.Ft
Lichens & algae, LR.FLR.Lic.Ver.Ver
Lichens & algae, LR.FLR.Lic.YG
Mussel beds, LS.LBR.LMus.Myt.Mx
Mussels & Barnacles, LR.HLR.MusB
Mussels & Barnacles, LR.HLR.MusB.Cht
Mussels & Barnacles, LR.HLR.MusB.Cht.Cht
Mussels & Barnacles, LR.HLR.MusB.MytB
Mussels & Barnacles, LR.HLR.MusB.Sem.Sem
Mussels & Barnacles, LR.MLR.MusF.MytFR
Sand, LS.LSa.FiSa.Po
Sand, LS.LSa.MoSa.AmSco.Eur
Sand, LS.LSa.MoSa.BarSa
Sand, LS.LSa.St.Tal
Shingle, coarse sand, mixed sediments, LS.LCS.Sh.BarSh
Short faunal turf; crusts & cushions, LR.FLR.CvOv.SpByAs
Short faunal turf; crusts & cushions, LR.FLR.CvOv.SpR
ATKINS
N
Biotope codes have been aggregated using CCW lifeform categories. The legend shows the lifeform category and each biotope that appears within that lifeform category on this map.
0 0.05 0.1 0.2 0.3 0.4 0.5 km
ATKINS
Atkins Limited
West Glamorgan House
12 Orchard Street
Swansea
SA1 5AD
Fax +44 (0)1792 472019
Tel +44 (0)1792 841172
Client:
Project title:
CCW Ecological Effects of Beach Nourishment
Map Title:
Port Eynon
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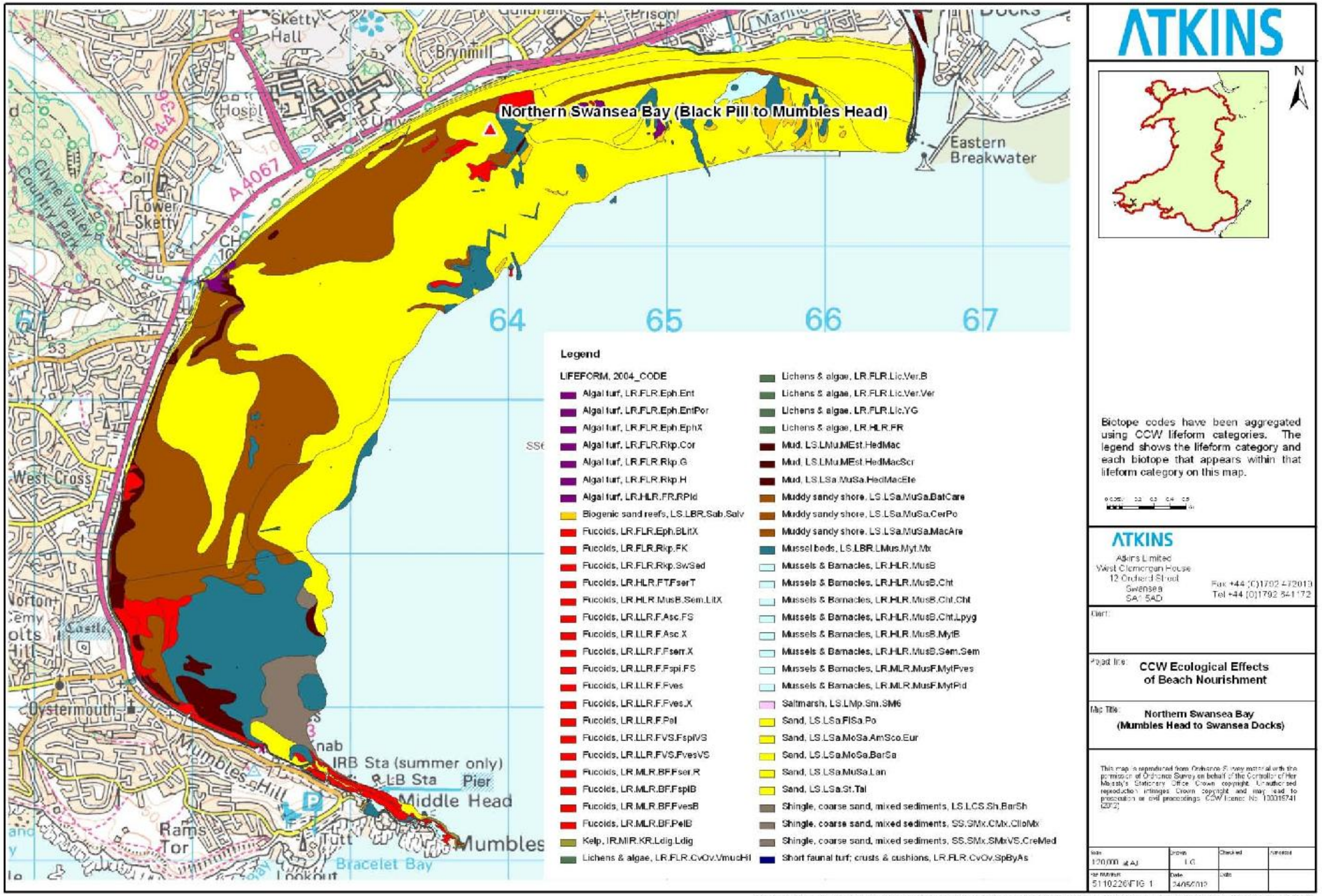

