Impacts of Bait Digging on the Gann: An Evidence Review

Sean Evans, James Moon, Anne Bunker and Matthew Green

Natural Resources Wales

Evidence Report No 81

About Natural Resources Wales

Natural Resources Wales is the organisation responsible for the work carried out by the three former organisations, the Countryside Council for Wales, Environment Agency Wales and Forestry Commission Wales. It is also responsible for some functions previously undertaken by Welsh Government.

Our purpose is to ensure that the natural resources of Wales are sustainably maintained, used and enhanced, now and in the future.

We work for the communities of Wales to protect people and their homes as much as possible from environmental incidents like flooding and pollution. We provide opportunities for people to learn, use and benefit from Wales' natural resources.

We work to support Wales' economy by enabling the sustainable use of natural resources to support jobs and enterprise. We help businesses and developers to understand and consider environmental limits when they make important decisions.

We work to maintain and improve the quality of the environment for everyone and we work towards making the environment and our natural resources more resilient to climate change and other pressures.

Published by: Natural Resources Wales
Maes y Ffynnon
Penrhosgarnedd
Bangor
LL57 2DW

01248 387220

© Natural Resources Wales 2015

All rights reserved. This document may be reproduced with prior permission of Natural Resources Wales

Further copies of this report are available from the library

Email: library@cyfoethnaturiolcymru.gov.uk

Evidence at Natural Resources Wales

Natural Resources Wales is an evidence based organisation. We seek to ensure that our strategy, decisions, operations and advice to Welsh Government and others are underpinned by sound and quality-assured evidence. We recognise that it is critically important to have a good understanding of our changing environment.

We will realise this vision by:

- Maintaining and developing the technical specialist skills of our staff;
- Securing our data and information;
- Having a well resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

This Evidence Report series serves as a record of work carried out or commissioned by Natural Resources Wales. It also helps us to share and promote use of our evidence by others and develop future collaborations. However, the views and recommendations presented in this report are not necessarily those of NRW and should, therefore, not be attributed to NRW.

Report series: NRW Evidence Report
Report number: 81
Publication date: July 2015
Title: Impacts of Bait Digging on the Gann: An Evidence Review
Author(s): Evans, S., Moon, J., Bunker, A.R. and Green. M.

Distribution List (core)

NRW Library, Bangor 2
National Library of Wales 1
British Library 1
Welsh Government Library 1
Scottish Natural Heritage Library 1
Natural England Library (Electronic Only) 1
Contract Manager 1

Distribution List (others - electronic)

Sue Burton, Pembrokeshire Marine SAC Officer
Blaise Bullimore, Carmarthen Bay & Estuaries EMS Officer
Mike Camplin, NRW
Lily Pauls, NRW
Chris Lawrence, NRW
Paul Brazier, NRW
Ben Wray, NRW
Andrea Winterton, NRW
Colin Charman, NRW
Rowland Sharp, NRW

Recommended citation for this volume:

Evans, S., Moon, J., Bunker, A.R. and Green. M. 2015. Impacts of Bait Digging on the Gann: An Evidence Review. NRW Evidence Report No: 81 34pp, NRW, Bangor.

Contents

List of Figures

Crynodeb Gweithredol

Mae cloddio am abwyd ar draws gwastadeddau Gann wedi bod yn bryderon i'r awdurdodau perthnasol a'r trigolion lleol fel gilydd ers cryn amser. Er yr amheuwyd ers tro fod y gweithgaredd hwn yn niweidiol, nid oedd gwybodaeth am hyd a lled a difrifoldeb y niwed oherwydd diffyg tystiolaeth safle benodol gydlynol i gefnogi'r farn hon. Mae'r diffyg tystiolaeth hwn wedi bod yn rhywfaint o rwystr i'r ymdrechion diweddar i geisio lleihau effaith gweithgareddau niweidiol drwy roi mesurau rheoli ar waith (cyfyngiadau ymdrech/gofodol).

Yn dilyn cwblhau rhaglenni gwaith a oedd yn ceisio mynd i'r afael â'r diffyg gwybodaeth am effaith ddeddfwriaethol a gweithgaredd casglu rhynglanwol, a wnaed drwy Brosiect a ariannwyd gan Gronfa Ecosystem Wydn Llywodraeth Cymru, 'Canllawiau ar gyfer Abwyd Rhynglanwol a Chasglu Gwymon Cynaliadwy', roedd angen adolygiad manwl o dystiolaeth effaith palu am abwyd ar lefel safle benodol ar gyfer y Gann. Nod yr adolygiad tystiolaeth hwn oedd adeiladu ar ganfyddiadau'r Casgliad Rhywogaethau Rhynglanwol yng Nghymru: Adolygiad Effaith (Pery et al., 2014) drwy goladu'r wybodaeth oedd ar gael yn barod a'r dystiolaeth orau oedd ar gael ar effeithiau cloddio am abwyd. Roedd yr adolygiad yn canolbwyntio'n bennaf ar effeithiau casglu abwyd a gloddiwyd â llaw ar gynefinoedd a rhywogaethau'r Gann, gan dynnu ar astudiaethau a wnaed yn ardal yr adolygiad ac ymhellach.

O'r dystiolaeth a adolygwyd mae'n amlwg fod palu am abwyd wedi arwain at addasu cynefin arwahanol a phendant gydag effeithiau dramatig ar ffawna ac ymddangosiad graean mwdlyd cymysg cysgodol y Gann, y math o gynefin lle mae'r rhan fwyaf o weithgaredd casglu abwyd yn digwydd. Mae cloddio am abwyd yn arwain at addasiad ffisegol strwythur y gwaddod a symud yn uniongyrchol neu niweidio rhywogaethau targed a rhai heb fod yn darged. Mae'r effeithiau mwyaf amlwg yn y Gann yn cynnwys creu ardaloedd mawr o gynefin unffurf y tarfwyd arnynt a'r rheiny'n cynnal amrywiaeth o rywogaethau prin ac yn ffafrio amlder rhywogaethau sy'n bachu ar eu cyfle fel yr Abwydyn Gwyrdd targed *Alitta virens*. Sylwodd astudiaethau lleol pwysig fel Bassindale and Clark (1960), Edwards et al (1992) a Palmer (1993) newidiadau i ddosbarthiad a helaethrwydd rhywogaethau, yn cynnwys cynnydd dramatig yn nifer *A. virens*. Er nad oedd modd i'r astudiaethau hyn briodoli'r newidiadau a welwyd i un gweithgaredd, mae gan y newid yn y rhywogaethau trechol i'r *A.virens* prinnach, a geisir yn ddyfal, oblygiadau parhaus i gymunedau isfilodaidd y Gann lle mae palu dwys yn arwain at amgylchedd sy'n ffafriol i gasgliadau sy'n cael eu tarfu llawer fel y nodweddir gan rywogaethau sy'n bachu ar eu cyfle. Mae data monitro o raglen fonitro isfilodaidd Ardal Cadwraeth Arbennig (ACA) Forol Sir Benfro gan Cyfoeth Naturiol Cymru yn 2007 a 2012 (Green and Camplin, in prep.) yn dangos casgliadau lle mae'r rhywogaethau trechaf yw rhai sy'n bachu ar eu cyfle sy'n nodweddiadol o gynefinoedd y terfir arnynt mewn rhai safleoedd. Mae effeithiau andwyol fel hyn yn cynrychioli dirywiad y cynefin ACA dynodedig, ac, er nad yw'r amcanion cadwraeth yn anelu at gyrraedd cyflwr digyfnewid anniffiniedig, mae'n amlwg fod y dirywiad wedi digwydd ers y dynodiad yn 2004. Mae angen cymryd camau er mwyn rheoli gweithgareddau yn benodol ar y safle, diogelu nodweddion rhag dirywiad pellach, hwyluso adfer yr ardaloedd sydd ar hyn o bryd wedi'u niweidio neu wedi dirywio'n anffafriol a sicrhau dyfodol hirdymor y safle.

Mae adfer cynefinoedd a rhywogaethau ar ôl tarfu hir a dwys yn y Gann yn debygol o fod yn araf ac mae'n bosibl na fudd buddiannau unrhyw leihad mewn ymdrech o

ganlyniad i ymyriad rheolaeth yn cael eu gweld am nifer o flynyddoedd. Hyd yn oed pe bai'r mesurau rheoli yn llwyddo i ostwng lefelau tarfu dros amser, mae'n fwy na thebyg, heb gyflwyno parthau dim cymryd parhaol, y bydd rhai rhywogaethau yn dal i gael eu cau allan o'r ardaloedd sy'n cael eu palu (neu eu bod yno, ond bod llai ohonynt).

Roedd hi tu hwnt i gwmpas yr adroddiad hwn i bennu pa ddwysedd neu faint gofodol yr ymdrech balu (os o gwbl) fyddai'n golygu lefel dderbyniol ac yn caniatáu adfer y safle i gyflwr ffafriol sy'n addas i amrywiaeth uchel o rywogaethau. Mae argymhellion yn Bean and Appleby (2014) yn cyflwyno opsiynau ar gyfer lefelau amrywiol o gloddio abwyd a gellid barnu y byddai unrhyw ostyngiad mewn cloddio abwyd yn golygu gwelliant ar y sefyllfa bresennol. Byddai astudiaeth hirdymor ychwanegol ar adferiad yn dilyn ymyriad rheoli yn fuddiol a byddai'n helpu penderfyniadau rheoli yn y pen draw.

Rhagwelir y bydd yr adolygiad hwn o gymorth i ddarparu sail tystiolaeth ddigonol y gall trafodaethau rheoli yn y dyfodol rhwng Cyfoeth Naturiol Cymru ac aelodau eraill Grŵp Awdurdodau Perthnasol Ardal Cadwraeth Arbennig Forol Sir Benfro symud ymlaen arnynt.

Executive Summary

Bait digging across the Gann flats has been a concern of relevant authorities and local residents alike for a considerable time. Although the activity has long been suspected to be damaging, the extent and severity of damage was unknown with a lack of coherent, site specific evidence in support of this view. This lack of evidence has somewhat hindered recent efforts seeking to reduce the impact of damaging activities through the implementation of management measures (effort/spatial restrictions).

Following the completion of work programmes seeking to address legislative and intertidal collection activity impact knowledge gaps, completed through a Welsh Government Resilient Ecosystem Funded *Guidelines for Sustainable Intertidal Bait and Seaweed Collection Project*, a detailed review of bait digging impact evidence at a site specific level was required for the Gann. This evidence review aimed to build on the findings of the *Intertidal Species Collection in Wales: Impacts Review* by Perry *et al*. (2014) by collating existing knowledge and best available evidence on the impacts of bait digging. The review focused mainly on the impacts of hand dug bait collection activities to the habitats and species of the Gann, drawing on studies undertaken both in the Gann and further afield.

