Fanore Beach and Dune Management Report: Current Problems and Planning for the Future

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(Report Commissioned by: Burren & Cliffs of Moher Geopark Tourism for Conservation LIFE Project, LIFE 11/IE/922, Clare County Council.)

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(Front page photographs: Devoy, R.J.N. (2016) Road sign to Fanore on the R477; Devoy, R.J.N. (2012) View north westwards over the Fanore beach and dune system, NW County Clare, Ireland.)

EXECUTIVE SUMMARY

In December 2015 GeoparkLIFE (The Burren & Cliffs-of-Moher Geopark), with Clare County Council (CCC), commissioned a Study of the Fanore Beach and Dunes. This was to examine and report on the following main themes:-

i. The current operations of coastal processes and linked environmental changes at Fanore;

ii. The erosion and sediments movements in the beach and dune-front areas;

iii. The likely impacts of future climate warming on the Fanore area;

iv. The current state of and needs for Site infrastructure, protection and conservation measures;

v. The implications of climate warming impacts for the future management of the Site.

Two site visits were made covering a period of 3 days (between December 2015 and May 2016) to undertake field reconnaissance and information gathering, as the basis for subsequent Site data update on earlier Reports for the area, and development of this Report.

Conclusions on the Site functioning are, that it is relatively stable at the present time, in spite of apparent dune-front and beach area erosion since c. 2000. Coastal sediments appear to be remaining within the Fanore embayment and moving back onshore after significant storm erosive events. Following appraisal of climate warming impacts on the area from recent research literature sources, indicate that the Fanore beach and dunes are very likely to move onshore at an increasing rate, particularly as driven by rising sea-levels by 2050 and beyond. Sediments released from the future re-organisation of these environments will spread north and south from the Site, as controlled by the Burren Limestone escarpment to the immediate east of Fanore Beach. Sands are likely to cover adjacent farm lands and also impact on the main north - south R477 highway; creating new dune forms and landscape.
Recommendations for actions at the Site include:-

i. Renewal and re-organisation of present Site protection and conservation infrastructures (e.g., fences, beach stairs, walkways).

ii. Development of additional Site Visitor facilities, given likely significant future increases in recreational uses of this area, as part of the Burren and its Geopark.

iii. Upgrade of Site Interpretative Displays and other signage.

iv. Increased involvement, through education programmes and continued Site studies – monitoring, of the local community, schools - third level students and Visitors in *building capacity* for uses of the area, under climate warming impacts.

v. Integrated review of the DoECLG - NPWS, CCC, Geopark and linked organisations, as devolved to local levels, of appropriate coastal and wider environmental management and particularly conservation policies. This to take serious account of the impacts of future climate warming in Ireland.

1.0 INTRODUCTION: WORK BRIEFS FOR REPORTING ON THE FANORE SITE

This study was commissioned by GeoparkLIFE under the *Burren and Cliffs-of-Moher Geopark Tourism for Conservation LIFE Project, LIFE 11/IE/922*, Clare County Council. A document for, *Fanore Dunes and Intertidal Zone Protection and Management Plan: Tender Request*, was plublished/ advertised 22 September 2015, detailing the aims and an accompanying brief for a Fanore Dunes and Beach Management and Planning Report (as in 1.1 here) (Fig. 1). A subsequent meeting took place on 3 December 2015, with members of MaREI, University College Cork (Prof. Robert Devoy and Dr Jimmy Murphy), in order to view and to meet with representatives from GeoparkLIFE (Ms Zena Hoctor) and the Engineering Division, Clare County Council (Mr Steve Lahiff), at which the problems of the Fanore beach and dune systems' management were discussed. Subsequently, a separate brief for a management report for the site was agreed (as in 1.2 here) which established the aims and basis for this smaller scale study. The report is to pay particular attention to the following:- the beach and linked dune-front erosion experienced since c.2003; the management measures and practices in operation and the likely future environmental protection and conservation needs for the beach and dunes areas. An initial visual inspection of the Site, dune-complex and adjacent land areas, was completed with Ms Hoctor and Mr Lahiff.

1.1 GeoParkLIFE Tender Document
(Issued by Clare County Council, 22 September 2015)

"The Burren and Cliffs-of-Moher Geopark, a Clare County Council initiative, manages the Burren Tourism for Conservation LIFE Project (LIFE11/IE/922). The aim of this LIFE project is to strengthen the integration of tourism and natural heritage, reconciling tourism development with conservation of geology, biodiversity and cultural heritage in the Burren area of Co. Clare. The innovative aspect of the Project will be to advance tourism for conservation as a European methodology of value to local communities. This will aim to be a strong demonstration project with pilot actions being stimulated to test the use of tourism for conservation in the Burren. For further information on the GeoparkLIFE programme please go to www.burrengeopark.ie

The GeoparkLIFE programme is focused on 3 areas:-

1. Developing a sustainable ethos and practices amongst a critical mass of tourism businesses
2. Demonstrating integrated management practices at a selection of sites and monuments
3. Strengthening community and policy support for the conservation of natural and cultural heritage.

As part of this work, the conservation and visitor management of Fanore dunes and beach are being highlighted.

In order to progress this work, consultant(s) are currently being sought to assess the current condition and usage of the publicly owned lands (Clare County Council) at Fanore Beach including the car park, sand dune system and intertidal zone (Figs 1a, b) and subsequently prepare a comprehensive management plan to address identified site issues.

1a.

1b.

Figures 1a. Location of Fanore-Murroogh, Co. Clare and, 1b. The Fanore beach - dune project Site, outlined in red (Source: OSI air photograph & GeoparkLIFE Tender Document).

Scope of Work Required:

It is proposed to appoint a consultant(s) to undertake the following:-

- Summarise and update key data relevant to this site,
- Inform on the current condition of the site with special emphasis on the dune system and intertidal zone,
- Assess the effectiveness of conservation works carried out to date and recommendations made in previous conservation reports prepared for the site including,
    - Dr A. Browne 2003 '*Habitat Survey of Fanore Dunes'* Clare County Council;
    - Dr A. Browne 2007 '*Fanore Monitoring Programme – An outline'* Clare County Council and
    - E. Keegan 2008 '*Fanore Dune Monitoring*' Clare County Council,
- Identify and distinguish between the impacts caused by visitor recreational use, wildlife, livestock and by natural causes (storm damage, climate change),
- Prepare a site management plan and make recommendations for any remedial works required,
- Prepare a visitor management plan to address issues to include parking, interpretation, signage and access (this will involve consultation with a universal design project being conducted by the Burren & Cliffs of Moher GeoPark in partnership with the National Disability Authority at various sites in the Burren, including Fanore),
- Provide costings and a phased work plan for site and visitor management plan. Identify any permissions/planning required.

The consultant(s) will work closely with the GeoparkLIFE Steering group appointed to the project.

1.2 Work Brief and Objectives for a Fanore Beach - Dune Systems Management Report, MaREI, University College Cork

This report is to address the current and potential future issues in the management of the beach-dune systems of Fanore (Figs 1 - 3) and to make recommendations for actions needed.

Study Elements are to address the following:-

1. Assessment of the sediment flows and hydrodynamic processes operating at the site, from the nearshore - beach areas and as linked to the contiguous dunes,
2. Assessment of the current condition and functioning of the beach-dune system, including habitat status, and of the sand-sheet and farmed areas developing eastward to the R477 road and the base of the limestone upland of the Burren which limit the site,
3. Assessment of the value and effectiveness of the present dune fencing, sand-trap and other management techniques that have been used in the beach-dune area. Much of the 'fencing' and linked infrastructure is now degraded and undergoing storm-driven erosion at the shoreface, as well as other threats of loss, particularly from people pressure,
4. Evaluation of the measures currently in use to manage people's access to the beach (e.g., board-walks) and to restrict unwarranted movement into the dune areas (e.g., fencing),
5. To recommend the use and options for any future remedial measures needed (including 'soft' and /or 'hard' engineering techniques, as appropriate) to help stabilise the shoreface and 'front edge' of the dunes, as well as the interactions with the channel of the River Caher which cuts through the site,
6. To recommend the need and options for the management of the main sand dunes and wider site area, including consideration of the possible renovation of fencing and walkways, or the innovation of other management techniques,
7. Evaluation and recommendations on site monitoring and data gathering to allow effective future planning of the dune system. This would be linked to consideration of the use of the area for environmental education (i.e., school student and wider community involvements, e.g., in monitoring activities, project work and as liked to item 8.),
8. Evaluate and recommend for the medium to longer terms (decadal scales, 2030 - 2050) the likely future impacts of climate warming on the beach and dune environments, particularly the implications these will have for planning and policy development by the regulatory bodies (e.g., Clare County Council, NPWS). Consideration would be given to the development of the area as part of a Geopark and of the wider tourism impacts and needs, e.g., part of the Atlantic Way and growth of beach tourism.

2.0 METHODOLOGY

In order to provide information for the further development of a Fanore beach and sand dunes systems' management plan, and for linked areas, it was deemed necessary to:-

2.1 Determine the management approaches employed historically at the site and evaluate the current status of the dunes and identify any patterns of change. This was undertaken through:-

i. Review of relevant and appropriate literature,
ii. Initial site visit with field and reconnaissance work. This to be followed by subsequent site visit(s) with visual inspection, photography and linked field-technique surveys, to update existing map and air photographic information; acquire data for any changes of shoreline positions using GPS-mapping techniques; assess the current state and evidence of the beach and linked dune systems' functioning and uses (e.g., for sediments and sedimentary movements, erosion of the beach, dune front and interior vegetation covers, site ecology, animal and human impacts, positions of existing site fencing, coastal protection measures, buildings and tourism facilities, site signage, roadways, footpaths and access points).

A review was conducted of existing reports and associated literature on the site beach and dune systems, dune degradation and dune protection measures at Fanore and for adjacent coastal areas of the Murroogh . This was essentially a desktop review of all materials (published materials, grey literature and website sources) that could be gathered from sources, including Clare County Council, Environmental Protection Agency, Failte Ireland, National Parks and Wildlife Service and relevant Government Departments.