Northern Swansea Bay (Black Pill to Mumbles Head)
Eastern Breakwater
64
65
66
67
Legend
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Algal turf, LR.FLR.Eph.EntPor
Algal turf, LR.FLR.Eph.EphX
Algal turf, LR.FLR.Rkp.Cor
Algal turf, LR.FLR.Rkp.G
Algal turf, LR.FLR.Rkp.H
Algal turf, LR.HLR.FR.RPid
Biogenic sand reefs, LS.LBR.Sab.Salv
Fucoids, LR.FLR.Eph.BLitX
Fucoids, LR.FLR.Rkp.FK
Fucoids, LR.FLR.Rkp.SwSed
Fucoids, LR.HLR.FT.FserT
Fucoids, LR.HLR.MusB.Sem.LitX
Fucoids, LR.LLR.F.Asc.FS
Fucoids, LR.LLR.F.Asc.X
Fucoids, LR.LLR.F.Fserr.X
Fucoids, LR.LLR.F.Fspi.FS
Fucoids, LR.LLR.F.Fves
Fucoids, LR.LLR.F.Fves.X
Fucoids, LR.LLR.F.Pel
Fucoids, LR.LLR.FVS.FspiVS
Fucoids, LR.LLR.FVS.FvesVS
Fucoids, LR.MLR.BF.Fser.R
Fucoids, LR.MLR.BF.FspiB
Fucoids, LR.MLR.BF.FvesB
Fucoids, LR.MLR.BF.PelB
Kelp, IR.MIR.KR.Ldig.Ldig
Lichens & algae, LR.FLR.CvOv.VmucHil
Lichens & algae, LR.FLR.Lic.Ver.B
Lichens & algae, LR.FLR.Lic.Ver.Ver
Lichens & algae, LR.FLR.Lic.YG
Lichens & algae, LR.HLR.FR
Mud, LS.LMu.MEst.HedMac
Mud, LS.LMu.MEst.HedMacScr
Mud, LS.LSa.MuSa.HedMacEte
Muddy sandy shore, LS.LSa.MuSa.BatCare
Muddy sandy shore, LS.LSa.MuSa.CerPo
Muddy sandy shore, LS.LSa.MuSa.MacAre
Mussel beds, LS.LBR.LMus.Myt.Mx
Mussels & Barnacles, LR.HLR.MusB
Mussels & Barnacles, LR.HLR.MusB.Cht