From the evidence reviewed herein, it is apparent that bait digging has resulted in discreet and definite habitat modification with dramatic impacts on the fauna and aesthetics of the Gann's sheltered mixed muddy gravels, the habitat type within which the majority of bait collection activity occurs. Bait digging results in physical modification of the sediment structure and direct removal of, or damage to, target and non-target species.

The most notable impacts in the Gann include the creation of large areas of physically disturbed, homogenous habitat that support reduced species diversity and favour the proliferation of opportunistic species such as the target, king rag *Alitta virens*. Important local studies such as Bassindale and Clark (1960), Edwards *et al.* (1992) and Palmer (1993) noted changes to species distribution and abundance, including a dramatic increases in the abundance of *A. virens*. Whilst it was not possible for these studies to attribute the observed changes to a single activity, the change in dominant species to the highly sought after, less widely available *A. virens* has continued implications for infaunal communities of the Gann. Intense digging for *A. virens* results in an environment conducive to highly disturbed assemblages characterised by opportunistic species.

Monitoring data from Natural Resources Wales' 2007 and 2012 Pembrokeshire Marine Special Area of Conservation (SAC) infaunal monitoring programme (Green and Camplin, in prep.) revealed assemblages to be dominated by opportunist species, typical of disturbed habitats, at a number of sites. Such community shifts represent degradation of designated SAC habitat and, whilst the conservation objectives do not seek to achieve an indefinable pristine state, it is clear that degradation has occurred since site designation in 2004.

Action is required in order to bring about site specific management of activities, safeguard features from further degradation, facilitate restoration of currently unfavourable damaged or degraded areas and to secure the long term future of the site.

Restoration of habitats and species from prolonged and intense disturbance in the Gann is likely to be slow and the benefits of any reduction in effort as a result of management intervention may not be realised for a number of years. It is probable that, even if management measures were successful in reducing the levels of disturbance over time, without the introduction of permanent no take zones, certain species may continue to be precluded from dug areas (or present but at reduced abundance).

It was beyond the scope of this report to determine what intensity or spatial extent of digging effort (if any) would constitute an acceptable level and allow for the restoration of the site to a favourable condition that would be conducive to high species diversity. Recommendations in Bean and Appleby (2014) present options for varying levels of bait exploitation and it may be deemed that any reduction in bait digging effort would represent an improvement on the current situation. An additional long-term study into recovery following management intervention would be beneficial and ultimately aid management decisions in the future.

It is anticipated that this review will assist in providing a sufficient evidence base upon which future management discussions between Natural Resources Wales and other members of the Pembrokeshire Marine Special Area of Conservation Relevant Authorities Group can progress.

1. Introduction

Concerns over the impact of intensive commercial and recreational bait collection activities in the Gann are long standing and have been the subject of renewed focus in recent years with relevant authorities seeking to better manage activities and achieve favourable condition and status for the interest features of the site. In a survey of the distribution and intensity of bait collection activities within the Milford Haven estuary, Morrell (2007) found that the Gann was the most exploited bait collection site in the Haven with its muddy gravels supporting large aggregations of the much sought after angling bait species king rag *Alitta virens*.

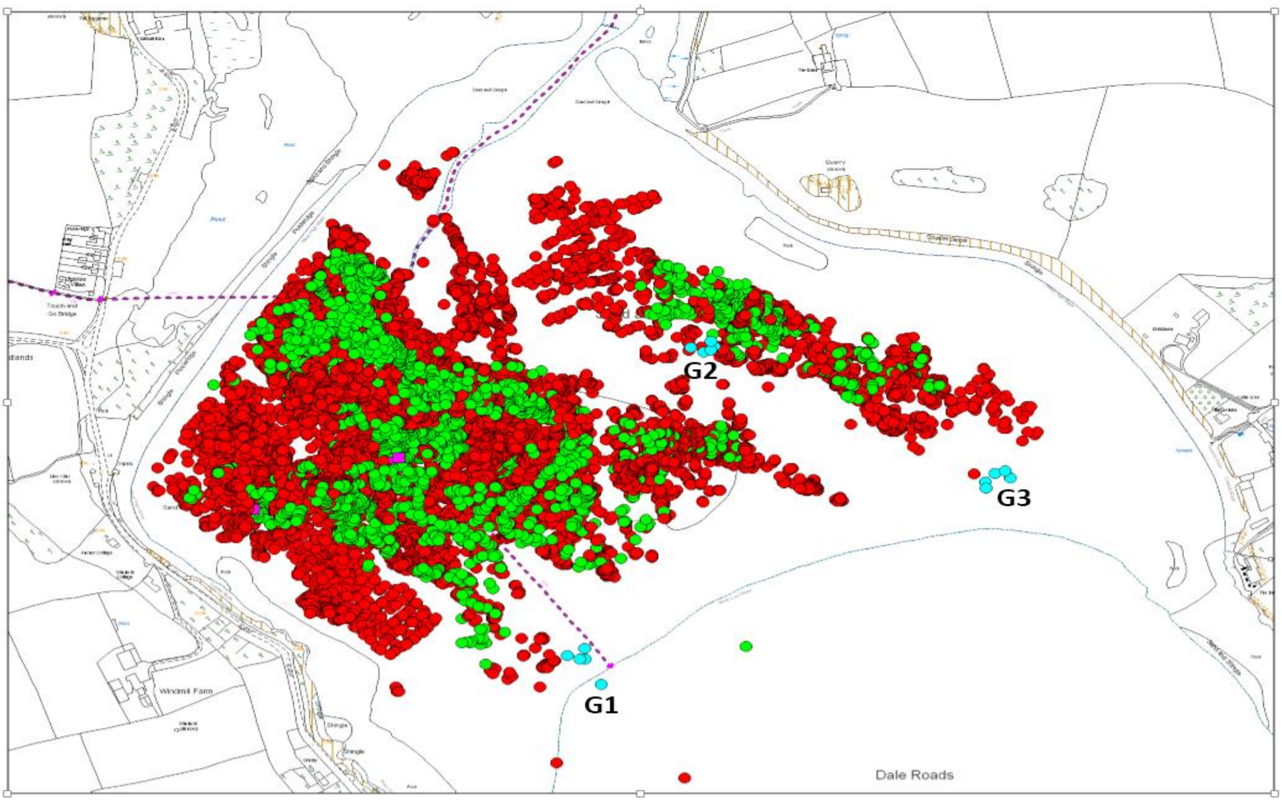


Figure 1. Red and Green points represent the GPS locations of dug 'worm holes' indicating the spatial extent of digging effort (different colours represent different survey seasons, 26,615 holes were recorded in total). Blue points represent the 2007 Milford Haven Inlets macrobenthic monitoring programme sample locations G1 – G3.

A number of high priority actions, assigned to Natural Resources Wales through the Pembrokeshire Marine Special Area of Conservation (SAC) Management Scheme (MS) in 2008, are currently being implemented in an effort to better manage commercial and recreational bait collection activities and safeguard SAC features. These actions include reviewing existing legislation, clarifying legal responsibility and developing well defined management measures to safeguard habitats and species sensitive to bait collection (such as zoning, closed seasons, access restrictions), with particular reference to the habitats and species in the Gann (see relevant management scheme living resources and recreational activity actions in sections 6.4 C+G, 6.6 C, 6.9 C, 6.10 D and sections 6.6 A+C, 6.9 C+E, 6.10 D respectively).

Work undertaken in relation to the Welsh Government Resilient Ecosystem funded *Guidelines for Sustainable Intertidal Bait and Seaweed Collection Project* has begun to address some of these actions. The legislative and intertidal species collection impacts reviews commissioned by the Pembrokeshire Marine SAC RAG (Bean and Appleby, 2014 and Perry *et al.,* in prep), currently in preparation but due to report imminently, make us better placed to assess the merits and legal underpinning of future management strategies seeking to reduce the impact of bait digging on the Gann. The specific management mechanisms are subject to ongoing discussions between relevant parties and are yet to be determined, with calls for a clearer understanding of the current weight of evidence in support of likely management decisions. Evidence of the nature and scale of impacts is required in advance of any decision on management actions.

A holistic approach has been adopted to manage bait digging effort with the aim of delivering an outcome that supports both sustainable anthropogenic activities and favourable habitat condition conducive to high species diversity typical of habitats present (when undisturbed). A number of management strategies have been outlined in a case study of the Gann by Bean and Appleby (2014) and are currently being considered. Any effort restrictions resulting from management actions will need to take account of the wider implications such as the potential for displacement of digging effort to nearby sites of similar sensitivity.

1.1 Scope and Aim

This report aims to build on the findings of the Intertidal Species Collection in Wales: Impacts Review (Perry *et al*., in prep) and collate existing knowledge and best available evidence relating to the impacts of bait digging on habitats and species in the context of relevant conservation objectives. It is anticipated that this review will assist in providing the evidence base upon which future management discussions between Natural Resources Wales and other members of the Pembrokeshire Marine SAC RAG can progress. The scope of this review is to mainly focus on the impacts of hand digging bait collection, drawing on studies undertaken in the Gann and further afield along with any pertinent anecdotal observations.

2. Habitats, Species and Designations

The Gann estuary near the village of Dale, Pembrokeshire, is a relatively sheltered inlet close to the entrance of the Milford Haven Waterway. Extensive saltmarsh dominates the upper reaches giving way to mudflats and sandflats lower down, fringed by intertidal rocky shore communities and saline lagoon habitat at Pickleridge lagoon. The Gann's intertidal mudflats and sandflats, 'the flats', are a complex mix of habitats encompassing the largest single area of littoral mixed sediment sheltered muddy gravel habitat in Wales and forms the focus for discussion throughout this site specific review.

The flats fall within the Pembrokeshire Marine Special Area of Conservation, Milford Haven Waterway Site of Special Scientific Interest and are a Biodiversity Action Plan priority habitat. Brief descriptions of these designations are outlined below and further detail can be found in CCW (2009), CCW3 and JNCC3 respectively.