Field visits were undertaken in December 2015 and more detailed work in May 2016, in order to determine the existing usage of the dunes, dune erosion – degradation patterns, shoreline and dune-front positions, use of signage, state of the site fencing and of any coastal protection beach infrastructures (e.g., stairway and paths), visitor facilities, established walking routes and 'rights of way'.

2.2 Gather all relevant data sources (e.g., OS maps and air photographs) and utilise a Geographical Information System (GIS) - mapping basis to define, e.g., shoreline variation(s), site fence positions and land use patterns. A Global Positioning System (GPS) was used to survey access points and walking routes. The relevant geospatial holdings were collected and collated in a local GIS-map base (OSI Map Genei and ESRI Software).

2.3 Analysis and assessment of site environmental functioning and management issues resulting from use by people of rock-cliffed to linked, soft sedimentary and sand dominated dune coasts (Carter, 1988; Messelink et al., 2011). This

was based upon expert review of relevant local, national and international literature, together with fieldwork carried out with 2.1 and 2.2.

2.4 Provide 'scenario(s)' of likely future changes to these Earth beach and dune systems at Fanore, as based upon expert knowledge of the impacts of climate warming and linked Earth process - environmental, social and economic changes for Ireland[1].

2.5 Recommendations for future immediate site infrastructural needs and for the development of management and planning of the site (Fanore beach and dunes) which are under public ownership and the control of Clare County Council. These are based upon expert understanding of appropriate and 'best practice' approaches in the use, management and planning of coastal systems.

To identify best practice in management approaches a general review of contemporary literature was conducted. This included reference to national and international management techniques in beach and linked sand dune protection and conservation measures, control of use and access by people access, signage and fire control. Contact was also be made with established professionals to ensure that recommended practices were up to date and successful.

3.0 SITE DESCRIPTION, CHARACTERISATION, PROCESSES, IMPACTS AND ANALYSIS

3.10 Site Description, Geomorphological and Wider Environmental Context

Fanore beach and sand dunes, Ordnance Survey Ireland (OSI) Grid Reference (GR) M104008 are located c.3 km south of Black Head, Co. Clare (e.g., OSI Discovery Map Series, Number 51)[2] (Figs 2a, b). The dunes are part of the larger Murroogh area dunes, which in turn comprise a major element of the Blackhead - Poulsallagh Special Area of Conservation (SAC) (SAC 000020)[3]. The site is situated on the northwest coast of County Clare, within the Burren region and is backed immediately (<1km) by the Carboniferous Limestones and Karst uplands of the Burren[4]. These uplands rise eastwards in a series of low angled, stepped planar surfaces to reach heights of >300 m at Gleninagh Mt. (GR M107100) (Figs 3a, b). This topography and geomorphology result primarily from the regional geology and associated rock characteristics, with horizontally structured and massively bedded

[1] e.g., Dwyer, 2012; Desmond et al., 2015; O'Dwyer, 2016).

[2] Davies & Stephens, 1978; Robinson, 1977; Burren National Park, 2016

[3] Ryle et al., 2009; National Parks & Wildlife Service, 2014

[4] Whittow, 1974; McNamara, 2009; McNamara & Hennessy, 2010; The Burren and Cliff of Moher Geopark, 2016

Limestones (with beds commonly >50 m thick) (Figs 4). The dune system between Fanore and Murroogh covers an area of c.1 km^2, with the escarpment slopes of the Burren forming its eastern limit (Figs 3-4). The regional coastal background to the site is comprised of a range of environments: these include, rock-cliffed and rock-platform coasts; extensive intertidal limestone reefs; 'soft' glacigenic cliffs with fronting boulder beaches (Fig. 5a-c); coarse clastic (boulder and cobble sized) 'storm' beaches (Fig. 5d-e); dune-front slopes and 'cliffs'; small scale (<200-300 m long, approximately north to south aligned) rock-headland controlled crenulate bays, as found at Fanore (viz. cover photograph); larger Bay - Headland wave dissipative, sand- beach systems, with backing sand dune barriers, as at Lehinch, south Burren region (Fig. 6a-d).

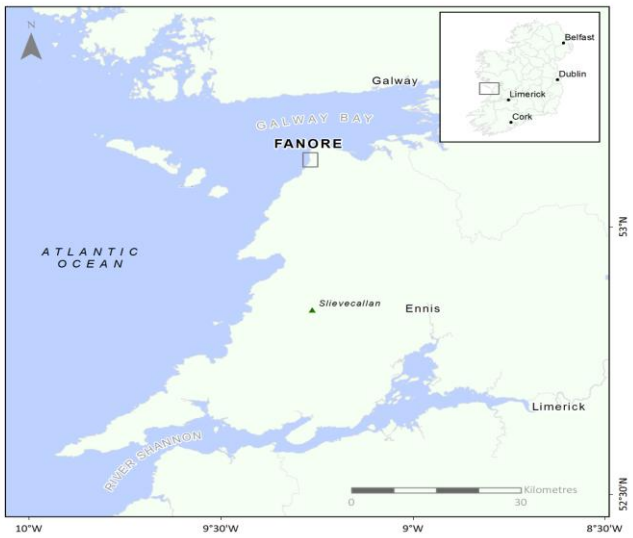
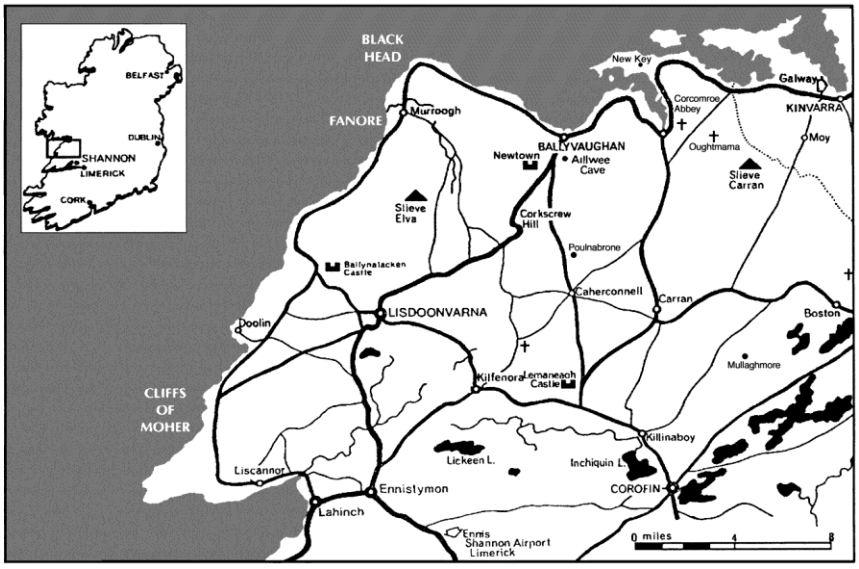


Fig. 2a.



Figures 2a. and 2b. Fanore - Murroogh location in the Burren, County Clare, Ireland (Fig. 2b. Source: Open web).

Figures 3. Air photograph of the Fanore beach - dune Site and the wider Burren area. Photographs show the beach area (left of photos), the backing sand dunes and the course of the Caher River through the site from the Limestone uplands (photos right to centre). Centre of the photographs shows the coverage of the dunes on the northern part of the Site by a Caravan-Trailer Park and service road network. The centre - bottom right shows the Limestone upland of the Burren, with the main road (R477) marking the escarpment base of this upland and the effective eastern limit of dune sands (Source 3b: Ordnance Survey of Ireland).

Fig.4a.

Fig. 4b.

Fig. 4c. 

Figures 4a-c. Massive and horizontal bedding, characteristic of the Burren Carboniferous Limestones. 4a. At Moneen Mt., Ballvaughan; 4b. At Poulsallagh, c.8km south of Fanore; 4c. At the entrance to Fanore Beach, bedding seen the upland Limestone escarpment slopes, which form the eastern limit to the Fanore dune sands.

Fig. 5a. 

Fig. 5b. 

Fig. 5c. 

Figures 5a-c., 5a. View southwards from Poulsallagh, showing Limestone Pavement, geologically structured Rock Platforms (photograph centre) and the rock-cliffed coast of the Burren; 5b. Limestone reef and pavement exposures from beneath covering beach sands, Fanore; 5c. Soft-sedimentary glacigenic cliffs and linked boulder beaches, Fanore area.

Fig. 5d. 

Fig. 5e. 

Figure 5d-e., 5d. Coarse clastic (cobble - boulder sized) sediments, Doolin area: coast view is to the northwest; 5e. Storm-driven boulder beach at Poulsallagh, south of Fanore.

Fig. 6a. 

Fig. 6b. 

Figure 6a-b., 6a. Dune-front sands and cliff, Fanore; 6b. Fanore Beach (May, 2003), showing a narrow and quasi- dissipative type beach. The underlying structural geology, with 'horizontal' limestone bedding, forms an important control to beach width rather than simply the volume of sediment accumulation (Carter & Woodroffe, 1994). Limestone Rock Reefs outcrop within the Bay, indicating a relatively shallow depth of sands above bedrock (Source: Browne, 2003).

Fig. 6c. 

Fig. 6d. 

Figure 6c-d., 6c. Fanore Beach (May 2016), view north to rock - boulder boundary headland; 6d. Lehinch, Liscannor Bay, view north over and along the beach-dune barrier. Rip-rap, rock armouring and backing concrete revetment walls, as coast protection - defences, are shown in front of the dunes and the northern end of the town.