Mussels & Barnacles, LR.HLR.MusB.Cht.Cht
Mussels & Barnacles, LR.HLR.MusB.Cht.Lpyg
Mussels & Barnacles, LR.HLR.MusB.MytB
Mussels & Barnacles, LR.HLR.MusB.Sem.Sem
Mussels & Barnacles, LR.MLR.MusF.MytFves
Mussels & Barnacles, LR.MLR.MusF.MytPid
Saltmarsh, LS.LMp.Sm.SM6
Sand, LS.LSa.FiSa.Po
Sand, LS.LSa.MoSa.AmSco.Eur
Sand, LS.LSa.MoSa.BarSa
Sand, LS.LSa.MuSa.Lan
Sand, LS.LSa.St.Tal
Shingle, coarse sand, mixed sediments, LS.LCS.Sh.BarSh
Shingle, coarse sand, mixed sediments, SS.SMx.CMx.ClloMx
Shingle, coarse sand, mixed sediments, SS.SMx.SMxVS.CreMed
Short faunal turf; crusts & cushions, LR.FLR.CvOv.SpByAs
ATKINS
Biotope codes have been aggregated using CCW lifeform categories. The legend shows the lifeform category and each biotope that appears within that lifeform category on this map.
ATKINS
Atkins Limited
West Glamorgan House
12 Orchard Street
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SA1 5AD
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Client:
Project title:
CCW Ecological Effects of Beach Nourishment
Map Title:
Northern Swansea Bay (Mumbles Head to Swansea Docks)
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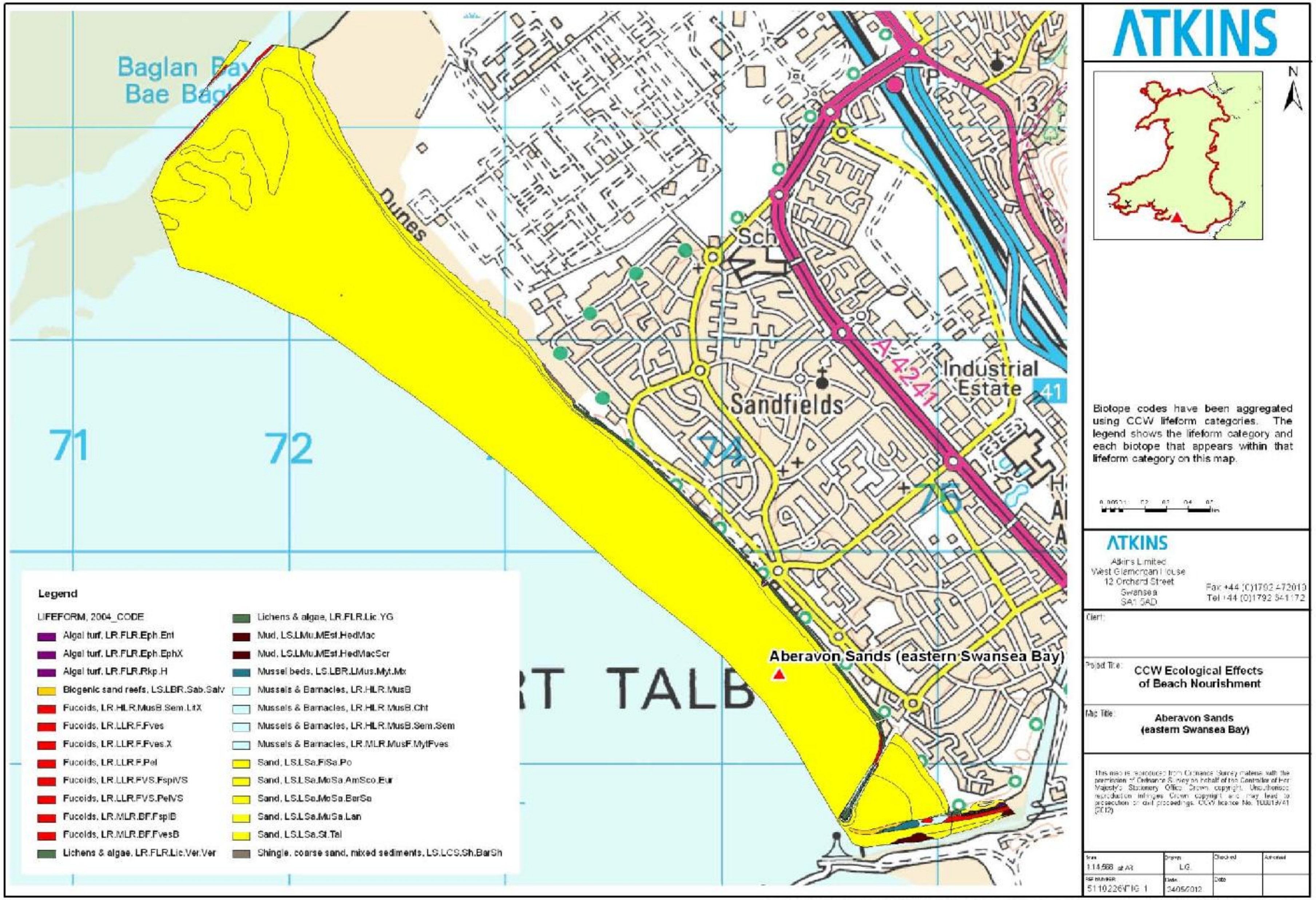
Scale
1:20,000 at A3
Drawn
LG
Checked
Approved
Number
5110226\FIG 1
Date
24/05/2012
Date