2.1. Pembrokeshire Marine Special Area of Conservation (SAC)

Pembrokeshire Marine SAC was designated in December 2004 under the EC Habitats Directive 1992 (Council Directive 92/43/EEC (1992) on the conservation of natural habitats and of wild fauna and flora). The site was selected for 8 Habitats Directive Annex I marine habitats and 7 Habitats Directive Annex II species interest features. It is considered to be one of the best UK examples of:

- Large shallow inlets and bays
- Estuaries
- Reefs
- Grey seal *Halichoerus grypus*

and to support a significant presence of:

- Atlantic salt meadows *Glauco-Puccinellietalia maritimae*
- Mud-flats and sand-flats not covered by seawater at low tide
- Coastal lagoons
- Submerged or partially submerged sea caves
- Sandbanks which are slightly covered by seawater all the time
- Allis shad *Alosa alosa*
- Twaite shad *Alosa fallax*
- River lamprey *Lampetra fluviatilis*
- Sea lamprey *Petromyzon marinus*
- Otter *Lutra lutra*
- Shore dock *Rumex rupestris*

The Directive aims to promote the maintenance of biodiversity and with designated component features contributing towards a coherent Europe wide ecological network of protected sites serving to maintain and restore listed habitats and species. Numerous developments and activities threaten habitat and species diversity and have the potential to result in deterioration of SAC features; bait digging is one such activity. In the Haven hand digging for bait is common on many shores where species of high angling bait value, such as lugworm and ragworm (especially king rag), are targeted in areas where bait resource is readily accessible and commonly available. Morrell (2007) found that ragworm were the most popular target species with numerous aggregations across a number of sites subject to large scale digging effort.

Figure 2. Hand digging for bait in the Gann. Photo courtesy of Mike Camplin

Figure 3. and Figure 4. Spoil heaps and depressions left in sheltered *Zostera noltei* beds, Angle bay following bait digging. Photo courtesy Anne Bunker

Figure 5. Widespread physical modification of the Gelliswick Bay foreshore as a result of bait digging.

Morrell (2007) found that the Gann was a particularly important and most heavily exploited area for hand digging targeting king rag *A. virens* due to the presence of now dense aggregations within relatively easy access. The spatial extent of harvesting activity varies throughout the year with hand digging occurring largely within the mud-flats and sand-flats not covered by seawater at low tide feature. As well as being a feature in its own right, mudflats and sandflats are a component part of the estuaries and large shallow inlets and bays features.

Significant modifications to the structure and function of these features are known to occur through anthropogenic induced changes to sediment dynamics, water quality, physical habitat integrity removal of target and damage to non-target species. Such modifications are considered significant where detrimental impact on SAC habitats and their typical species and or species features occur, resulting in the conservation objectives of the site to be undermined. These objectives are outlined in the following section and are one of the key drivers behind the move towards the implementation of effective management measures to address the issue of bait digging. This is necessary to secure the long term physical, biological and chemical structure and function of the habitat and the abundance, condition and diversity of its typical species.

2.2 Conservation Objectives

The Pembrokeshire Marine SAC conservation objectives are defined in advice provided by the Countryside Council for Wales (CCW) in fulfilment of Regulation 35 of the Conservation of Habitats and Species Regulations 2010 (formerly Regulation 33 advice under the 1994 Habitats Regulations, now amended) .The objectives for the conservation of *habitat* interest features are:

To achieve favourable conservation status all the following, subject to natural processes, need to be fulfilled and maintained in the long-term. If these objectives are not met restoration measures will be needed to achieve favourable conservation status.

Structure and Function

The physical biological and chemical structure and functions necessary for the long-term maintenance and quality of the habitat are not degraded. Important elements include;

- *Geology*
- *Sedimentology*
- *Geomorphology*
- *Hydrography and meteorology*
- *Water and sediment chemistry*
- *Biological interactions.*

Typical Species

The presence, abundance, condition and diversity of typical species are such that habitat quality is not degraded. Important elements include;

- *Species richness*
- *Population structure and dynamics*
- *Physiological heath*
- *Reproductive capacity*
- *Recruitment*
- *Mobility*
- *Range*

In the context of this review the key element of these objectives is the need 'to ensure that the management and control of activities or operations likely to adversely affect the habitat feature is appropriate for maintaining it in favourable condition and is secure in the long term' (CCW, 2009). In compiling these objectives, CCW recognised that historic and ongoing modification of varying severity and extent had occurred and continues to occur as a result of human activity. The conservation objectives do not seek to achieve an indefinable pristine state but rather to safeguard features from further degradation and, where possible and necessary, restore currently unfavourable features from damaged or degraded states.

Any management measures taken forward need to be considered in light of these objectives and the likelihood of their success in achieving favourable conservation status, as defined in Article 1 of the Habitats Directive:

'Conservation status of a natural habitat means the sum of the influences acting on a natural habitat and its typical species that may affect its long term natural distribution, structure and functions as well as the long term survival of its typical species within the territory referred to in Article 2. The conservation status of a natural habitat will be taken as 'favourable' when:

- *its natural range and the areas it covers within that range are stable or increasing, and*
- *the specific structure and functions which are necessary for its long term maintenance exist and are likely to continue to exist for the foreseeable future, and*
- *conservation status of typical species is favourable as defined in [Article] 1(i).'*

2.3 Milford Haven Waterway Site of Special Scientific Interest

The waterway is a ria system comprised of extensive rocky shores, sandy beaches, embayments, sheltered mudflats, muddy creeks and wider foreshore which supports diverse marine biological communities. This site is of special interest for it's:

- Geology
- Ancient woodland
- Marine biology
- Saltmarsh
- Swamp
- Saline lagoons
- Rare plants and invertebrates
- Nationally important waterfowl
- Greater horseshoe bat *R. ferrumequinum*
- Lesser horseshoe bat *R. hipposideros*
- Otter *Lutra lutra*

The potential for bait collection activities to impact upon intertidal site sediment dynamics, contaminant levels and target species has been noted as a key management issue in the MHW management statement (CCW[1]). The management statement makes particular reference to observed changes at muddy gravel sites within the Haven and calls for considerations of attempts to limit impacts on intertidal features. A number of operations likely to damage the special interest features of the site are listed in Countryside Council for Wales Site of Special Scientific Interest: Operations Requiring Consultation with the Countryside Council for Wales document

(CCW[2]) in fulfilment of Section 28(4) (b) of the Wildlife and Countryside Act 1981 (as amended).
Bait digging is listed as a notifiable operation under operation reference number 16 b 'Fisheries management and seafood or marine life collection, including the use of traps or fish cages and bait digging likely to damage the flora, fauna or features for which the site is of special interest'.

Consultation with, and prior consent from, NRW is required in order to undertake listed operations within designated SSSI areas. Whilst the list of operations is not a prohibited list, and in many instances it may be possible to carry out listed operations under consent in ways as to avoid damaging site interest features, there are concerns that intertidal community changes observed over the last 10 or more years are a result of bait collection (CCW[1]), particularly in muddy sediment areas such as the Gann where regular bait collection occurs with little other anthropogenic activity.

2.4 Biodiversity Action Plan Priority Habitat

Sheltered muddy gravels are a Biodiversity Action Plan Priority Habitat of principal importance listed under Section 42 of the Natural Environment and Rural Communities (NERC) Act 2006. Under the Act, public authorities have a duty to have regard to biodiversity in exercising their functions. There are concerns that current and historic bait digging activity has had and continues to have a detrimental impact on biodiversity, particularly in sheltered muddy gravel habitat areas such as those characterised by the diverse muddy gravel biotope LMX.Psyllid (now superseded by LS.LMx.Mx.CirCer *Cirratulids and Cerastoderma edule in littoral mixed sediment*) shown in Figure 6.

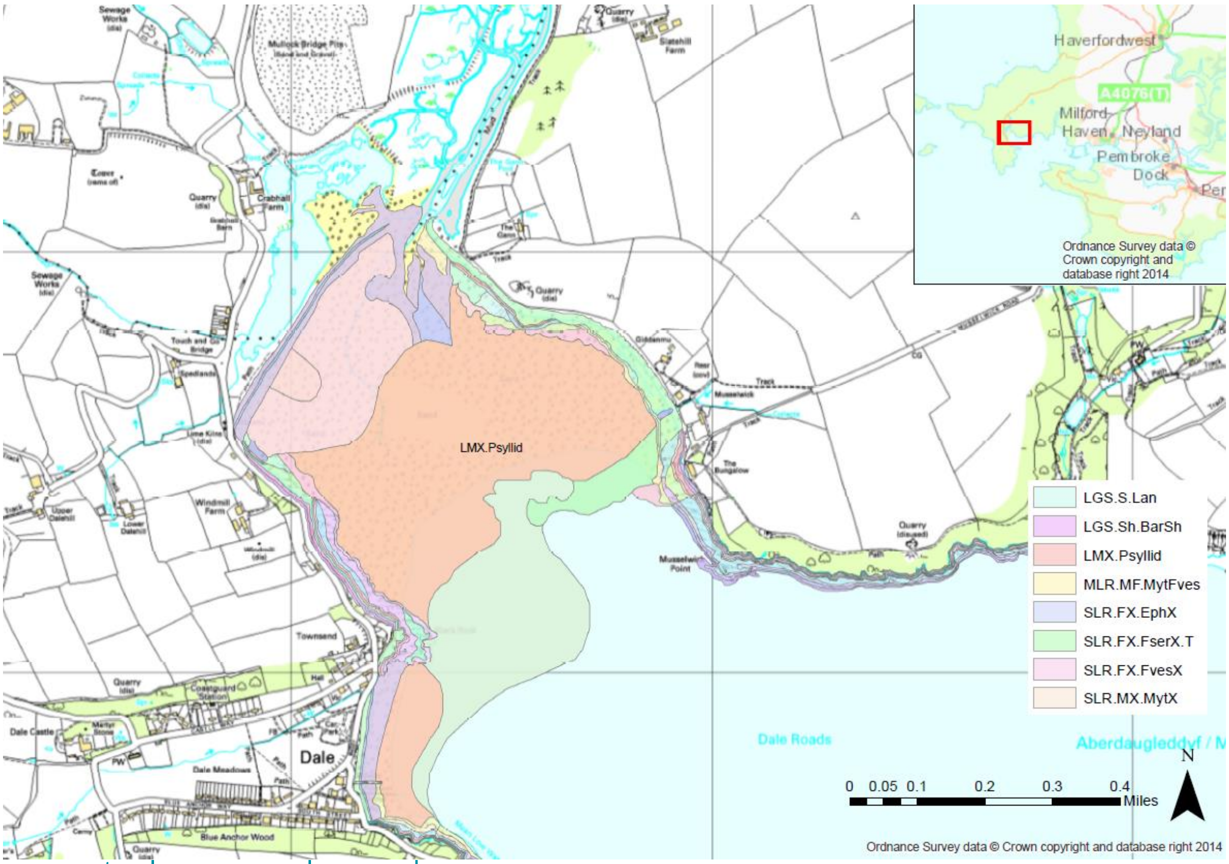


Figure 6. Phase 1 habitat distribution of the Gann flats showing the large extent of littoral mixed muddy gravel (LMX.Psyllid biotope).