3.2 Nature of the Beach Environment and Physical Systems

In many of these bay environments (small to large scales) coarse to finer sediments (e.g., boulder - cobble to gravels - sands sized) may occur at the head of beaches (i.e., upper part of

the intertidal zone), as seasonal coarse clastic fans - sheet spreads and/ or, as structured back-beach boulder frames and berm barriers. In front of these are developed low gradient (<1^0) dissipative beaches, often <100 m wide (as distance to LWM) and upwards to c.150 - 300 m wide, as in the south Burren region (Figs. 6b-d). These foreshore and main to lower intertidal beach areas are dominated by medium to coarse sized sands (Fig. 7), as at Fanore. Some may have seasonal (Winter - Spring) exposures of underlying materials, e.g., of rock (as reef type areas), boulder lags (from eroding glacigenic sediments) and in some locations, biogenic sediments (i.e., peats)[5] derived from the retreat of the blocking beach-barrier and dune systems, exposing these formerly protected back-barrier sediments (Fig. 8).

Figure 7a. Fanore Beach (upper to mid beach levels), showing the dominance of sands sized sediments.

[5] Carter, 1988; Randazzo et al., 2015

Figure 7b. Fanore Beach, sands comprised of medium - coarse sand size ranges, together with the occurrence of fine gravel to occasional pebble sized sediments.

Fig. 8a.

Fig. 8b.

Figure 8a-b. Fanore Beach, showing exposures of, 8a. limestone reef and pavement and, 8b.boulder lags.

The sands and the coarser sediments found on the beaches and dunes are probably of initial glacigenic origin. Following release of the sands from their current seabed sources offshore, through water - wave erosion and bottom current action, these sediments have been moved onshore overtime. This movement has been driven primarily by postglacial sea-level rise (SLR) and the control of the dominant southwest - westerly wind-wave regimes on these high energy, Atlantic coasts[6]. The sands are now likely to be added to from present day coastal erosion, from beach and cliff sedimentary sources[7]. Where the backing land surface heights and topography is suitable then sand dunes have formed. These may develop over extensive areas of the coast if the sediment supply, wind - wave energy regime and topography allow. Alternatively, they may be limited by the topographic - relief and geological controls, together with coastal process factors, to form as beach and dune-barrier systems. The coastal systems at Fanore have been characterised by some as, 'dunes developed over a former gravel beach'[8]. It is likely though that the site is more complex and formed as part of a larger offshore beach and dune barrier structure that migrated onshore, with progressive 'ramping' of the dune sands under wind action onto the higher landward limestone surfaces.

The dune systems developed within the bays of the Burren region, and wider in Southwest - Western Ireland, are varied in morphology and structure, reflecting the different dominant

[6] Devoy et al., 1996; Lozano et al., 2004; Delaney et al., 2012; Devoy, 2008, 2015; Kandrot, 2014, 2016; Kandrot et al., 2016.

[7] MIDA, 2016; Institute of Engineers, 2016.

[8] Delaney et al., 2013; NPWS, 2014.

coastal processes operating at particular locations[9]. At Lehinch (Fig. 6d), the larger end-scale bay and dune-barrier system is developed at the estuary mouth of the River Inagh, which drains with its tributaries the southern area of the Burren; contributing sediments from the river catchment to this site and possibly along coast. The Fanore beach and dunes area is an analogous, but smaller scale and a more topographically controlled type of system. These Bay - River estuary blocking barrier sands systems (varying scales) are common on Ireland's coasts, developed as extensive transgressive, on-shore 'rolling' beach-barrier structures (Fig. 9)[10], e.g., Portmarnock - Rush (north Dublin Bay); Tacumshin - Lady's Island (Wexford); Longstrand (West Cork); Derrynane Bay, Dingle Bay, Tralee Bay and Ballyheigue (Kerry)[11].

[9] e.g., Carter, 1988; Carter and Woodroffe, 1994; Devoy et al., 1996.

[10] e.g., Cowell & Thom, 1994; Woodroffe, 2002.

[11] Carter et al., 1989; Gault et al., 2007; Orford et al., 1988,1997; Cooper & Jackson, 2015; Randazzo et al., 2015; (Cooper et al., 1997; O'Shea & Murphy, 2013; O'Shea, 2015; Science Direct Report, 2013; Devoy, 2015a; Kandrot, 2016; Kandrot et al.,, 2014, 2016).

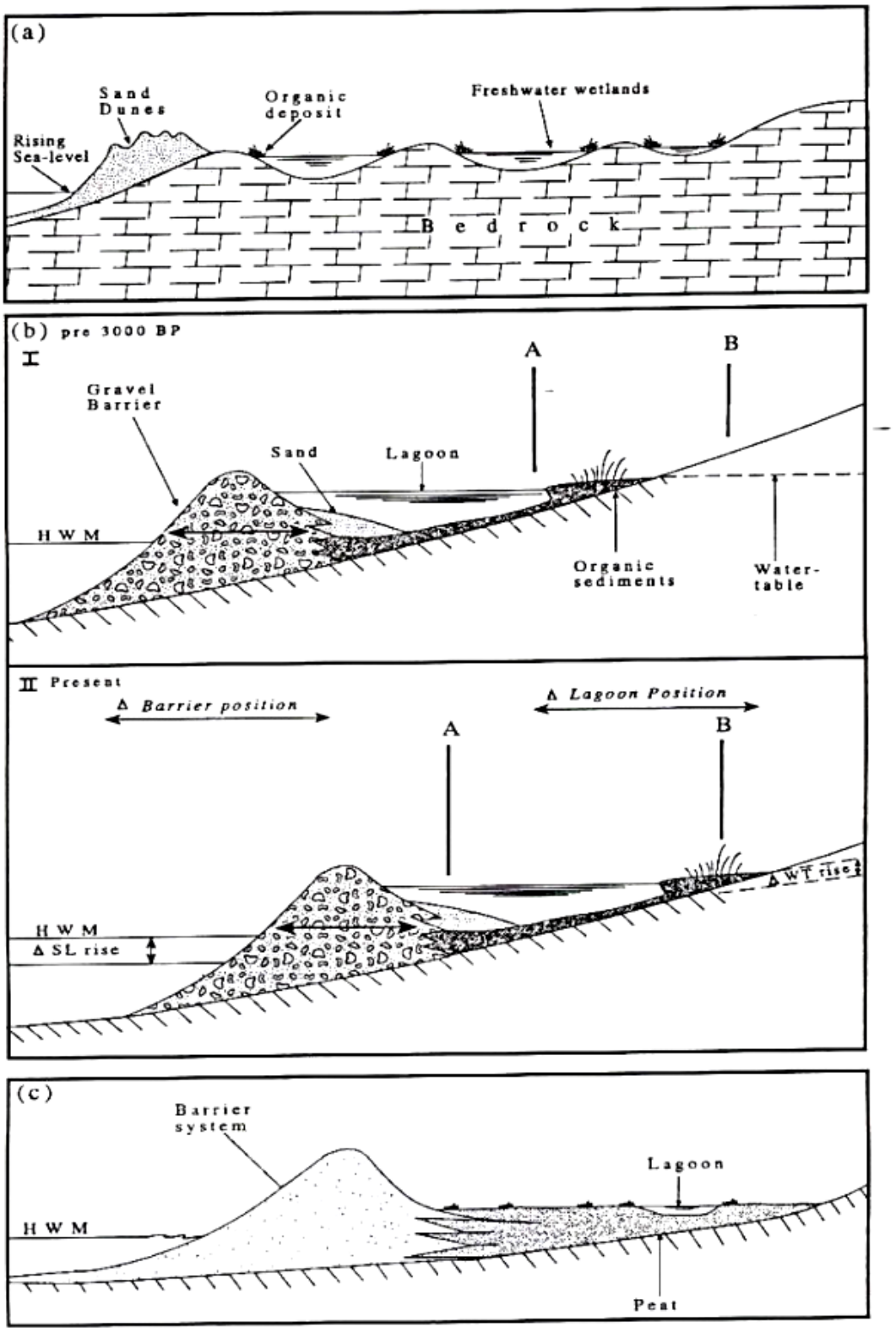


Figure 9. A conceptual model of onshore beach-barrier onshore movement under Holecene sea-level rise, West coast Ireland (Source: Devoy et al., 1996).

3.21 The Site

The beach system and backing dune-front at Fanore form in a small coastal embayment (Bay) (c.1.1 km wide), running approximately north - south and covering an area of c. 63 ha[12] (e.g., Figs 6b-c, 7, 8 & 10). The Bay is defined by low rock (Carboniferous Limestone Series) controlled headlands, on an otherwise boulder - cobble beach and rock-cliff dominated coastline. The northern headland(s) to the embayment define the outlet to the Caher River which exits through the beach area (Fig. 11) There is no contemporary estuary here, only a gravel - boulder based river channel (c.20m wide at beach end). The river channel form, and the wider topographic low of the embayment area, results from rock structural causes coupled with river down-cutting and erosion, development of the associated limestone drainage patterns and glacier scouring – rock excavation.

Figure 10a. The Fanore Beach - Dune Site, view to northwest over the crenulate coast, with bay-headland type morphology constraining beach and sand dune sediment accumulation.

Sediments supply to the Bay from this river source is likely to be low throughout the year, in spite of relatively high rainfall and seasonal discharge levels (the earlier soil cover has gone in the main from the limestone uplands and much of the catchment is vegetated). Water discharges from the river are controlled by the limestone hydrology and flows are frequently low and seasonally dominated[13].

[12] Ryle et al., 2009; Delaney et al., 2013; NPWS, 2014.

[13] Drew, 1990; McNamara & Hanley, 2010; NPWS, 2014; McCormack et al., 2014; Burrenbeotrust, 2016.

Figure 10b. Air photograph (Source: OSI) of Fanore, showing the main areas A - C are in public ownership (Clare Co. Co.) and constitute the Site in this report: area A is the main intertidal to upper shoreline zone; B is the area of mobile, "White Dunes", merging into C (dashed blue line), as the areas of fixed, Grey Dunes and Dune Grasslands - meadow. Area D is an integral part of this Dunes complex (under the SAC), but is in private ownership and is used extensively for long-term mobile homes and caravans. Other areas contiguous with A - C constitute farmlands, also in private ownership.

Fig. 11a. 

Fig. 11b. 