ATKINS
Baglan Bay
Bae Bag
Dunes
Sch
Sandfields
A4241
Industrial Estate
41
71
72
74
75
Aberavon Sands (eastern Swansea Bay)
RT TALB
Legend
LIFEFORM, 2004_CODE
Algal turf, LR.FLR.Eph.Ent
Algal turf, LR.FLR.Eph.EphX
Algal turf, LR.FLR.Rkp.H
Biogenic sand reefs, LS.LBR.Sab.Salv
Fucoids, LR.HLR.MusB.Sem.LitX
Fucoids, LR.LLR.F.Fves
Fucoids, LR.LLR.F.Fves.X
Fucoids, LR.LLR.F.Pel
Fucoids, LR.LLR.FVS.FspiVS
Fucoids, LR.LLR.FVS.PelVS
Fucoids, LR.MLR.BF.FspiB
Fucoids, LR.MLR.BF.FvesB
Lichens & algae, LR.FLR.Lic.Ver.Ver
Lichens & algae, LR.FLR.Lic.YG
Mud, LS.LMu.MEst.HedMac
Mud, LS.LMu.MEst.HedMacScr
Mussel beds, LS.LBR.LMus.Myt.Mx
Mussels & Barnacles, LR.HLR.MusB
Mussels & Barnacles, LR.HLR.MusB.Cht
Mussels & Barnacles, LR.HLR.MusB.Sem.Sem
Mussels & Barnacles, LR.MLR.MusF.MytFves
Sand, LS.LSa.FiSa.Po
Sand, LS.LSa.MoSa.AmSco.Eur
Sand, LS.LSa.MoSa.BarSa
Sand, LS.LSa.MuSa.Lan
Sand, LS.LSa.St.Tal
Shingle, coarse sand, mixed sediments, LS.LCS.Sh.BarSh
Biotope codes have been aggregated using CCW lifeform categories. The legend shows the lifeform category and each biotope that appears within that lifeform category on this map.
ATKINS
Atkins Limited
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Client:
Project Title:
CCW Ecological Effects
of Beach Nourishment
Map Title:
Aberavon Sands
(eastern Swansea Bay)
Scale
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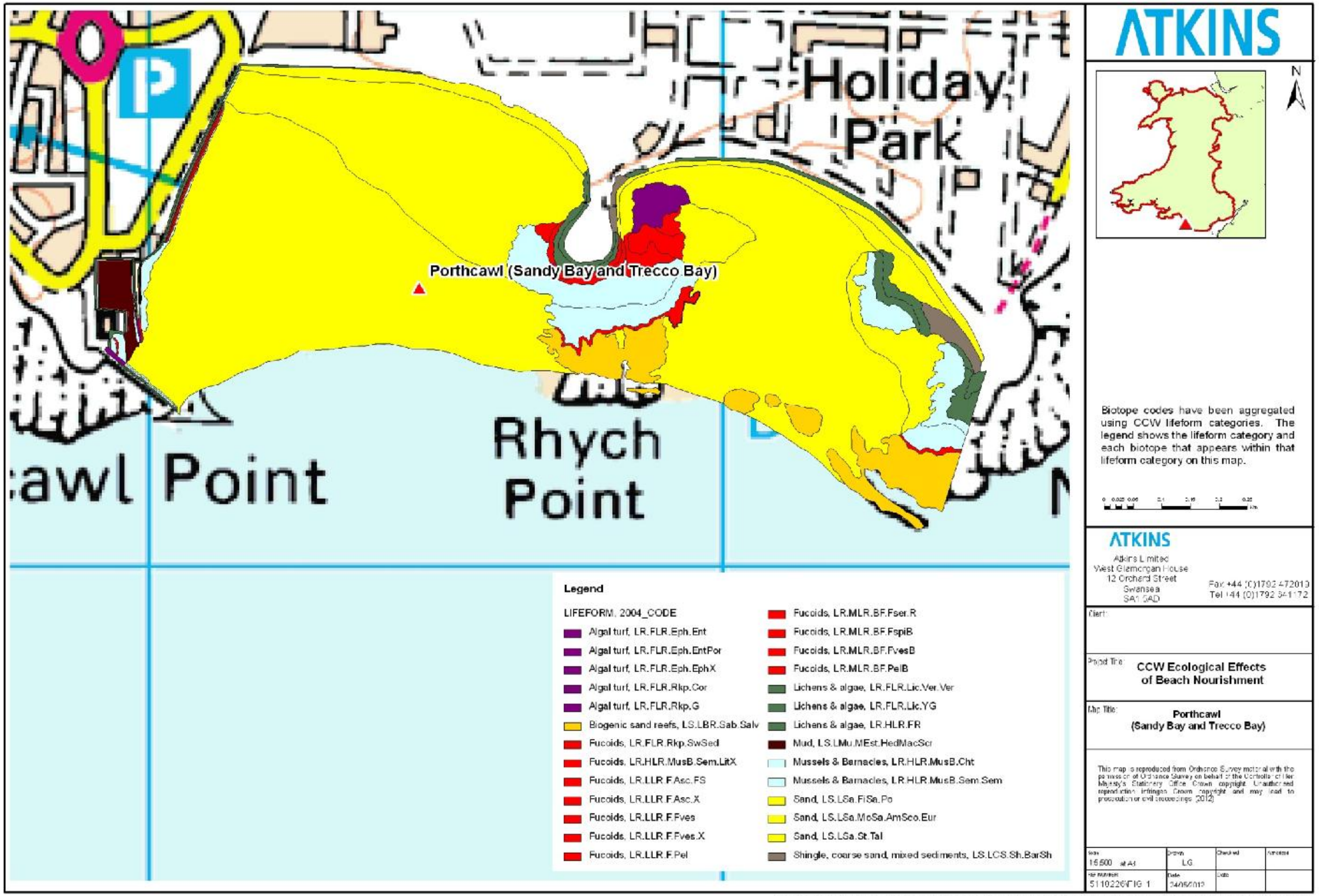
Drawn
LG
Checked
Authorised
REF NUMBER
5110226/FIG 1
Date
24/05/2012
Date