Examples of this nationally important habitat under almost fully saline conditions are rare (Edwards *et al.*, 1992) and the Gann is a particularly important site given the high proportion of mixed muddy gravel habitat found and its paucity across the rest of Wales and the UK.

This review will consider evidence available on the impacts of bait digging and seek to better understand the scale, severity and extent of impacts that have occurred in view of the sites conservation objectives and important habitats.

3. Evidence of Impacts

Bait digging has the potential to impact upon a range of different species and habitats. Impacts include disturbance to bird populations, prey species depletion, habitat damage, depletion of target and non-target species through direct physical damage/disturbance or removal or habitat change, suspension of previously entrained pollutants, loss of fine fractions and increased turbidity. The aesthetic impacts of bait digging in intertidal soft sediments, pictured in Figures 7 and 8, are immediately apparent following hand digging activity, however, the long term implications at habitat and species level are considerably less clear and require more detailed examination.

Figure 7. and Figure 8. The intertidal area of the Gann showing typical post-digging disturbance

For the purposes of this review, the focus is mainly on degradation, i.e. anthropogenic induced damage or deterioration of features, in terms of habitat modification and impacts on target and non-target species. The wider impacts of bait digging and other intertidal species harvesting activities have been discussed throughout Perry *et al*. (2014, in prep) and Fowler (1999) and are beyond the scope of this report.

The scale of degradation is typically a function of; the nature of an activity, the duration and extent over which an activity occurs, the location in which an activity is undertaken, the frequency and intensity of an activity and the sensitivity and recoverability of the species and habitats impacted. As detailed in CCW's Pembrokeshire Marine SAC conservation advice package (CCW, 2009), damage and deterioration are considered to have occurred where there are:

- *permanent and long-term changes to distribution or reduction in extent of a feature or features component, or temporary modifications or reductions sufficiently significant to negatively impact on biota or ecological processes;*
- *reductions in ecological function caused by loss, reduction or modification of habitat structural integrity;*
- *interferences in or restriction of the range, variety or dynamism of structural, functional or ecological processes, e.g.: alteration of habitat structure, obstruction of tidal streams, chronic or acute thermal, salinity or suspended sediment elevations or reductions;*
- *reductions in structure, function and abundance of species populations;*
- *changes in reproductive capacity, success or recruitment of species populations;*
- *increases in abundance and range of opportunist species through the unnatural generation of preferential conditions (e.g. organic enrichment), at the expense of existing species and communities.*

The impacts of an activity are typically method and location specific (Fowler 1999, Perry *et al*., in prep). There have been a number of studies undertaken in the Gann and surrounding areas including Bassindale and Clark (1960), Ballantine (1961), Edwards *et al*. (1992), Palmer (1993) and Morrell (2007) focusing on site ecology, exposure and more recently bait collection effort, impacts and resource availability.

These studies are considered alongside additional activity and or habitat specific studies undertaken outside of the review area which serve to provide a better understanding of typical impacts from similar activities across equivalent, albeit discreetly different, habitat types. Where appropriate, impacts identified in the literature that have relevance to observed and suspected trends in the Gann have been considered in the context of the location specific detail below.

3.1 Site Exposure and Sediment Characteristics

The Gann is situated in the lee of the Dale peninsula and as a result is sheltered from the prevailing wind and waves from the west and south west. Subsequently large storm waves will not reach this location due to the constraints of wave refraction around Dale Point. Ballantine (1961) looked at creating a biological exposure scale of the area around Dale and classified the Gann as a 'very sheltered' environment where wave action is significantly reduced. Due to the fetch limited conditions of the

Milford Haven Waterway any waves generated are the direct result of wind speed over a given fetch (fetch is the horizontal distance over which wave-generating winds blow). The Gann has a fetch window of approximately 60º with the longest fetch of 7.5 miles to the ESE (105º) towards Pennar Point (see figure 9).

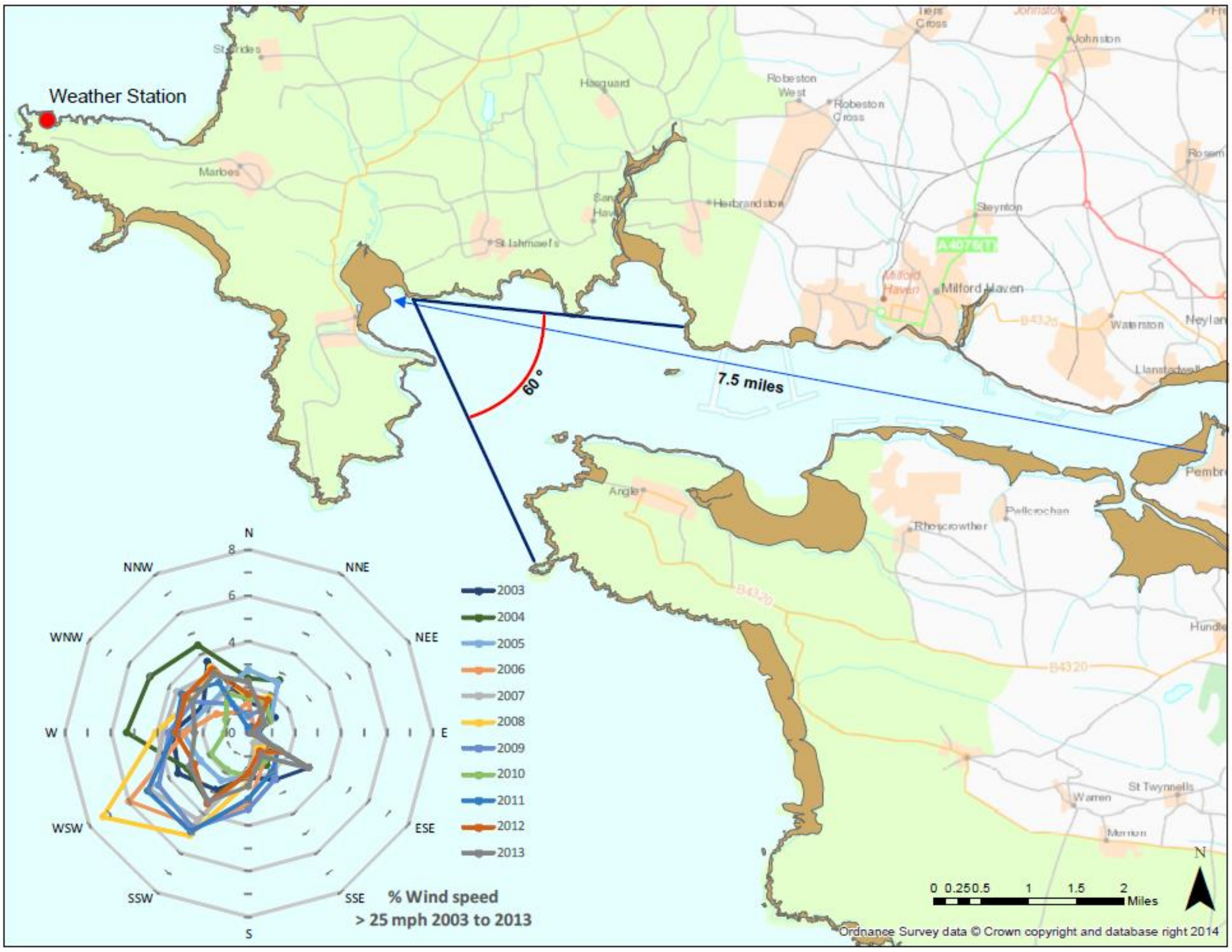


Figure 9. Approximate fetch window, fetch distance and wind rose used in the prediction of significant wave height (Hs) for the Gann flats.

A simplified calculation of predicted significant wave height in Dale can be achieved by utilising a Nomograph of wave height as a function of wind speed and fetch length (see U.S Army Corp of Engineers, 2002). For example an average wind speed of 25 mph from the ESE would produce waves of approximately 1.75 ft (0.46m) with a period of 3 seconds. The wind rose in Figure 9 (inset) shows the percentage of wind velocities exceeding 25 mph over a period of 10 years (data from Wooltack point weather station). It is evident from this data that the wind from the East to South East sector experiences winds over 25 mph for only a small percentage of the time (typically < 2 %). Therefore due to the sheltered nature of the Gann the potential for sediment erosion and transport is minimal. On rare occasions when a strong onshore ESE wind does occur the frequency and duration of those events is not deemed to be conducive to significant changes in topography or sediment re distribution. In addition due to the embayed nature of the Dale flats, situated away from the main channel, the tidal currents in the vicinity of the Gann are negligible even under spring tidal velocities.

This is reflected in the sediment character of the Gann as an area dominated by littoral mixed muddy gravel (Figure 6). The link between the physical environmental conditions and biotopes is further explored by Connor *et al.* (1997a) who produced comparative tables in order to enable a rapid comparison of the species composition and the principal physical characteristics between sets of biotopes. These show that for species rich mixed sediment shores such as the Cirratulids and *Cerastoderma edule* in littoral mixed sediment biotope (LS.LMx.Mx.CirCer), the typical wave exposure for 86% of sites sampled is very sheltered with the remaining 14% falling in the ultra-sheltered category. In addition, typical tidal stream velocities were calculated as 62.5 % weak and 37.5% very weak.

Although the sediment composition is clearly mixed, the particle size analysis results for the Cirratulids and *Cerastoderma edule* in littoral mixed sediment biotope suggest that the size fractions are in two distinct categories with a large proportion of silt/clay (17%) and medium pebble (16%) with the remainder split between the fine sand and small pebble fractions. It may be concluded that this type of sediment environment is particularly stable given the combination of the physical conditions and the sediment characteristics described.

3.2 Impacts on Habitat

Changes to habitat structure and composition occur primarily as a result of direct physical disturbance where sediments are methodically worked by experienced and novice diggers alike. The physical recovery of habitats following disturbance varies according to several factors such as harvesting method, the degree of site exposure and habitat type. Changes to the structure of sheltered, poorly sorted sediments habitats are thought to be most enduring with physical recovery occurring more slowly than in coarse sandy wave exposed areas (Fowler, 1999). In a study of trial plots in Blackness, Forth estuary, McLusky *et al.* (1983) found that 'recovery' of dug areas, defined by target species repopulation; takes place most quickly where holes and trenches are back filled. Areas dug using the 'infill' backfilling method were indistinguishable from controls after 22 days compared with only partial recovery (50 % of control population) in dug spoil mound areas after 80 days. The study noted the importance of environmental conditions including rainfall and wind-driven waves as key factors in physical recovery of tidal flats and, together with re-population data, highlighted the importance of backfilling in promoting physical and species (*Arenicola marina)* population recovery.