Figure 11a. - b. Outlet channel of the Caher River at Fanore Beach. The channel is dominated by cobble – boulder sized sediments.

Consequently, sediments moving into the accommodation space created by the Bay are trapped and continue to move on-land under onshore wind-wave action to form the dune complex. Sands within the Bay are characterised by fine - medium sediments size ranges (0.006 - 0.6 mm), as commonly found on Ireland's western coasts[14]. Continuous conveyor-belt like movement of these sands over time has allowed them to move up over relatively high ground and extend in part over the headland areas. The beach and dunes are controlled primarily by the onshore supply of sediments, and particularly here, the rock structure and the morphology of the underlying limestone surface.

Much of the Site is found overlying limestone pavement, which shows the operation of water solutional weathering (Karst processes), common to the Burren (Fig. 12). Areas of this pavement are found outcropping from beneath the dunes. Erratics are also found within the dunes[15]. The limestone surface in the region has been dissected by ice scouring during the Late Quaternary, which has added to the topographic control on sand deposition at Fanore. Glacigenic sediments also occur at the Site and in places underlie the dunes[16]. More extensive areas of limestone pavement, showing evidence of former ice movement across the area are developed in coastal areas to the south (Fig. 12).

Figure 12. Limestone Pavement and degraded solutional features in the Fanore area, with a glacier-transported rock erratic lying on top of the pavement. These are common geomorphological features of the Burren, Geopark landscapes.

[14] e.g., Science Direct, 2013; Devoy, 2015a.

[15] Ryle *et al.*, 2009.

[16] Edwards & Warren, 1985; Ehlers & Gibbard, 2004; Knight et al., 2004.

The Fanore Site has a range of dune forms and a diversity of environmental settings (Figs 13 & 14)[17]. This Report shows the occurrence of six primary habitats/ vegetation communities and linked physical systems: of category1210, Annual Vegetation Drift Lines; 1220, Perennial Vegetation of Stony Banks; 2110, Embryonic Shifting Dunes; 2120, Marram Dunes (White Dunes); 2130, Fixed Dunes (Grey Dunes), which are of highest habitat and conservation priority, and 8240, Limestone Pavements (found in association with the sand dune habitats)[18].

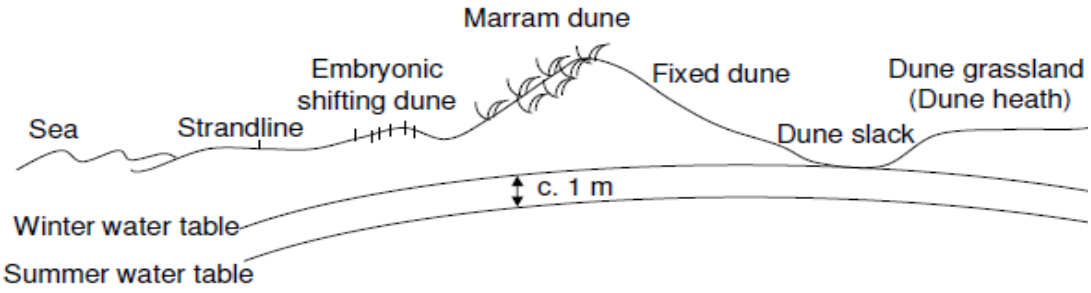


Figure 13. Coastal Dunes showing an idealised sea to land plant and associated habitats succession (Source: Delaney et al., 2013). The Dune Slack environment is currently absent at Fanore, but may have been there in the postglacial and could redevelop under climate warming conditions. The dominant habitats are those of the Fixed Dune Grasslands (Grey Dunes) c.62ha, with a small component c. 0.4ha of Embryonic Shifting Dunes (mobile/ Foredune) dunes.

Low foredunes (c.1 m high) (EU Annex I Habitats 1210 and 2110, Ryle et al., 2009) are developed at the head of the present beach-bay area (Figs 6a-b, 8), forming in response to contemporary storminess and wind action. These are backed by 'condensed' shore-parallel dune ridge structures, reaching heights of >4-5 m above beach levels, forming areas of continuing sand movements, supporting Marram and Lyme grass dominated plant communities (Figs 13 & 14). These represent the landward elements of past coastal positions and sand accumulation during the late Holocene (i.e., last c.4,000 years). The Dune Slack environment (Fig 13) is currently absent at Fanore, but may have been there in the postglacial and could redevelop with future area water table changes, higher rainfall conditions and SLR under climate warming. Eastwards these dune structures have degraded through wind action and now form areas of low sand hills (<1-2m high), becoming effectively a sand sheet eastwards, forming vegetated Fixed Dune Grasslands (Grey Dunes, Habitat 2130), with a range of grass, calcicole and other herb dominated plant communities[19].

[17] Ryle et al., 2009; NPWS, 2014; Delaney et al., 2013.

[18] Ryle *et al.*, 2009; NPWS, 2014.

[19] Ryle et al., 2009; Delaney, 2014.

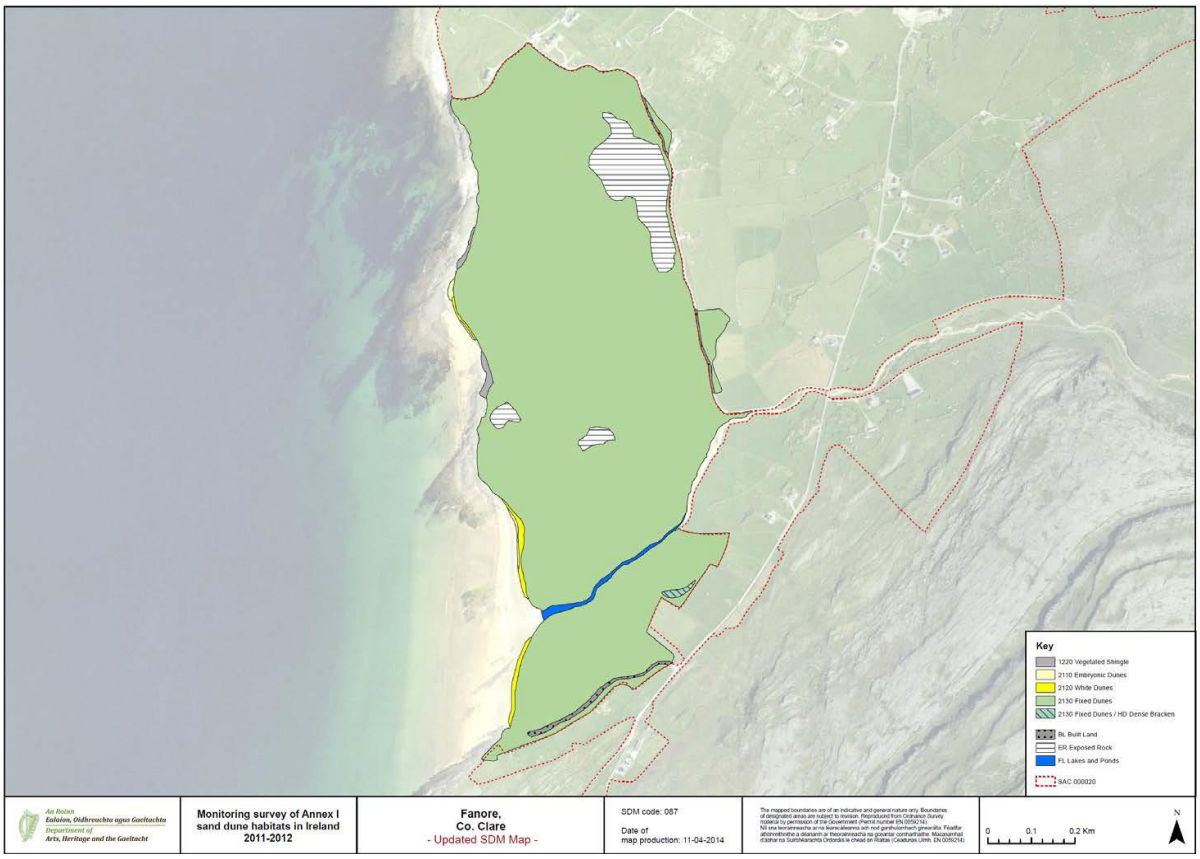


Figure 14. The Fanore Area, showing the Five Annex I sand dune and linked habitats recorded at the Site during the Coastal Monitoring Project (Source: Ryle et al., 2009). KEY: Dotted red line = SAC 000020; Blue = Rivers, Lakes & Ponds; White with horizontal black lines = Exposed rock; Dotted grey = Built land; Green = 2130, Fixed Dunes; Hashed Green = 2130, Fixed Dunes/ dense Bracken; Yellow = 2120, White Dunes; Pale Yellow = 2110, Embryonic Dunes; Grey, at the coast = 1220, Vegetated Shingle. (See original publication for higher resolution of the key.)

3.30 Fanore Beach Processes

Fanore embayment is controlled by a hydrodynamic regime driven predominantly from a southwest to west wind - wave regime (c.200 - 280^{o}) and linked nearshore current components[20] .

[20] Clifford, 2002; Lozano et al., 2004; Dunne et al., 2008; Dwyer, 2012; Gleeson et al., 2013; Marine Institute, 2015; Gallagher et al., 2014, 2016; O'Brien et al., 2014.

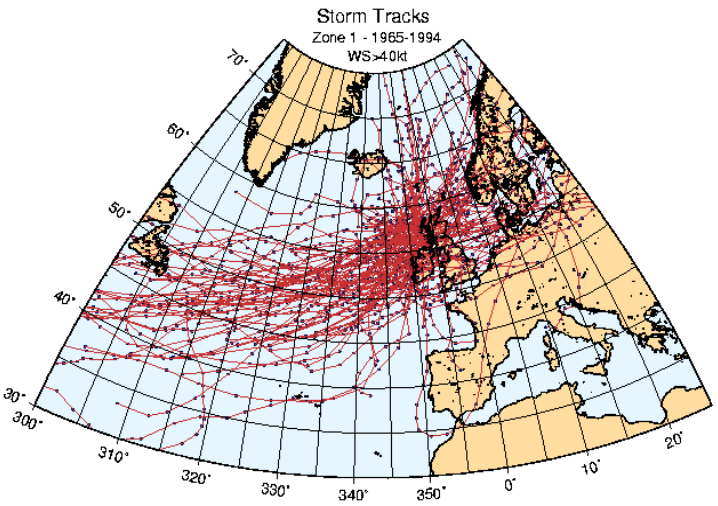


Figure 15a. Focus of major extra-tropic storms in the North Atlantic on Ireland (Source: Lozano et al., 2004).