Holiday Park
Porthcawl (Sandy Bay and Trecco Bay)
Rhych Point
Point
Legend
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Algal turf, LR.FLR.Eph.EntPor
Algal turf, LR.FLR.Eph.EphX
Algal turf, LR.FLR.Rkp.Cor
Algal turf, LR.FLR.Rkp.G
Biogenic sand reefs, LS.LBR.Sab.Salv
Fucoids, LR.FLR.Rkp.SwSed
Fucoids, LR.HLR.MusB.Sem.LitX
Fucoids, LR.LLR.F.Asc.FS
Fucoids, LR.LLR.F.Asc.X
Fucoids, LR.LLR.F.Fves
Fucoids, LR.LLR.F.Fves.X
Fucoids, LR.LLR.F.Pel
Fucoids, LR.MLR.BF.Fser.R
Fucoids, LR.MLR.BF.FspiB
Fucoids, LR.MLR.BF.FvesB
Fucoids, LR.MLR.BF.PelB
Lichens & algae, LR.FLR.Lic.Ver.Ver
Lichens & algae, LR.FLR.Lic.YG
Lichens & algae, LR.HLR.FR
Mud, LS.LMu.MEst.HedMacScr
Mussels & Barnacles, LR.HLR.MusB.Cht
Mussels & Barnacles, LR.HLR.MusB.Sem.Sem
Sand, LS.LSa.FiSa.Po
Sand, LS.LSa.MoSa.AmSco.Eur
Sand, LS.LSa.St.Tal
Shingle, coarse sand, mixed sediments, LS.LCS.Sh.BarSh
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N
Biotope codes have been aggregated using CCW lifeform categories. The legend shows the lifeform category and each biotope that appears within that lifeform category on this map.
ATKINS
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Client:
Project Title:
CCW Ecological Effects of Beach Nourishment
Map Title:
Porthcawl (Sandy Bay and Trecco Bay)
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Approved
File Number
5110226\FIG 1
Date
24/05/2012
Date