Fowler (1999) noted that different collection methods tend to be favoured among different groups of bait collectors with professional and experienced diggers local to an area more likely to methodically work intertidal areas and backfill holes when compared to the numerous scattered hole approach typically adopted by recreational diggers.

Morrell (2007) identified that the Dale area and surrounding beaches of the northern Haven, inclusive of the Gann, are visited largely by diggers from the local area with limited but notable commercial scale digging undertaken by a small number of individuals. It is apparent from personal observation and anecdotal reports locally that the majority of dug holes in the Gann are not back filled, regardless of whether digging is being carried out for commercial or recreational purposes.

In a study of intertidal benthic community recovery rates following physical disturbance, Dernie *et al.* (2003) found that muddy sand habitats had the slowest physical and biological recovery rates but no significant difference in organic content across sites. Muddier sites were found to take longer to infill with post ‘treatment’ depressions, such as those shown in Figure 10, persisting in muddy sand and mud sites past day 213.

Figure 10. Accumulated physical depressions across the Gann flat, a scene typical of dug sheltered muddy gravels where physical sediment recovery is slow. Photo courtesy Anne Bunker.

Prolonged recovery times at muddy sites were presumed to be related to the hydrodynamic regime. This is in agreement with findings from Spencer *et al.* (1998) that the rate of sediment structure restoration is a function of local hydrography, exposure to natural physical disturbance and sediment stability. Spencer *et al.* also noted that removal of fauna from sediment causes destabilisation. The rate at which infilling of dug sites occurs may be a useful tool in predicting the recovery rate of associated communities (Dernie *et al.*, 2003). The flats are subject to year round baitworm exploitation with digging intensity varying spatially across the site throughout the year. Peak digging intensity occurs during the Autumn-Winter period but Morrell (2007) found that significant activity occurs outside of peak periods with up to 306 holes per 2500m^{-2} identified in the central part of the mudflat during a survey of bait holes on the flat in spring.

Given that the Gann is a sheltered, mixed muddy sediment environment where holes are not typically backfilled, physical recovery of sediment to pre disturbance distribution is likely to be slow.

The turnover of sediment is known to elicit changes in mean sediment size across dug sites along with possible implications for typical species of otherwise naturally occurring sediment profiles. In an investigation into the effects of bait digging on the Gann flat, Palmer (1993) demonstrated that the average percentage of mud increased by 4.4% with average particle size increasing by 0.5mm since earlier surveys undertaken in 1986 (change from medium sand - coarse sand in seven years). Whilst caution should be applied when inferring trends from mean particle size data in mixed sediment shores, given the inherent variability of such diverse sediment profiles, it is noteworthy that changes to species abundance, namely a decrease in *A. marina* abundance and increase in *Nereis virens* (now *A. virens)* were also observed. This correlates with a similar trend observed in an earlier study of the Gann by Edwards *et al*. (1992). The habitat requirements of infaunal species are often specific to sediment size/type with species occupying discreet areas e.g. harbour ragworm *Hediste diversicolor* preference for mud/muddy sand (Budd, 2008). Palmer (1993) concluded that whilst it was not possible to attribute changes in average particle size and species distribution to a particular activity, it was possible that an increase in the level of bait digging had led to a change in habitat more favourable to alternative, opportunistic species.

Edwards *et al*. (1992) describes how digging can lead to increased gravel content in surface layers where *'muddy gravel, spoil is left on the surface and with the incoming tide some of the finer sediment particles are winnowed away. This effectively increases the gravel content of the surface material. In time the hole itself begins to fill with mud, and thus, in the short term, pockets of fine sediment surrounded by gravel develop. These characteristic 'pock marks' cover much of the western side of the Gann Flat but decrease in abundance with distance from public access points.'* The pock marks described by Edwards *et al*. (1992) are a common sight at the Gann flats (collective term 'moonscape' locally) and can be seen in aerial imagery of the flats from 2008 (Figure 11).

Figure 11. Aerial image of the Gann flats from 2008 showing distinct 'pock marks' or 'moonscape' topography.

Watson *et al*. (2007) found that dug sites differ in their median particle size and organic content when compared to undug control sites where likely turning of the sediment resulted in loss of finer fractions with potentially significant implications for sediment load and turbidity. Bait digging is also known to mobilise previously entrained chemicals and alter the composition of surface sediments.

A study into the effects of intense digging on sediment and macrofaunal contaminant concentrations in Budle Bay, Howell (1985) reported increased levels of heavy metals in surface sediments and invertebrates following digging effort. Whilst no equivalent study has been undertaken in the Gann flats, habitat modification on sediment shores is most serious in low energy environments, where sediments are poorly sorted (mixtures of stones and mud) and often polluted (Fowler 1999). The intertidal flats of the Gann are a prime example of a low energy mixed muddy sediment shore with a legacy of historic pollution from heavy industry in the Haven. As such, chemical composition of the surface sediments and invertebrate populations may have been and continue to be modified as a result of current and historic digging effort.

The action of repeated digging over several decades may have had long term implications for the distribution of sediment fractions within the surface sediments and overall sediment structure. In the absence of baseline data for the Gann, it is not likely to be possible to quantify the timescale required for true recovery of sediments to an undisturbed condition, if indeed the current level of degradation is reversible.

The area has been subject to bait digging disturbance for decades and the sediment structure is such that the mobilisation and transport of fine material away from the area may limit any possible recovery to a pre disturbance state even if it were known. A reduction in disturbance is likely to result in a less homogenised, more stable sediment environment over time.

3.3 Impacts on Target and Non-target Species

3.3.1 Target species

The extent and severity of bait digging impacts on target species are often location or species specific. In a study into the effects of bait digging on lugworm *Arenicola marina* distribution and population recovery, McLusky *et al.* (1983) found that, despite affecting the population distribution, bait digging did not pose a significant threat to the target species. Similarly Spikes (1993), summarised by Perry *et al.* (in prep), demonstrated that the Lleiniog beach *A. marina* population was able to recover from exploitation. Ragworm species are typically tolerant of disturbance and have been found to occur in higher densities (total number of individuals) where bait digging occurs (Watson *et al*., 2007). However, in a case study of the boulder clay ragworm population in the Menai Strait, Olive (1993) concluded that the *A. virens* population showed susceptibility to over digging as a consequence of delayed maturation.

In a survey of the intertidal fauna of the Gann flats, Edwards *et al.* (1992) describe a striking decline in *A. marina* (among other species) and dramatic increase in *A. virens* abundance compared to the earlier survey of Bassindale and Clark carried out in

1958-59 (Bassindale and Clarke, 1960). Similarly, in a study of the effects of bait digging on the distribution of *A. marina* and *A. virens* on the Gann flat, Palmer (1993) found that *A. virens* was widely distributed compared to *A. marina*. Whilst these studies stopped short of attributing changes observed to a particular activity or cause, *A. virens* was not recorded previously by Bassindale and Clarke (1960). In the absence of any other significant anthropogenic activity on the Gann flat, it is probable that bait digging was a significant factor.

Historically *A. marina* was the main target species of the Gann but the now high density of relatively high mean weight *A. virens* (5.96 and 5.31g in winter and summer surveys respectively) and relative ease of access are likely to account for the Gann's favour among worm diggers (Morrell, 2007). Whilst some digging for lugworm species does occur at the site, the impact of wide scale ragworm harvesting is of most concern. Ragworms typically have a high population turnover lifecycle exhibiting loss of a large proportion of adult populations after spawning, followed by swift larval recruitment where adequate spawning populations remain either subtidally or in undisturbed areas (Fowler, 1999). Morrell (2007) noted that *A. virens* densities in the Gann were the second highest of all sites surveyed in Milford Haven with mean densities of 15 m^{-2} and 11 m^{-2} during the winter and summer survey periods respectively. Despite the area being subject to prolonged and intense large scale species extraction throughout the year, the *A. virens* population in the Gann appears to be able to sustain the current level of exploitation.

3.3.2 Non-target species

The process of digging for bait causes the death of many other non-target marine invertebrates by physical damage, burial and smothering or exposure to desiccation and predation (Fowler, 1999). Bait digging gives rise to changes in the abundance and distribution of non-target species where highly disturbed or unstable environments result. This type of environment favours short lived, opportunistic, high growth rate, early maturing species that are able to tolerate elevated disturbance levels and benefit from lower competition as a result of a reduction in the abundance or distribution of longer lived, slower growing species typical of undisturbed habitats.

The impacts of bait digging on macrofauna are well described, for example, in a two year study looking at the impact of bait digging on the infaunal and epifaunal communities of Chichester harbour, Farrell (1996) noted a significant reduction in density of certain species (*Cerastoderma edule, Amphitrite johnstoni, Harmothoe imbricata* and *Littorina litorrea*). *L. litorrea* recovered to above pre disturbance levels in the following year but species such as *C. edule* remained in significantly reduced numbers. Farrell attributed the success of *L. litorrea* to a change in surface sediment granulometry (increase of flint in surface sediments as a result of digging action). Digging led to a sharp reduction in the total biomass of species recorded that was still apparent in the short term (approximately one month after digging) in what is otherwise a stable environment.

McLusky *et al.* (1983) found that recovery of certain smaller short lived invertebrates, *Peringia ulvae* and *Macoma balthica,* was fairly swift with densities indistinguishable from pre disturbance levels within three weeks. Spikes (1993) found initially that the number and density of non-target species reduced around an area of disturbance, but that the dominant groups recovered after a few days. Spikes considered that the long term effects of digging on an Anglesey beach were negligible. Sandy beach communities' are typically made up of disturbance tolerant species that are well adapted to the less stable exposed nature of these habitats. Dernie *et al*. (2003) found that clean sand communities had the most rapid recovery rate, whereas muddy sand habitats had the slowest physical and biological recovery rates with a strong relationship between the rate at which physical structure of soft-sediment habitats are restored and biological component recovery (either through passive and active migrations or larval recruitment).

In a global assessment of benthic biota response and recovery to fishing, Kaiser *et al*. (2006) found that the effects of different fishing gear were strongly habitat specific. The projected recovery time (time taken for a return to near pre-fishing disturbance densities) of annelids following intertidal dredging in sand habitats was 98 days compared to that of up to 1210 days for muddy sand. A combination of physical, chemical and biological factors affect sediment stability. Muddy sand habitats are typically most stable and susceptible to change because they are influenced by a combination of all three factors and the impacts of digging are more pronounced in sheltered areas.