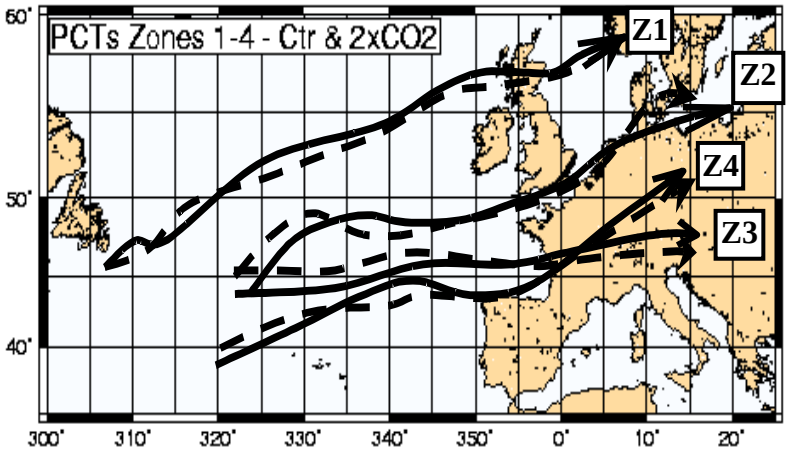


Figure 15b. Principal tracks of major storm (cyclones) movements under present conditions (solid black line) and of a warmed future climate (dotted line), indicate Ireland's western coasts receiving wind wave energy from two main storm corridors Z1 & Z2 (Source: Lozano et al., 2004).

The embayment receives the impacts of full Atlantic storm wave energy, with this site and adjacent coasts experiencing averaged winter monthly wave heights of c.4-5.5 m (Fig. 15)[21]. Storm surge events, particularly from September - April, produce even higher wave conditions, commonly >1m additional wave height elevations, as illustrated in the highly destructive multiple surge events of Dec. - Jan. 1989/ 1990 and similarly Dec. - Feb. 2013/ 2014[22].

[21] Orford, 1989; Vijaykumar et al., 2003; Devoy et al., 2004; Gallagher et al., 2014, 2016.

[22] Devoy et al., 1996; Dunne et al., 2008; Lowe et al., 2009; Jenkins et al., 2009; Devoy, 2015a.

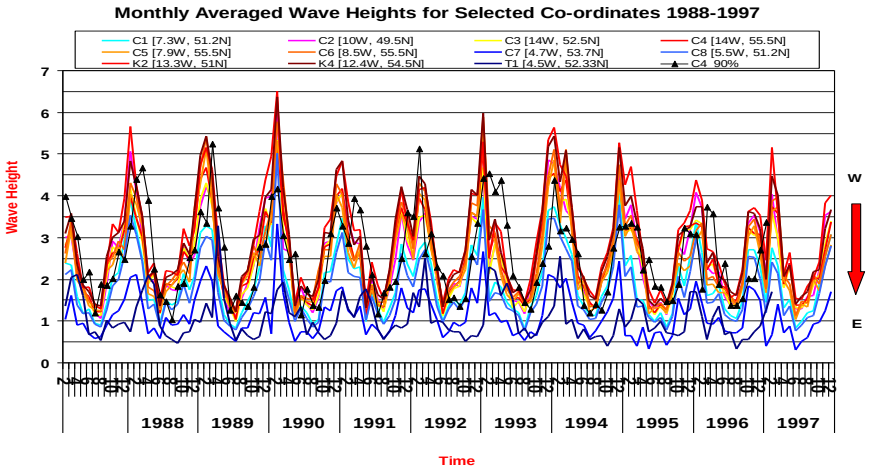


Figure 15c. Example of monthly averaged significant wave heights (in metres) around Ireland's coastal waters, based upon wave buoy and hindcast high resolution modelled data. Western coasts ('red' lines) show highest wave conditions and receipt of maximum wave energy on western coasts (West - East coasts) (Vijaykumar et al., 2003, Devoy et al., 2004).

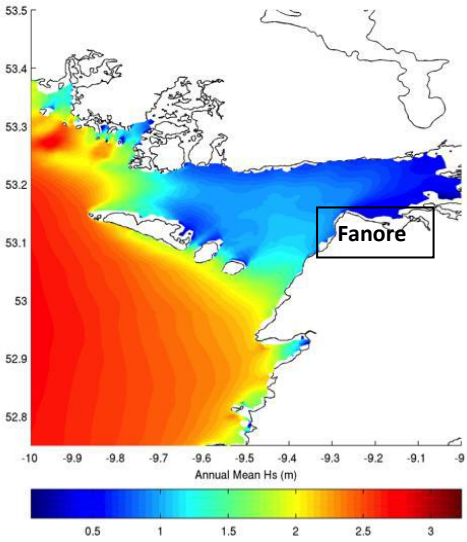
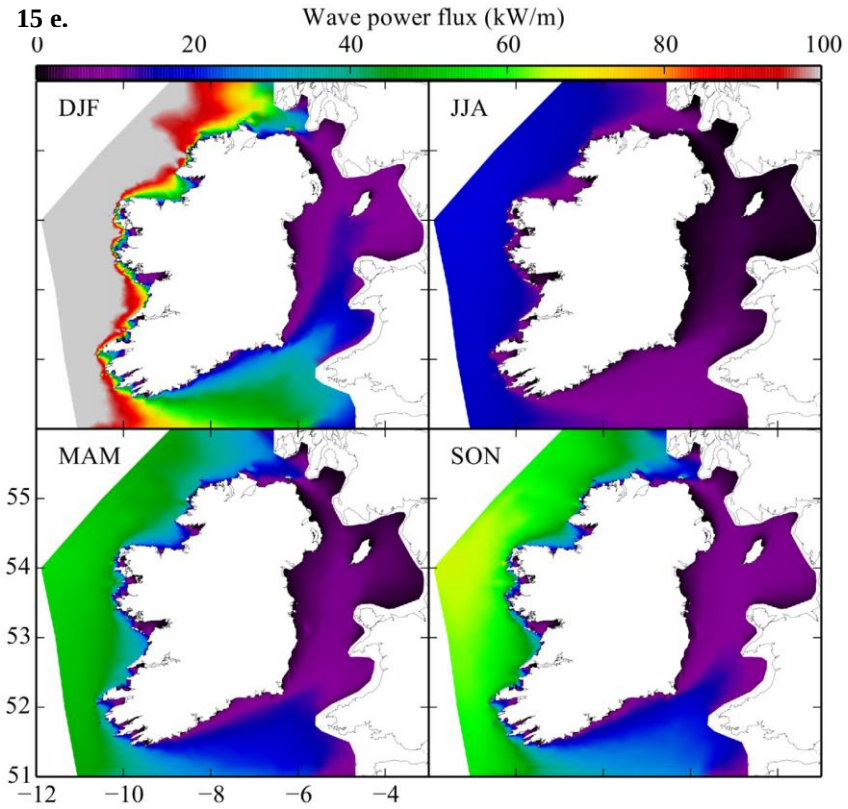
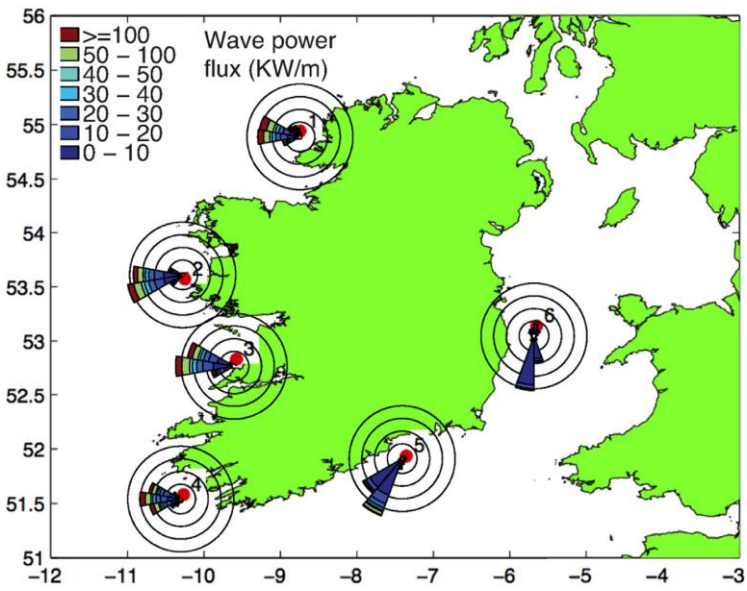


Figure 15d. Significant annual mean wave height climate (Hs) impacting the Fanore, North Clare region, based upon modelled hindcast records, 1979 – 2012. These data are consistent with the larger scale record in 15a. (Source: Gallagher et al., 2014).

15 e.



15 f.



Figures 15e. - f., 15e. Seasonal averages of wave power per metre of wave crest (kW/m) for Ireland; 15f. Directionality of the wave energy resource. Histograms of the maximum directionally resolved wave power per metre of wave crest at 6 locations around the Irish coast. The circles mark the 10 %, 20 %, 30 % and 40 % frequency of occurrence levels. (Source: Gallagher et al., 2014, 2015).

The wave and associated currents together produce net northerly sedimentary movements along the coast from the Cliffs of Moher and Doolin to Blackhead (Fig. 2).