APPENDIX 2: DIFFERENT BIOTOPES IDENTIFIED ON THE 10 CASE STUDY BEACHES

Biotope code	**Description**
IR.HIR.KFaR.LhypR.Ft	*Laminaria hyperborea* forest with dense foliose red seaweeds on exposed upper infralittoral rock
IR.HIR.KSed.LsacChoR	*Laminaria saccharina*, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles
IR.MIR.KR.Ldig.Ldig	*Laminaria digitata* on moderately exposed sublittoral fringe bedrock
LR.FLR.CvOv.SpByAs	Sponges, bryozoans and ascidians on deeply overhanging lower shore bedrock or caves
LR.FLR.CvOv.VmucHil	*Verrucaria mucosa* and/or *Hildenbrandia rubra* on upper to mid shore cave walls
LR.FLR.Eph.BLitX	Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata
LR.FLR.Eph.Ent	*Enteromorpha* spp. on freshwater-influenced and/or unstable upper eulittoral rock
LR.FLR.Eph.EntPor	*Porphyra purpurea* and *Enteromorpha* spp. on sand-scoured mid or lower eulittoral rock
LR.FLR.Eph.EphX	Ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata
LR.FLR.Lic.UloUro	*Ulothrix flacca* and *Urospora* spp. on freshwater-influenced vertical littoral fringe soft rock
LR.FLR.Lic.Ver.B	*Verrucaria maura* and sparse barnacles on exposed littoral fringe rock
LR.FLR.Lic.Ver.Ver	*Verrucaria maura* on very exposed to very sheltered upper littoral fringe rock
LR.FLR.Lic.YG	Yellow and grey lichens on supralittoral rock
LR.FLR.Rkp.Cor	Coralline crust-dominated shallow eulittoral rockpools
LR.FLR.Rkp.FK	Fucoids and kelp in deep eulittoral rockpools
LR.FLR.Rkp.G	Green seaweeds (*Enteromorpha* spp. and *Cladophora* spp.) in shallow upper shore rockpools
LR.FLR.Rkp.H	Hydroids, ephemeral seaweeds and *Littorina littorea* in shallow eulittoral mixed substrata pools
LR.FLR.Rkp.SwSed	Seaweeds in sediment-floored eulittoral rockpools
LR.HLR.FR	Robust fucoid and/or red seaweed communities
LR.HLR.FR.RPid	*Ceramium* sp. and piddocks on eulittoral fossilised peat
LR.HLR.FT.FserT	*Fucus serratus*, sponges and ascidians on tide-swept lower eulittoral rock
LR.HLR.MusB	Mussel and/or barnacle communities
LR.HLR.MusB.Cht	*Chthamalus* spp. on exposed eulittoral rock
LR.HLR.MusB.Cht.Cht	*Chthamalus* spp. on exposed upper eulittoral rock
LR.HLR.MusB.Cht.Lpyg	*Chthamalus* spp. and *Lichina pygmaea* on steep exposed upper eulittoral rock
LR.HLR.MusB.MytB	*Mytilus edulis* and barnacles on very exposed eulittoral rock
LR.HLR.MusB.Sem.LitX	*Semibalanus balanoides* and *Littorina* spp. on exposed to moderately exposed eulittoral boulders and cobbles
LR.HLR.MusB.Sem.Sem	*Semibalanus balanoides, Patella vulgata* and *Littorina* spp.on exposed to moderately exposed or vertical sheltered eulittoral rock
LR.LLR.F.Asc.FS	*Ascophyllum nodosum* on full salinity mid eulittoral rock
LR.LLR.F.Asc.X	*Ascophyllum nodosum* on full salinity mid eulittoral mixed substrata
LR.LLR.F.Fserr.X	*Fucus serratus* on full salinity lower eulittoral mixed substrata
LR.LLR.F.Fspi.FS	*Fucus spiralis* on full salinity sheltered upper eulittoral rock
LR.LLR.F.Fves	*Fucus vesiculosus* on moderately exposed to sheltered mid eulittoral rock
LR.LLR.F.Fves.X	*Fucus vesiculosus* on mid eulittoral mixed substrata
LR.LLR.F.Pel	*Pelvetia canaliculata* on sheltered littoral fringe rock
LR.LLR.FVS.FspiVS	*Fucus spiralis* on sheltered variable salinity upper eulittoral rock
LR.LLR.FVS.FvesVS	*Fucus vesiculosus* on variable salinity mid eulittoral boulders and stable mixed substrata
LR.LLR.FVS.PelVS	*Pelvetia canaliculata* on sheltered variable salinity littoral fringe rock
LR.MLR.BF.Fser.Bo	*Fucus serratus* and under-boulder fauna on exposed to moderately exposed lower eulittoral boulders
LR.MLR.BF.Fser.R	*Fucus serratus* and red seaweeds on moderately exposed lower eulittoral rock