Watson *et al.* (2007) simulated bait collection as part of a study into the impacts of bait digging on *A. virens* populations and macrofaunal communities in the Solent. A 5 year trial in the previously undug, sheltered muddy Creek Rithe site demonstrated that four species, *Neoamphitrite figulus,* its commensal *Harmothoë glabra, Cerastoderma edule and Nephtys hombergii*, were significantly reduced in numbers in dug areas compared to undug areas in all years sampled. This supports the conclusion that long-lived, larger and less abundant species suffer significant long-term reductions as a result of bait digging.

Although there was a decline in abundance of most species across all sites throughout the study period (unexplained but likely to be local environmental or other external factors), there was a significant decrease in species diversity across dug sites (Shannon-Wiener value (H) -dug area had a significantly lower mean value (H=0.5536±0.074) than the undug area (H=0.8105± 0.069)). The study concluded that permanent no-take zones may be the best option for preserving species that are lost as a result of bait collections as it is the continued disturbance that precludes the species which are unlikely to occur in an area subject to ongoing disturbance.

3.3.3 Trend observed in the Gann

Edwards *et al.* (1992) conducted a 29 station partial survey of the intertidal fauna of the Gann flat, building on earlier work of Bassindale and Clark (1960), which recorded a total of 111 species of which 60 were polychaete. Multivariate statistical analysis showed that four distinct assemblages determined by a combination of tidal level, freshwater influence and sediment type existed across sites surveyed with the majority of the flat below mid-tidal level. There were notable changes in species distribution since the earlier 1957-1959 survey, some of which could be accounted for in differences between sampling methodologies e.g. some of the smaller species retained by the sieving technique of Edwards *et al.* (1992) may not have been considered by Bassindale and Clark (1960). However, the fauna of the western part of the bay had changed considerably with the sabellids such as the fan worm, *Megalomma vesiculosum* and peacock worm *Sabella pavonina* found to have declined dramatically and much of the area dominated by *A. virens*, not previously recorded by Bassindale and Clark or in the first edition of Dale Fort Marine Fauna (Bassindale and Barrett, 1957). *Mellina palmata* was also much more widespread with a reduced spatial *A. marina* extent. *Lanice conchilega* distribution was much more restricted and limited to the lower shore.

Identifying the cause of the changes observed was beyond the scope of the study but the trends observed indicate that modifications to the distribution and abundance of typical species have occurred. It is likely that bait digging, the single major anthropogenic activity carried out in the area, has played a part in promoting or exacerbating these modifications. Several polychaete species not previously recorded were found to be present in reasonable numbers with the report surmising that it is possible that moderate levels of disturbance may promote diversity where an intermediate level of disturbance results in maximal diversity (greatest total number of species supported by the habitat).

The infauna of the Gann is monitored as part of Natural Resources Wales' Milford Haven Inlets Macrobenthic Monitoring programme in relation to the Pembrokeshire Marine SAC condition reporting. Data and analysis for monitoring at three sites undertaken in 2007 and 2012 are presented in Green and Camplin (in prep.). The monitoring has highlighted a reduction of mean taxa richness and number of individuals of between 2-18% and 25-72% over the survey period (very slight at G2).

The equability of taxa has increased at stations G1 and G3, and decreased at station G2 (Figure 12) where data analysis shows that, on average, a slightly larger proportion of the biomass was attributed to smaller (shorter lived) taxa in 2012. Station G2 is located north west of the other sample locations and most likely to be impacted by bait digging activity (see sample locations relative to 'worm holes' in Figure 1).

All sites sampled in the Gann showed a decline in number of taxa and abundance between years but there is low confidence in this negative trend due to the limited amount of data (two survey visits). It is worth noting, however, that the habitat has been subject to bait digging activities for a number of decades and any negative indicators identified through monitoring are in addition to degradation that is already likely to have occurred.

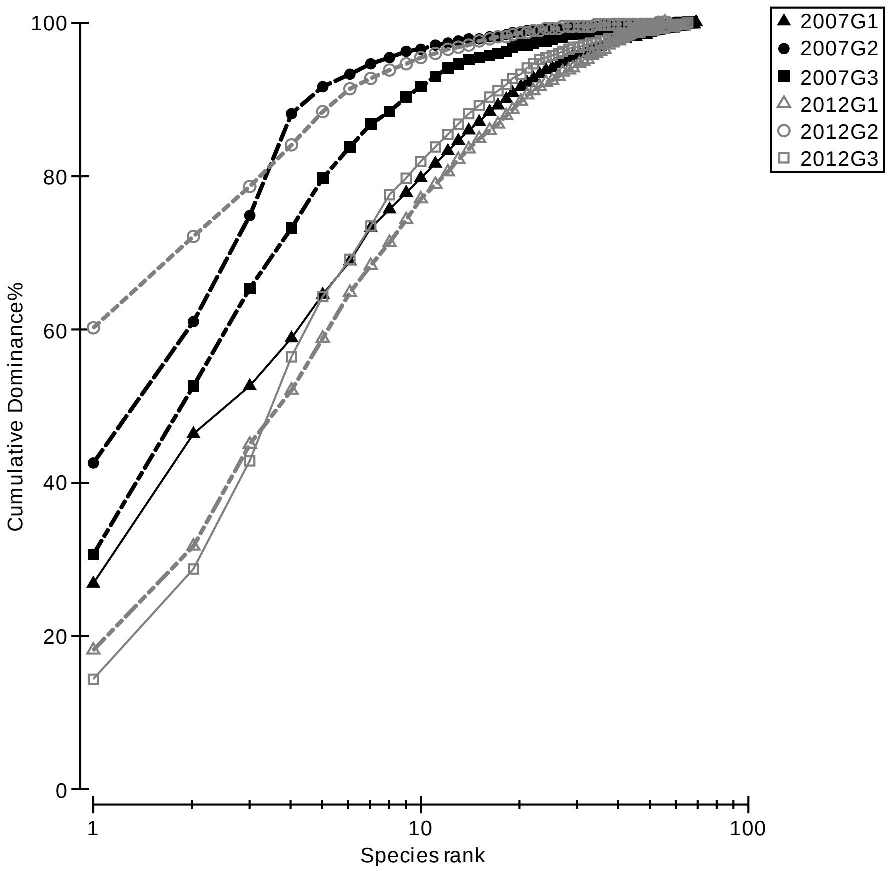


Figure 12. K-Dominance curve for mean taxa abundance for at stations at the Gann, Milford Haven Waterway in 2007 (black symbols) and 2012 (grey symbols).

The key community difference between station G2 and the other two stations is that G2 was found to be dominated by opportunistic species typical of disturbed habitats and contained fewer longer-lived, disturbance intolerant species (Figure 12 & 13). This is illustrated well by Figure 13 which shows the distribution of taxa abundance within AMBI sensitivity groups for all Gann infaunal sampling stations. At station G2 a notably higher proportion of opportunistic species were recorded in both years compared with other Gann stations. The AMBI index (AZTI Marine Biotic Index) (Borja et al., 2000) describes the sensitivity of a macro benthic community to anthropogenic and natural disturbance.

Gann taxa data were assigned to one of five AMBI groups (‘ecological group’ I – V) using the EA Infaunal Quality Index analysis excel work book look-up tool (IQI Workbook v2_07_20130809 DRAFT.xlsm) (Phillips et al., 2012). Group I describes the most sensitive taxa and V represent the most opportunistic taxa. Between 2007 and 2012 there was no improvement in species richness at G2 which showed a reduction in biodiversity (Shannon wiener index & K-Dominance plot Figure 12).

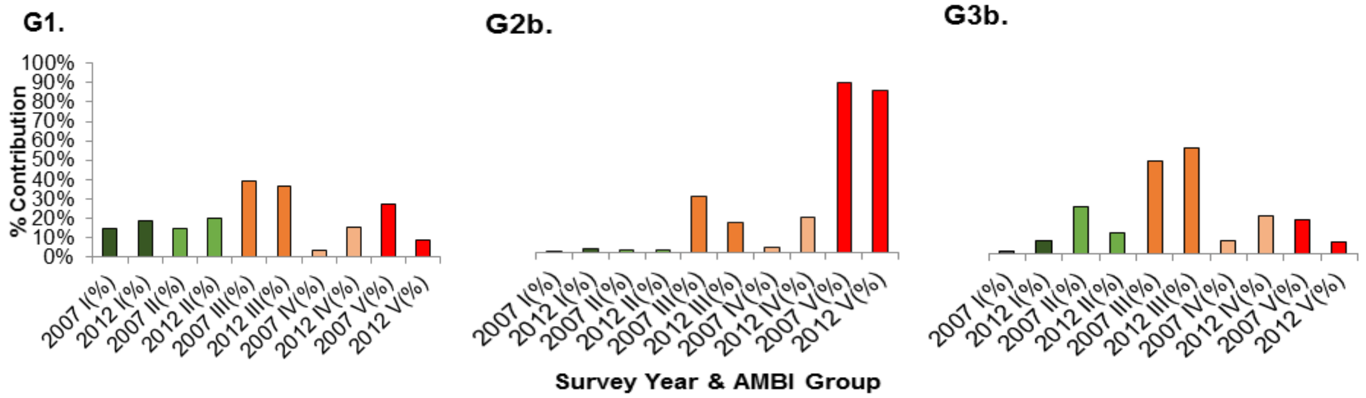


Figure 13. The average percentage contribution of the number of individuals classified into AMBI groups I – V at sampling stations around Gann Flats, Milford Haven estuary sampled with a day grab at high tide in 2007 and 2012, n = 5 (see Figure 15).