Site visits to Fanore Beach in 2000 - 2012, and more recently in December 2015 and May 2016 (for this Report) show that in spite of storm erosive events, sand accretion develops fairly rapidly post storm events at the base of the dunes (Fig. 16). The sands may subsequently undergo vegetation re-colonisation and develop as low foredune features (Ephemeral/ Embryonic Dune Habitats). This suggests that whilst dune sands are eroded under storms conditions, the sediments do not travel far within the embayment and, at least in part, are returned to the beach areas.

Fig. 16a.

Figure 16a-b., a. Fanore Beach, showing sand ridge and linked foredune develppment at the head of the beach dunefront area post storm events, 2012 - 14 (photograph May, 2016), 16b. Sand burial of the Emergency Safety Lifebuoy Station, illustrates the recent nature of sand accumulation at the dunefront, with some dune-front recovery at decadal scales .

Study of map, historical records, satellite and air photographic imagery for Fanore shows the relative stability and often rapid recovery of the dune-front and shoreline - upper beach positions at decadal scales (Figs 17, 16b.). Effectively the shoreline position at Fanore beach, as referenced by tide levels, e.g., Mean High Water Mark of Spring Tides (MHWMST)) has remained little changed for the past c.15-20 years. Since c.2000, storm-driven coastal erosion events at Fanore have removed c.1-2 m of dune-front sands in particular events. Rates of erosion for the beach areas, however, based upon Ordnance Survey maps together with air photographs, indicate that such values must be contrasted with lower mean values of <0.5m/ year, this rate operating since c.1840s (Fig. 17). As noted in 3.2 and 3.30, sands appear to have returned to the beach areas at times in intervening years of dune-front erosion and variations in apparent shoreline retreat along-beach exist, even at this small site scale. In different coastal process settings on western coasts of Ireland, similar patterns of effective sediments re-circulation have been observed within Bay-Headland environments[23]. To the north and south of Fanore, the coast is comprised mainly of rock-cliffs, or reflective coarse clastic beaches, then erosion rates are much lower (generally <0.3 m - <0.001m/yr) and no significant threat of coastal loss exists, or to associated SACs.

[23] O'Shea, 2016; Devoy, 2015a; Kandrot et al., 2016; Vial, 2008; Sala, 2010.

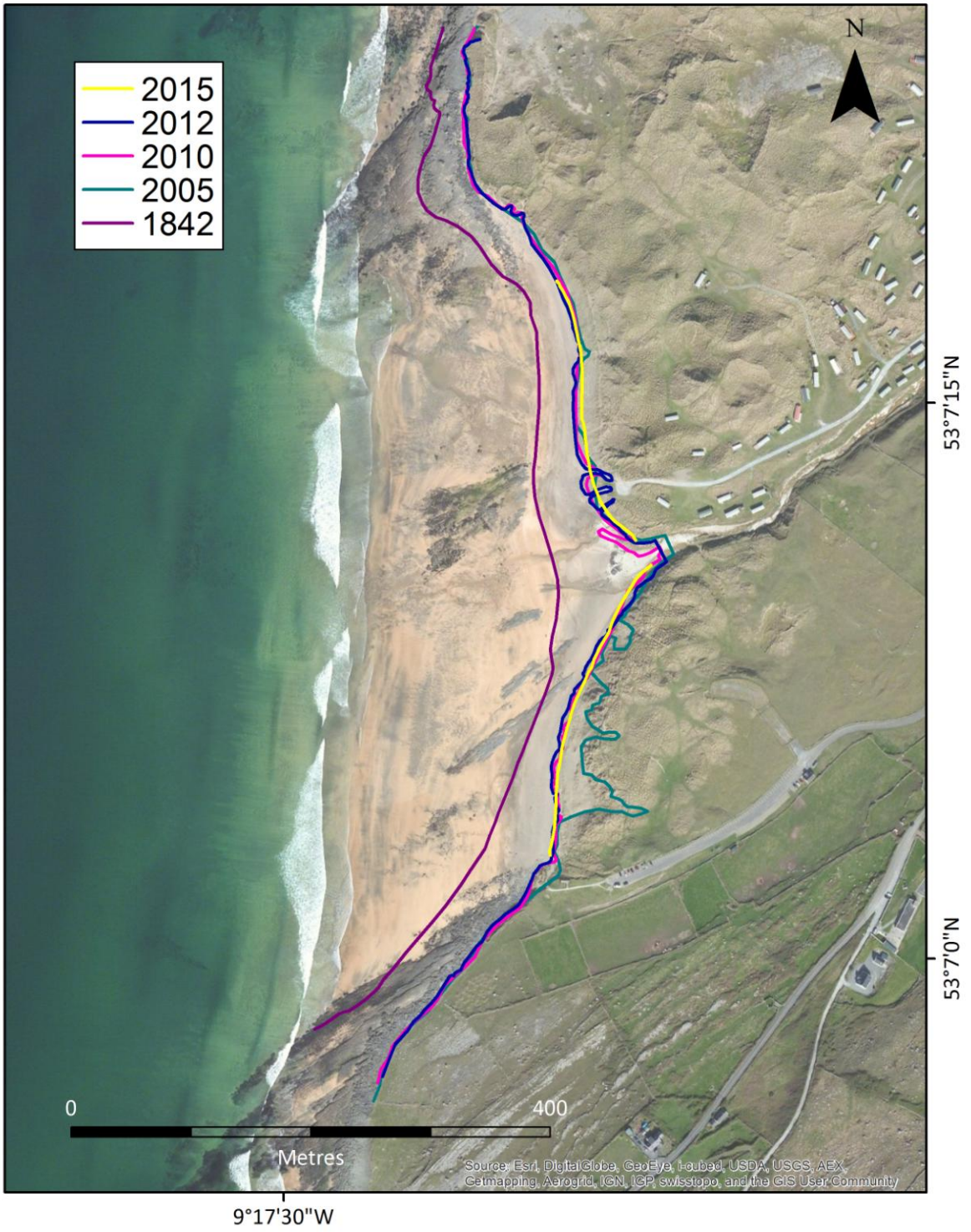


Figure 17. Shoreline (HWM) positions based upon Ordnance Survey (OSI) of Ireland First Edition, 1: 10,560 scale map; OSI aerial photographic coverage of the Fanore Beach and Dune area. Line positions (colours) show the positions of MHWMS by year (from the relevant document source). (Mapping detail made using ESRI & OSI MapGenie software.)

3.40 The Site Protection, Management and Conservation Measures Undertaken At Fanore

Summary of the completed Site actions have been noted in personal communication by Hoctor (2016) (e.g., on fencing/ infrastructure constructed as part the dune conservation and protection measures, concerned mainly with restricting people's movements into and uses of dunes; the servicing of Fanore Beach for visitor access and leisure infrastructure, i.e., beach access Stairs, Viewing Point, Roadways, Car Parks, Toilet facilities, Wastes and Waste Water disposal), Appendix 1. These actions have, in part, been made in response to the different Fanore and other Survey Reports since 2002, but also from the established Local Authority (Clare County Council) and Geopark roles in the provision of public infrastructures and the responsibilities for coastal protection works. These reports together provide an historical record of the changes at the site and establish effectively a baseline status of the current ecological and physical environmental conditions. Extensive photographic coverage of the different beach - dune protection measures and associated infrastructure undertaken are given in the reports[24].

3.41 Actions in the Beach Areas

In response to the overall erosion of the dunes in the past, through visitor impacts and apparent shoreline - dune-front recession, investment has been made since c.2003/5 into low cost, soft-type protection measures in attempts to fix the position of the upper beach/ foredunes and the dune-front. These actions link to other protection and conservation measures to help stabilise the dunes area as whole[25].

For the beach and dune-front the following actions have been implemented since c. 2003:-

Action 1. Post and re-enforced wire fencing has been put at the base of the dunes (Fig. 18), to limit people's access (from walking, horse riding/ pony trekking and the development of multiple routeways from the beach into the dunes). This action is intended to aid a reduction in dune susceptibility to sand blow-outs and other sand movements under wind action, as well as from direct wave erosion.

[24] e.g., Browne, 2007; Keegan, 2008.

[25] e.g., Delaney et al., NPWS, 2014; Hoctor, 2016

Figure 18. View northwards along Fanore Beach and dune-front (January 2006) from the newly built beach Stairway. The post-and-wire fencing is shown in the foreground and centre at the dune-foot of the photograph. The fencing serves to restrict people's access to the Dunes areas (Source: Browne, 2007).

Action 2. Some use has been made of low-cost sand fixing techniques, in attempts to limit the apparent dune-front erosion. Sand Matting has been placed in the upper beach - foredune zone, allowing Marram and Lyme grasses to colonise and to stabilise these sands. (No engineered built-coast protection structures have been used at Fanore to try to 'fix' the shoreline position and **this approach should not be used in future**.)

Action 3. Vertical, fabric-screen sand trap fencing has been positioned selectively in areas of blow-outs and developed bare sand and mobile-sand corridors, created earlier by people's trackways/ trampling) in the dune front (Figure 19). These actions (2 & 3) may have influenced and, in part, been responsible for the relative stability of the shoreline - beach position at Fanore post c.2000. But it is unlikely that these actions provide the full explanation, which will also involve waves – storms and sediments flux and re-cycling patterns from areas offshore.

Fig. 19a.

Figure 19a-b., a. Sand Trap screens with post-and-wire fencing, view north eastwards into the dune-front, Jan. 2006 (Source: AB); 19b. Sand trap Screen in eroded gully in the dune-front, northern edge of dunes, 2005 (Source: Browne, 2007). NOTE: THIS AREA OF FORMER SAND BREACHING/ EROSION HAS CURRENTLY HEALED (viz. Fig. 16a.)