Biotope code	Description
LR.MLR.BF.FspiB	*Fucus spiralis* on exposed to moderately exposed upper eulittoral rock
LR.MLR.BF.FvesB	*Fucus vesiculosus* and barnacle mosaics on moderately exposed mid eulittoral rock
LR.MLR.BF.PelB	*Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock
LR.MLR.BF.Rho	*Rhodothamniella floridula* on sand-scoured lower eulittoral rock
LR.MLR.MusF.MytFR	*Mytilus edulis*, *Fucus serratus* and red seaweeds on moderately exposed lower eulittoral rock
LR.MLR.MusF.MytFves	*Mytilus edulis* and *Fucus vesiculosus* on moderately exposed mid eulittoral rock
LR.MLR.MusF.MytPid	*Mytilus edulis* and piddocks on eulittoral firm clay
LS.LBR.LMus.Myt.Mx	*Mytilus edulis* beds on littoral mixed substrata
LS.LBR.Sab.Salv	*Sabellaria alveolata* reefs on sand-abraded eulittoral rock
LS.LCS.Sh.BarSh	Barren littoral shingle
LS.LCS.Sh.Pec	*Pectenogammarus planicrurus* in mid shore well-sorted gravel or coarse sand
LS.LMp.Sm	Saltmarsh
LS.LMu	Littoral mud
LS.LMu.MEst.HedMac	*Hediste diversicolor* and *Macoma balthica* in littoral sandy mud
LS.LMu.MEst.HedMacScr	*Hediste diversicolor*, *Macoma balthica* and *Scrobicularia plana* in littoral sandy mud shores
LS.LSa.FiSa.Po	Polychaetes in littoral fine sand
LS.LSa.FiSa.Po.Aten	Polychaetes and *Angulus tenuis* in littoral fine sand
LS.LSa.MoSa.AmSco.Eur	*Eurydice pulchra* in littoral mobile sand
LS.LSa.MoSa.BarSa	Barren littoral coarse sand
LS.LSa.MuSa.BatCare	*Bathyporeia pilosa* and *Corophium arenarium* in littoral muddy sand
LS.LSa.MuSa.CerPo	*Cerastoderma edule* and polychaetes in littoral muddy sand
LS.LSa.MuSa.HedMacEte	*Hediste diversicolor*, *Macoma balthica* and *Eteone longa* in littoral muddy sand
LS.LSa.MuSa.Lan	*Lanice conchilega* in littoral sand
LS.LSa.MuSa.MacAre	*Macoma balthica* and *Arenicola marina* in littoral muddy sand
LS.LSa.St.Tal	Talitrids on the upper shore and strand-line
SS.SMx.IMx.VsenAsquAps	*Venerupis senegalensis*, *Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment
SS.SMx.SMxVS.CreMed	*Crepidula fornicata* and *Mediomastus fragilis* in variable salinity infralittoral mixed sediment
SS.SSa.IMuSa.EcorEns	*Echinocardium cordatum* and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand

APPENDIX 3: MARLIN DEFINITIONS OF LEVEL OF SENSITIVITY

The sensitivity levels and definitions are taken from the MarLIN sensitivity assessment. More information on the assessment rationale and definitions are available on the MarLIN website at http://www.marlin.ac.uk/sensitivityrationale.php#table1

Defining 'sensitivity' sensu lato for habitats and species. (**) 'Reduced viability' includes physiological stress, reduced fecundity, reduced growth, and partial death of a colonial animal or plant.