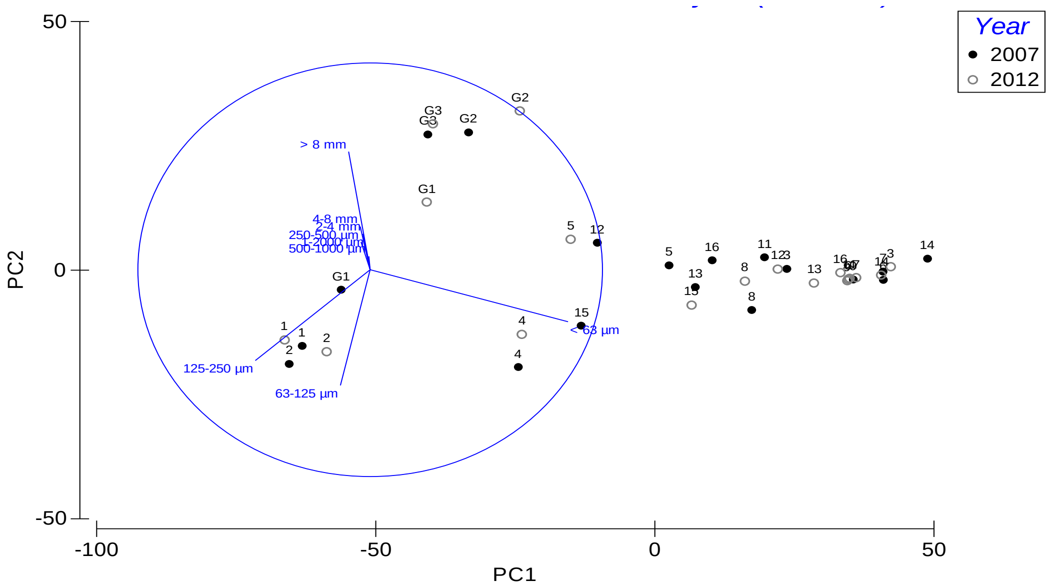


Figure 14. A 2-dimensional PCA ordination of mean untransformed sediment size class contributions from 18 stations around the Milford Haven Waterway Inlets sampled in 2007 (●) and 2012 (○).

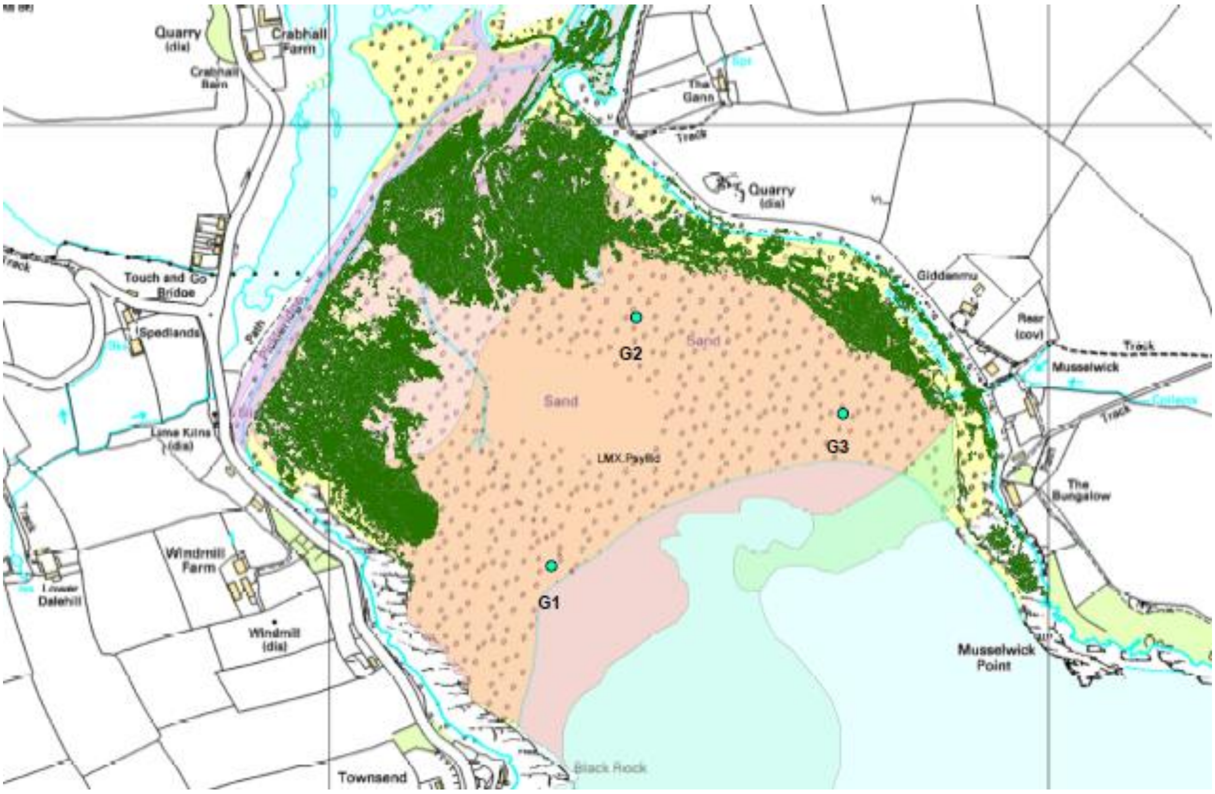


Figure 15. Map showing the sample sites (blue dots G1-G3) within the same littoral mixed muddy gravel biotope (LMX.Psyllid) and outside of the macro algae extent (dark green).

It is likely that G1 and G3 are under less natural environmental stress than G2 due to lower levels of desiccation and salinity variation given their lower shore position, however, all sites have similar sediment characteristics (Figure 14), are not associated with opportunistic macro algae which is indicative of freshwater influence and nutrient enrichment, and are located within the same biotope (Figure 15). Whilst some of the observed differences might be expected, the extent of the difference is unexpected.

4. Conclusions

Anthropogenic activities have the potential to significantly modify the structure and function of interest features through mechanisms such as changes to sediment dynamics, water quality or direct physical disturbance. It is acknowledged that local modifications and species level alterations have occurred in areas of the flats where bait digging takes place (Edwards et al., 1992; Palmer, 1993; Green and Camplin, in prep.).

Available evidence indicates that the distribution and abundance of longer-lived species are detrimentally impacted as a result of bait digging. The most notable impacts in the Gann include creation of large areas of physically disturbed homogenous habitat that support reduced species diversity and favour the proliferation of opportunistic species such as the target *A. virens.* This represents a significant detrimental impact on the typical species and associated communities of the Gann's mixed muddy gravel habitat and degradation of designated SAC habitat since designation in 2004 (e.g. Green and Camplin, in prep.).

Modification of feature components has negatively impacted upon biota and, whilst the conservation objectives do not seek to achieve an indefinable pristine state, it is clear that action is required to bring about site specific management of activities to safeguard features from further degradation, facilitate restoration of currently unfavourable damaged or degraded areas and to secure the long term future of the site.

Management measures that limit the duration, extent, frequency and intensity of bait digging activity help to reduce detrimental impacts where these are underpinned by effective regulation inclusive of enforcement. Management actions will need to be designed and implemented in such a way as to allow a sufficient recovery period for the desired improvements to occur.

Restoration of habitats and species from prolonged and intense disturbance in the Gann is likely to be slow and the benefits of any reduction in effort as a result of management intervention may not be realised for a number of years. The length of time required for the recovery of habitats and species to a pre-disturbance or date of designation state is not known and complicated by the extended length of time over which bait collection has been occurring in the Gann. It is probable that even if management measures were successful in reducing the levels of disturbance over time, without the introduction of permanent no take zones, certain species may continue to be precluded from dug areas (or present but at a reduced abundance).

Further work may be required in order to determine what intensity and spatial extent of bait digging effort can occur (if any) that will allow for an acceptable level of impacted habitat alongside restoration of the site to a favourable condition conducive to high species diversity. The extent to which ecosystem functioning is affected by bait digging is yet to be determined. It may be deemed that any reduction in bait digging effort would represent an improvement on the current situation.

5. Knowledge Gaps and Recommendations

5.1 Knowledge Gaps

The report demonstrates that there is sufficient information on which to make a confident management decision to facilitate restoration of the Gann flats.

Watson (2013, unpublished) raised some questions regarding favourable condition and ecosystem functioning. Knowledge gaps remain as to whether the changes observed are significant in terms of ecosystem functioning and identifying whether the community structure change observed amounts to the essential functions of the system being negatively affected would require further work.

Details of ecological and physical recovery times and the efficacy of any management measures for this special habitat could be obtained by monitoring after management has been applied. However, as Watson states, (Watson *et al*., (2007) the ecological benefit of any management actions should ideally be tested scientifically before implementation to ensure that the desired outcomes are achieved.

To determine site specific management actions, a good understanding is required of what level of activity is currently occurring, what level of activity can occur without the risk of continued degradation to habitats and species and what specifically would any management intervention be aiming to achieve. Thanks to the report on the assessment of bait collection activity in Milford Haven (Morrell, 2007) we have a good understanding of the levels of activity occurring but determining what represents an acceptable reduced level of activity is likely to be a difficult and lengthy undertaking with detrimental impacts occurring all the while.

It may be decided therefore that, it will not be possible to fill this knowledge gap because even an extensive research programme is likely to produce results that still require a judgement to be made of what is an acceptable amount of disturbance. Due to the high level of European and national protection afforded to the Gann, a precautionary approach should be adopted.

5.2 Recommendations

Recommendations on future management of the Gann are made in Bean and Appleby (2014) Pembrokeshire Case Study.

6. References

Budd, G. 2008. *Hediste diversicolor* Ragworm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme. Plymouth: Marine Biological Association of the United Kingdom

Ballantine, W. J. 1961. A biologically defined exposure scale for the comparative description of rocky shores, Field Studies, 1 (3), 1-19.

Bassindale, R. and Clark, R.B. 1960. The Gann Flat, Dale: Studies on the ecology of a muddy beach. Field Studies 1, (2), 1-22.

Bean E.J and Appleby T.P.S 2014. Guidelines for Sustainable Intertidal Bait and Seaweed Collection in Wales: Legislative Review. A report to the Pembrokeshire Marine SAC Relevant Authorities Group, University of the West of England: Bristol. 46 pp.

Borja, A., Franco, J. and Pérez, V., 2000. A Marine Biotic Index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin, 40 (12), 1100-1114.

Burton, S. 2008. Pembrokeshire Marine Special Area of Conservation Management Scheme on behalf of the Relevant Authorities Group.

Green, M. and Camplin, M. 2014. Milford Haven Inlets Macrobenthic Monitoring 2007-2012 , Analysis. Natural Resources Wales (in preparation)

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B. 2004. The Marine Habitat Classification for Britain and Ireland. Version 04.05

Connor, D.W., Brazier, D.P., Hill, T.O., & Northen, K.O. 1997. Marine Nature Conservation Review: marine biotope classification for Britain and Ireland. Volume 1. Littoral biotopes. Version 97.06. *JNCC Report*, No. 229.