Action 4. The pedestrian access to the beach has been formalised in the construction of a wooden sleeper-step and railed Stairway (Sand Ladder), c.12 m in height, cut into the dunes at the southern edge of the beach (Fig. 18). A corduroy wooden trackway(s) connect this and the dune-top with metalled Car Park areas. The stairway has had to be re-built on numbers of occasions since its first construction, due to the slumping of dune slopes with coast recession, direct erosion and usage. Fortunately, no public vehicle access to the beach exists, unlike on many larger beach areas in Ireland, with concomitant beach erosion impacts, e.g., as at Inch and north Dublin Bay beaches[26]. Vehicles access to the dunes areas at Fanore is prevented by a low bolder barrier (degraded) and some fencing at the car parks and along the main access road (Fig. 20). A wooden View Point has been built at the head of the stairs and is also linked to the corduroy pathway. Toilets and refuse facilities are provided at site (Fig. 20).

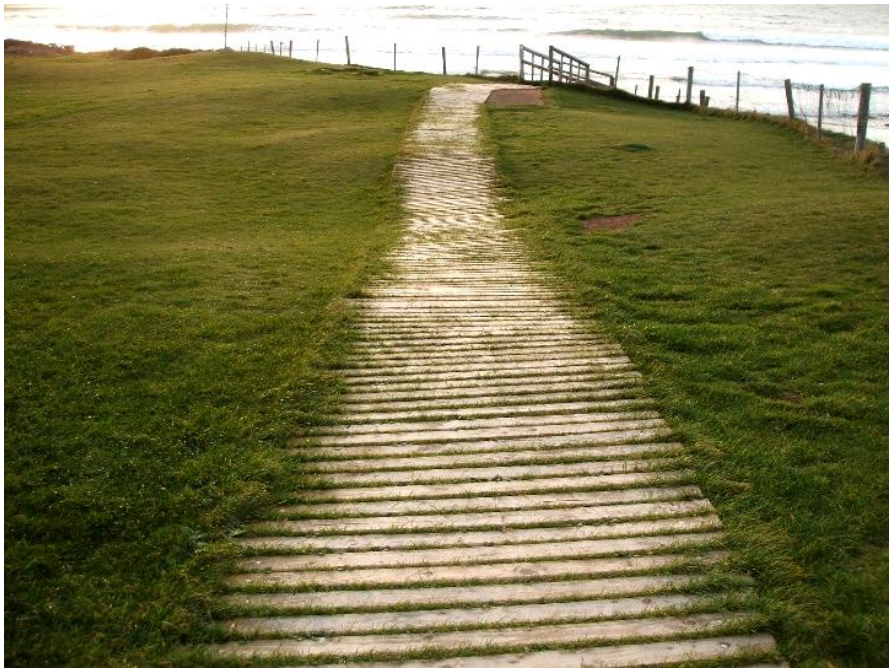


Fig. 20a.

[26] Gault et al., 2007; Science Direct, 2013.

Fig. 20b.

Fig. 20c.

Fig. 20d.

Fig. 20e.

Fig. 20f. 

Figure 20a-f., 20a. Corduroy wooden trackway to the stairway (Sources: Browne, 2007; Keegan, 2008); 20b.-c. Car Park and low boulder-barrier, used to stop vehicle access into the dunes, b. at the beach car park, c. at the Site entrance (Source: Ryle et al., 2009); 20d. Coast View Point; 20e. Toilets at the entrance to the Site; 20f. Refuse – recycling containers, at the Entrance.

Action 5. Limited post-and-wire and sand trap fencing has been positioned in the slumped and trampled dunes slopes areas adjacent to the Caher River channel outlet (Figure 21), to help limit erosion from people pressure in accessing the dunes areas from the beach.

Fig. 21a. 

Fig. 21 b.

Fig. 21c.

Figure 21a.-c., 21a. Remains of post-and-wire fencing at the Caher River outlet, Fanore Beach (Source: Browne, 2007); 21b. Fencing of the river channel and dunes margin, opposite the Caravan Park; 21a. & b. Eroded channel base and dune slopes, evidencing the inherent instability of this channel area. The

River forms the boundary to the privately owned lands to the north of the 'public' dune areas of Fanore. The long established Caravan Park provides a source of some people pressure on these dunes, opposite, e.g., creation of trackways; c. revetment walling to the river channel at the Caravan Park.

No built - engineered works have been undertaken in protection or fixing the channel-edge in the river outlet area, though some revetment walling have been constructed upstream by the landowners within the Caravan Park (Fig. 21c). This work seems more for purposes of site safety than any real action to reduce channel movements or erosion.

3.42 Actions In the Dunes, Back-Dune Areas

Complementary actions have also been established in the areas landwards of the beach and dune-front at Fanore. These include the ongoing provision of visitor facilities and infrastructure by Clare County Council. These measures include:- post-and-wire fencing with warning signage at the rear of the main dune-hills, to restrict people access through the dunes to the beach, together with trampling of the dune vegetation cover and dune erosion; interpretative fixed-board type displays; corduroy wooden walkways to the beach; car parks, metalled access roads; toilets; showers for beach tourists/ surfers)[27].

Visitor numbers to Fanore are now significant, with surveys (2014-16) showing totals of 62, 667 visitors a year (2014-2015), with peak numbers occurring between April to August; as might be expected, co-incident with the Spring time (Easter period) start to the holiday season and to later school breaks (Appendix 2).

Behind the dune-front zone, the Marram and Lyme Grass dominant vegetation on the dunes are replaced progressively landwards at the Limestone upland margin of the Site (Fig. 22), by effectively a *sandsheet* (derived from degraded low dune forms) with a complex of other Grasses and Herb-rich plant communities[28]. These areas, and within the dune-hills, are grazed by rabbits, maintaining the current grass-sward, but which add to the problems of ground disturbance at Fanore, together with the activities of their predators (e.g., fox, badger). These areas have been grazed by sheep and cattle in the past, with animal grazing continuing on farmlands adjacent to the Site.

[27] Further details of these in, Browne, 2007; Keegan, 2008; Hoctor, 2016.

[28] Ryle et al., 2009.

Fig. 22a.

Fig. 22b.

Fig. 22c.

Fig. 22d.

Fig. 22e.

Fig. 22f.

Figure 22a.-f., 22a. View eastwards from the dune-hills over the rear sandsheet and grass sward/ meadow at Fanore; 22b. Grass sward – Herb plant community, showing *Gentiana verna* (Spring Gentian, calcicole plant species: an element of the Lusitania refugia plants in the Burren); 22c.-d. Rear of the dune-hills showing grass sward type plant communities and rabbit induced sand disturbance; 22e.-f. View (e., 2012) from the Fanore Site entrance area northwards over the back-dune, dune margin - *sandheet* areas, showing animal grazing on adjacent lands.

3.43 Commentary On Actions

Action 1. The primary problem for the maintenance of the dune system is to prevent or, limit the access and use of the dunes areas by people, particularly into the vulnerable White Dunes and linked dune-hills habitats. This has been approached to date by the use of lines of post-and-wire fencing (with warning signage), curtaining the access to the dune-front from both the seaward and landward sides of the dunes (Fig. 23). Visitor pressure on the dunes has continued, however (Fig. 23).

23a.

23b.

Fig. 23c.

Figure 23a-c., 23a. Long term Trackways across the back of the dunes' areas; 23b. Tracks around the dunes' margins and across the dunes, as 'short-cuts' to the beach; 23c. Uses for recreation, camp and cooking fires.

This pressure has resulted in breakage of the fences, extensive trampling of the Dune vegetation and the development of indiscriminate trackways (Fig. 24). The fence-lines have often becoming the line of travel for people and consequent dune erosion, coupled with a range of other exploitative uses (e.g., camp fire and BBQ sites) (Fig. 23). The present level of control of these activities, and importantly the prevention of dune buggies/ vehicles on the Dunes and the initiation of worse erosion problems, has probably been important in maintaining the present Dune stability.

Fig. 24a.

24b.

Fig. 24c.

Fig. 24d.

Fig. 24e.

Figure 24a.- e., Breakage of fence lines, development of trackways and trampling along fence line, with consequent dune erosion.

It is arguable though whether their continuance, together with use of wider conservation goals is necessary in future, given the likely impacts of climate warming on the Dune system (see 4.0 and 5.0).

A case can be made for no further action on the area, except the removal of the now unsightly broken fencing. The Fanore dunes are only a small area of a much larger area of dunes, as linked to the Blackhead - Poulsallagh complex of SACs. The dunes to the north (in private ownership and in part used as a Caravan and Trailer-home Park) and contiguous with the Site, are the same/ very similar in character to those at Fanore under public ownership[29]. Visual survey of the dunes areas for this report (Dec. 2015 & May 2016) showed no especial, or unique elements to the Fanore Site (e.g., physical features, vegetation or wider ecology), though some 'rare' plants were noted in earlier surveys[30]. Consequently, the dunes at Fanore could remain unfenced in future and allow them to adjust with visitor pressures and under the impacts of climate warming. Such an approach may be used to public advantage (and e.g., for Clare Co. Co.), as developing a research - experimental dunes site to monitor these environmental impacts (i.e., climate and tourism), as part of current research initiatives approved and funded by e.g., DoECLG, EPA, NPWS. Certainly, a decision for 'no fencing', or related dune protection actions would save money! This approach may, however, be politically and in current conservation policy terms, unacceptable. Effectively, adopting a policy of no infrastructural protection works could result in a return to unacceptable rates of dune erosion and sand movements onto adjacent lands.

But, under future climate warming projections (Section 4.0) such erosion of the dunes, consequent sand blows – movements and wider environmental changes are very likely to happen anyway to dunes such as these at Fanore due to SLR, storminess - winds and climate change. So, why 'spend money' now trying to stop the inevitable?

Action 2 Interpretative Displays. These Displays, and linked warning - explanatory signage, has been developed and used at the Site since c. 2003. Some updating and replacement of this has occurred (Hoctor, 2016 pers. comm.) The signage on fences and the interpretative information displays are of standard, commonly used type (Figs. 25 & 26). The employment and positioning of the 'Displays' is uninspiring and the Warning signage probably unproductive, though covering public liability insurance needs[31]. Some of these displays and the signage need a new approach and upgrading (Section 5.0, Recommendations).

[29] e.g., Ryle et al., 2009; Delaney et al., 2013.