Where there is insufficient information to assess the recoverability of a habitat or species (insufficient information) the precautionary principle will be used and the recovery will be assumed to take a very long time i.e. low recoverability in the derivation of a sensitivity rank.

Rank	Definition
Very High	"Very high" sensitivity is indicated by the following scenario: o The habitat or species is very adversely affected by an external factor arising from human activities or natural events (either killed/destroyed, "high" intolerance) and is expected to recover only over a prolonged period of time, i.e. >25 years or not at all (recoverability is "very low" or "none"). o The habitat or species is adversely affected by an external factor arising from human activities or natural events (damaged, "intermediate" intolerance) but is not expected to recover at all (recoverability is "none").
High	"High" sensitivity is indicated by the following scenarios: o The habitat or species is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, "high" intolerance) and is expected to recover over a very long period of time, i.e. >10 or up to 25 years ("low" recoverability). o The habitat or species is adversely affected by an external factor arising from human activities or natural events (damaged, "intermediate" intolerance) and is expected to recover over a very long period of time, i.e. >10 years (recoverability is "low", or "very low"). o The habitat or species is affected by an external factor arising from human activities or natural events (reduced viability **, "low" intolerance) but is not expected to recover at all (recoverability is "none"), so that the habitat or species may be vulnerable to subsequent damage.
Moderate	"Moderate" sensitivity is indicated by the following scenarios: o The habitat or species is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, "high" intolerance) but is expected to take more than 1 year or up to 10 years to recover ("moderate" or "high" recoverability). o The habitat or species is adversely affected by an external factor arising from human activities or natural events (damaged, "intermediate" intolerance) and is expected to recover over a long period of time, i.e. >5 or up to 10 years ("moderate" recoverability). o The habitat or species is affected by an external factor arising from human activities or natural events (reduced viability **, "low" intolerance) but is expected to recover over a very long period of time, i.e. >10 years (recoverability is "low", "very low"), during which time the habitat or species may be vulnerable to subsequent damage.

Rank	Definition
Low	"Low" sensitivity is indicated by the following scenarios: o The habitat or species is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, "high" intolerance) but is expected to recover rapidly, i.e. within 1 year ("very high" recoverability). o The habitat or species is adversely affected by an external factor arising from human activities or natural events (damaged, "intermediate" intolerance) but is expected to recover in a short period of time, i.e. within 1 year or up to 5 years ("very high" or "high" recoverability). o The habitat or species is affected by an external factor arising from human activities or natural events (reduced viability **, "low" intolerance) but is expected to take more than 1 year or up to 10 years to recover ("moderate" or "high" recoverability).
Very low	"Very low" is indicated by the following scenarios: o The habitat or species is very adversely affected by an external factor arising from human activities or natural events (killed/destroyed, "high" intolerance) but is expected to recover rapidly i.e. within a week ("immediate" recoverability). o The habitat or species is adversely affected by an external factor arising from human activities or natural events (damaged, "intermediate" intolerance) but is expected to recover rapidly, i.e. within a week ("immediate" recoverability). o The habitat or species is affected by an external factor arising from human activities or natural events (reduced viability **, "low" intolerance) but is expected to recover within a year ("very high" recoverability).
Not sensitive	"Not sensitive" is indicated by the following scenarios: o The habitat or species is affected by an external factor arising from human activities or natural events (reduced viability **, "low" intolerance) but is expected to recover rapidly, i.e. within a week ("immediate" recoverability). o The habitat or species is tolerant of changes in the external factor.
Not sensitive*	The habitat or species may benefit from the change in an external factor (intolerance has been assessed as "tolerant*").
Not relevant	The habitat or species is protected from changes in an external factor (i.e. through a burrowing habit or depth), or is able to avoid the external factor.
Insufficient information	

APPENDIX 4: DATA ARCHIVE APPENDIX

Data outputs associated with this project are archived as Project No. 354 and Media No. 1333 on server–based storage at the Countryside Council for Wales.

Data outputs relate only to the GIS layer that determines the intertidal area on each of the 10 case study beaches within which biotopes were identified (see maps in ***Appendix 1***). These maps were produced using GIS data obtained from CCW on 07/02/2012 under a Data Loan Agreement for this project. The following data sets were made available:

Data set	Copyright owner
Phase 1 intertidal dataset (biotopes & Target Notes)	CCW

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'. The metadata is held as record no 114892.