Countryside Council for Wales 2009. Pembrokeshire Marine European Marine Site: Advice Provided by the Countryside Council for Wales in Fulfilment of Regulation 33 of the Conservation (Natural Habitats, &C.) Regulations 1994

Dernie, K.M., Kaiser. M.J., and Warwick, R.M. 2003. Recovery rates of benthic communities following physical disturbance. Journal of Animal Ecology. 72, 1043–1056

Edwards, A, Garwood, P and Kendall, M. 1992. The Gann Flat, Dale: thirty years on. Field Studies 8 59-75

Farrell, P. 1996. The environmental impact of bait digging: effects on the infauna and epifauna of Chichester Harbour. Report for the Institute of Marine Sciences, Portsmouth.

Fowler, S.L. 1999. Guidelines for managing the collection of bait and other shoreline animals within UK European marine sites. English Nature (UK Marine SACs Project). 132 pages.

Howell, R. 1985. The effect of bait digging on the bioavailability of heavy metals from surficial intertidal marine sediments. Marine Pollution Bulletin, 16, 292-295.

Kaiser, M.J., Clarke, K.R., Hinz, H., Austen, M.C.V., Somerfield, P.J. and Karakassis, I. 2006. Global analysis of response and recovery of benthic biota to fishing. Marine Ecology Progress Series 311: 1 – 14.

Morrell, S.L. 2007. Assessment of bait collection activity, impact and bait resources within Milford Haven waterway. (Unpublished report to CCW)

McLusky, D.S., Anderson, F.E. & Wolfe-Murphy, S. 1983. Distribution and population recovery of Arenicola marina and other benthic fauna after bait digging. Marine Ecology - Progress Series, 11, 173-179.

Olive, P.J.W. 1993. Management of the exploitation of the lugworm *Arenicola marina* and the ragworm *Nereis virens* (Polychaeta) in conservation areas. Aquatic Conservation 3, 1-24.

Palmer, T. 1993. The Gann Flat, Dale: An Investigation into the Effects of bait Digging. M.Sc. Thesis. Bangor University School of Ocean Science

Perry F., Morris, E. and Burton, S. 2014. Intertidal Species Collection in Wales: Impacts Review. A report to the Pembrokeshire Marine SAC Relevant Authorities Group (in preparation)

Phillips, G. R., Anwar, A., Brooks, L., Martina, L.J., Prior, A. and Miles A. C., 2012. The continued development of a Water Framework Directive classification scheme for the marine benthic invertebrate component: the infaunal Quality Index. Environment Agency. 202pp

Spencer, B.E., Kaiser, M.J. and Edwards, D.B. 1998. Intertidal clam harvesting: benthic community change and recovery. Aquaculture Research. 29. 429 - 437

Spikes, M. 1993. The environmental impacts of bait digging at Lleiniog Beach, Anglesey. M.Sc. Thesis. Bangor University School of Ocean Science (not obtained)

U.S. Army Corp of Engineers. 2002. Coastal Engineering Manual, EM 1110-2-1100, U.S. Army Corp of Engineers, Washington D.C. (in 6 parts).

Watson, G.J., Farrell, P., Stanton, S. & Skidmore, L.C. 2007. Effects of bait collection on *Nereis virens* population and macrofaunal communities in the Solent, UK. Journal of the Marine Biological Association of the United Kingdom 87: 703-716

Watson, G., Murray, J.M., Schaefer, M., Bonner, A. and Gillingham, M. 2013. Does local marine conservation work? Evaluating management strategies for bait collection in the solent. A report to natural England with Funding from the Crown Estate's Marine Stewardship fund. University of Portsmouth (unpublished)

CCW[1]: *Site of Special Scientific Interest Management Statement: Milford Haven Waterway*. [Online] Available from: http://www.ccgc.gov.uk/landscape--wildlife/protecting-our-landscape/special-landscapes--sites/protected-landscapes-and-sites/sssis/sssi-sites/idoc.ashx?docid=02294e48-00d8-4610-9b1a-4492efd876db&version=-1 [Accessed: 27 November 2014]

CCW[2]: *Site of Special Scientific Interest: Operations Requiring Consultation with the Countryside Council for Wales*. [Online] Available from: http://www.ccgc.gov.uk/landscape--wildlife/protecting-our-landscape/special-landscapes--sites/protected-landscapes-and-sites/sssis/sssi-sites/idoc.ashx?docid=16eb8728-53f9-4110-908f-906bf072e6a3&version=-1 [Accessed: 27 November 2014]

CCW[3]: *Site of Special Scientific Interest Summary Citation: Milford Haven Waterway*. [Online] Available from: http://www.ccgc.gov.uk/landscape--wildlife/protecting-our-landscape/special-landscapes--sites/protected-landscapes-and-sites/sssis/sssi-sites/idoc.ashx?docid=6d009ff8-f0a2-42af-be29-17bb96457d1c&version=-1 [Accessed: 27 November 2014]

JNCC[1]: European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC). *Supporting documentation for the Third Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2007 to December 2012 Conservation status assessment for Habitat: H1140 - Mudflats and sandflats not covered by seawater at low tide.* Section 2.5 Main pressures. F02 (02.05, 03.01) - Fishing and harvesting aquatic resources. [Online] Available from: http://jncc.defra.gov.uk/pdf/Article17Consult_20131010/H1140_WALES.pdf [Accessed 27 November 2014]

JNCC[2]: MCZ Features. *Sheltered Muddy Gravels.* [Online] Available from: http://jncc.defra.gov.uk/page-6029 [Accessed 27 November 2014]

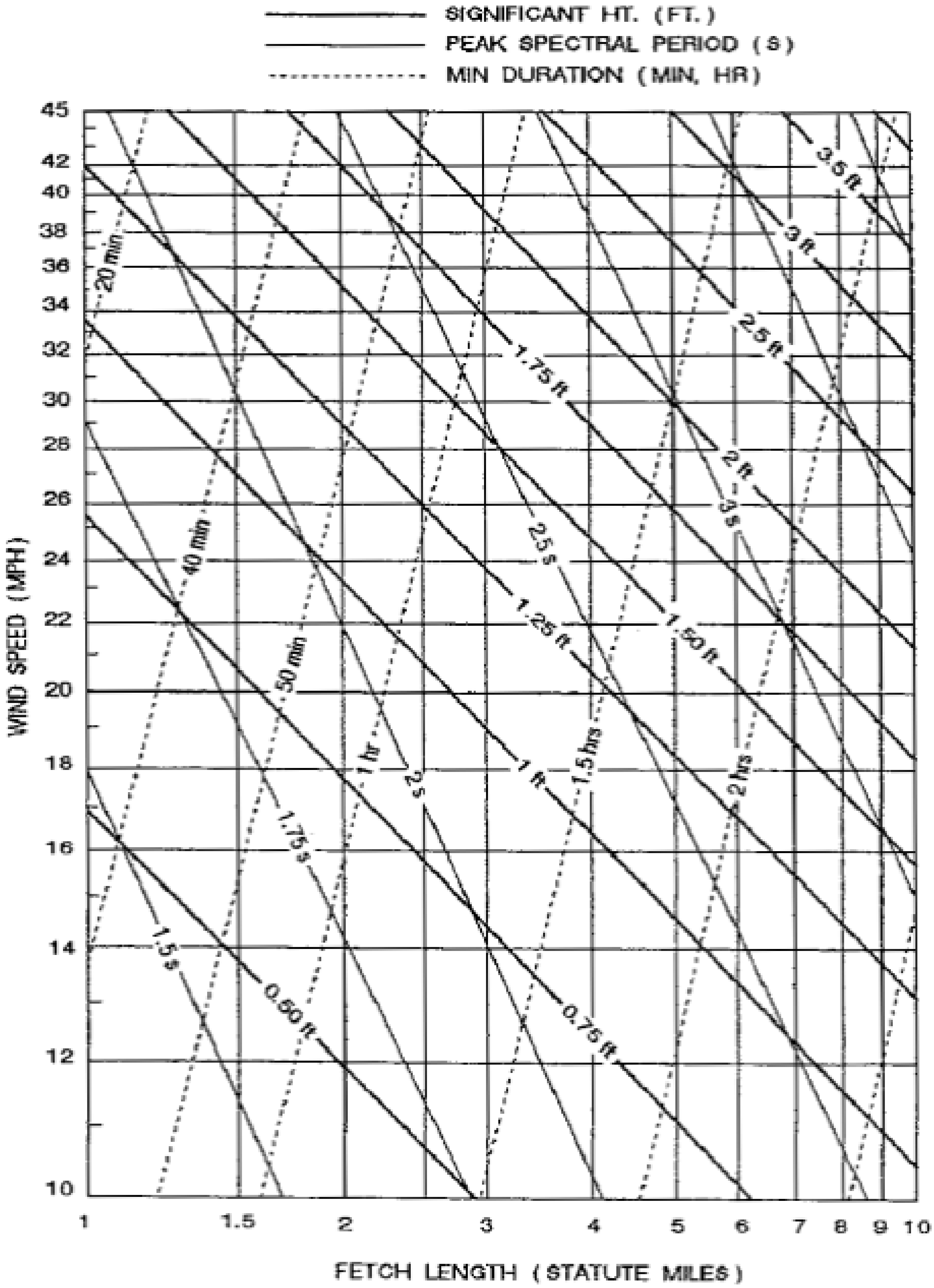
JNCC[3]: UK Biodiversity Action Plan; Priority Habitat Descriptions. BRIG (ed. Ant Maddock) 2008 (updated December 2011). *Sheltered Muddy Gravels* (p79) [Online] Available from: http://jncc.defra.gov.uk/PDF/UKBAP_PriorityHabitatDesc-Rev2011.pdf [Accessed 27 November 2014]

JNCC[4]: The Marine Habitat Classification for Britain and Ireland. *LS.LMx.Mx.CirCer -Cirratulids and Cerastoderma edule in littoral mixed sediment*. [Online] Available from: http://jncc.defra.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001583 [Accessed 27 November 2014]

Acknowledgements

The authors would like to thank Mike Camplin, Lily Pauls, Chris Lawrence, Paul Brazier, Ben Wray, Andrea Winterton, Blaise Bullimore and Sue Burton for commenting on the draft report and Helen Charlett for the formatting.

Appendix 1. Significant Wave Height Nomograph, U.S Army Corp of Engineers 2002



Appendix 2. Map of NRW Milford Haven Inlets Macrobenthic Monitoring Locations for 2007 and 2012

Data Archive Appendix

No data outputs were produced as part of this project.

Published by: Natural Resources Wales
Maes y Ffynnon
Penrhosgarnedd
Bangor
LL57 2DW

01248 387220

© Natural Resources Wales 2015

All rights reserved. This document may be reproduced with prior permission of Natural Resources Wales

Further copies of this report are available from the library

Email: library@cyfoethnaturiolcymru.gov.uk