[30] Ryle et al., 2009; Delaney et al., 2013; NPWS, 2014.

[31] Gault et al., 2007.

Fig. 25a.

Fig. 25b.

Fig. 25c. 

Fig. 25d. 

Figure 25a. - d. Interpretative and Information displays used at the Site; 25d. Shower facility at the Site, with Display boards also in this dune-head, car park area.

Fig. 26a.

Fig. 26b.

Fig. 26c.

Fig. 26d.

Fig. 26e.

Figure 26a-e. Warning signage, as free standing and attached to fences at the Site.

3.50 Analysis of the Environmental Concerns: Fanore Beach and Dune Systems

3.5.1 Conservation Policy and Approaches

Numbers of habitat surveys and linked environmental studies have been completed for Fanore since 2002[32]. Included in these are recommendations for conservation and management measures at the Site, many of which have been implemented by Clare County Council[33] (Appendix 1).

The dunes at Fanore Beach are seen as an area of importance for environmental protection and conservation[34]. The coastal character of the Site and linked SACs brings Earth Systems diversity to the Burren region, one of World Heritage status and a major regional - international amenity, and in which coastal environments are of considerable resources value. The forming of the Burren and the Cliffs-of- Moher Geopark, together with the opening up of Ireland's coastal Atlantic Way (Failte Ireland, 2012/13), adds significantly to this amenity.

[32] Burren Connect, 2013.

[33] Lindsay, 2002; Browne, 2004, 2007; Keegan, 2008; Ryle et al., 2009; Delaney et al. 2013; NPWS, 2014; Hoctor, 2016.

[34] NPWS, 2014; Delaney et al., 2013.

But, these initiatives also represent further drivers in the need to maintain a careful watch upon national to regional scale conservation and habitats' protection policies and measures, together the economic valuation of heritage, rural - natural environments.

The context in which the management approach at Fanore operates lies with the National Parks and Wildlife Service (NPWS), part of the Department of Arts, Heritage and the Gaeltacht, together with the relevant Local Government Authorities (viz. Clare County Council), the Department of Environment, Community and Local Government (DoECLG), other State Agencies (e.g,. the EPA, OPW) and nominated environmental management organisations (e.g., the Burren and Cliffs-of-Moher Geopark). Together, these are primarily responsible for the management and planning control of Ireland's rural environments. This responsibility is defined under international and national legislation and protocols[35].

The NPWS is at the cutting edge of this administrative core, in undertaking and supervising environmental review at the site level. A significant criterion of the NPWS evaluation of any change in environments is *ecosystem conservation*, in which the sustainability of habitats and their wider Earth Systems is maintained. Consequently, threats to an area's environmental functioning, from the specific plant and animal ecology levels to land use and landscapes changes, are of concern. Human actions in an area, through environmental usage and proposed built developments are subject to controls under the Habitats Directive and the linked National legislation. The management of 'natural' environmental changes (e.g., in vegetation change, land erosion) resulting from the operation of environmental drivers (e.g., hydrological, coastal processes), are also of importance and may require conservation interventions in order to maintain environmental stability[36].

Questions arise now though, based upon the present understanding of climate warming risks and impacts, as to whether the established approaches and practices in planning and management will develop robust and environmental sustainability outcomes in future (Section 4.0)[37]. There are also concerns as how much individual site-based decisions on management by Local Authorities (LAs) and linked managers are too local. Do decisions taken at these levels reflect knowledge adequately of any ongoing regional – national - international strategic response for environmental conservation needs, in which the likely impacts of long-term environmental changes must be considered? The repercussions of climate warming are now recognised in Ireland as of fundamental significance to future planning and policy decisions for all areas of environmental management[38].

[35] European Habitats Directive 92/43/EEC (Commission of the European Communities, 2007); the Natura 2000 listing of SACs (Natura 2000; NPWS, 2015); the National Spatial Strategy and complementary national legislation in the Planning and Development Act 2000, Government of Ireland (2005), Clare County Council (2010).

[36] Gault et al., 2007; DoEHLG, 2009/10; NPWS, 2014.

[37] e.g., IPCC, 2014a, b; UK Government, *Climate Risk Assessment*, 2015.

[38] Dwyer, 2012; Climate Ireland, 2016; IPCC, 2014c; EPA-Ireland, in prep; COP 21, 2016; Gray et al., 2014.

3.5.2 Questions For Management

For Fanore, management issues arise, therefore, as to what more, if anything, should be done as consequence of the following:-

1. The Fanore beach and the dunes areas under public ownership, are being closely supervised by Clare County Council and the Burren and Cliffs-of-Moher Geopark management. However, adjacent dune areas and lands privately owned (e.g., dune areas as Caravan Park, Fig. 3) are subject to less active control and maintenance. This poses problems for the effectiveness and rigour of the protection and conservation measures undertaken by Clare County Council and the Geopark at the site overall.
2. In 2013/14, the impact of 'Hurricane' Darwin and subsequent high magnitude storms in 2014 - 2016 caused erosion to the Fanore dunes and appears to pose a threat to the sustainability of this environment. What is the significance of this erosion in the context of the development of appropriate coastal protection measures at Fanore in the future short - medium terms (to c.2050)? Similar issues arise for coasts throughout Ireland, as to the appropriate and 'best practise' approaches to coastal management under future climate warming.
3. More widely, for the Dunes, how should the Site be managed under the continuing and future impacts of climate warming into the mid to late 21st Century? Are current recommended and 'legally' required conservation approaches and practices appropriate?
4. The future impacts of people on these 'delicate' coastal habitats at Fanore, from increased visitor pressures resulting from the raised amenity value of the Burren region and people's greater demands for varying leisure and recreation pursuits (walking, riding, water sports, touring), are likely to be high. Under future climate warming trends such coastal areas may become even more attractive for recreational use[39]. Due to these social and economic pressures, again, what management and planning policy and approaches are needed to help conserve the Site, and linked areas, their ecology, environmental sustainability and amenity values?

4.0 IMPACTS OF PRESENT PROCESSES, FUTURE CLIMATE WARMING: SCENARIOS FOR COASTAL CHANGES AT FANORE

Climate warming as a function of post-industrial intervention in the atmosphere-ocean systems by people is now widely accepted as happening[40]. "Warming of the [European and global] climate system is unequivocal. Since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the

[39] IPCC, 2007b, 2014b; Desmond et al., 2015.

[40] IPCC, 2007a, b; 2014a, b.

amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased. Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. In the Northern Hemisphere, 1983-2012 was likely the warmest 30-year period of the last 1400 years".[41] For Ireland 2014, and continuing to 2015, were recorded as among the wettest and the warmest years on record (mean annual values across regions) and consistent with similar wider trends for Europe and globally[42]

Rates of Sea-level Rise (SLR) for European waters derived from satellite altimetry and tide gauge data show values for Ireland's coasts of 2.5 - 3.4 mm /year at present (Fig. 27a).[43] These values are significantly above the 1 - 2 mm/year rates of rise recorded for coasts since the 1880s to early1990s (Fig. 27b). This observed acceleration in the rates of SLR for European waters fits with the rate of rise for the global and regional modelled projections for future SLR. The global mean value of rise is likely to be at least 0.55 - 0.6 m by c.2100, for medium scale climate warming scenarios (RCP values of 2.6 - 4.5; Fig. 27c)[44]. Downscaled projections of this future rise for Ireland's coasts vary due to regional - local scale controls, particularly that of earth crustal behaviour (Fig. 28). Modelled values for Ireland's central western coasts (covering Fanore) are for c.0.44 m of SLR by 2080 - 2100[45].

[41] IPCC, 2014c.

[42] e.g., Met Éireann, 2016; Irish Times, 2015; EU Commission Report on Climate Change, July 2016.

[43] e.g., European Environment Agency, 2014.

[44] Church et al., 2014.

[45] Dunne et al., 2008; Lowe et al., 2009.

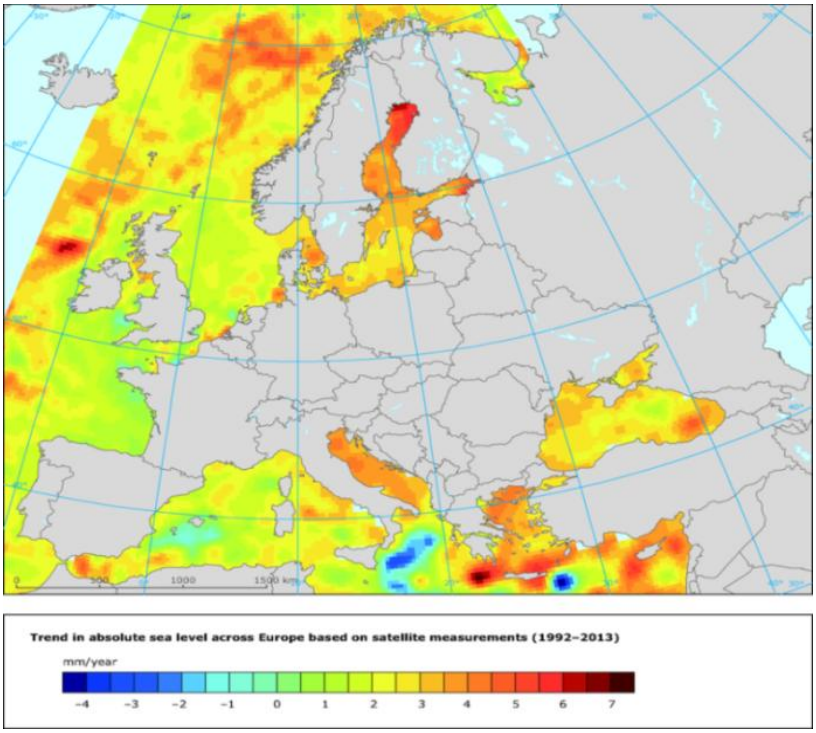


Figure 27a. Trends in recent sea-level rise for European coasts, from satellite data. (Source: European Environment Agency, 2014).

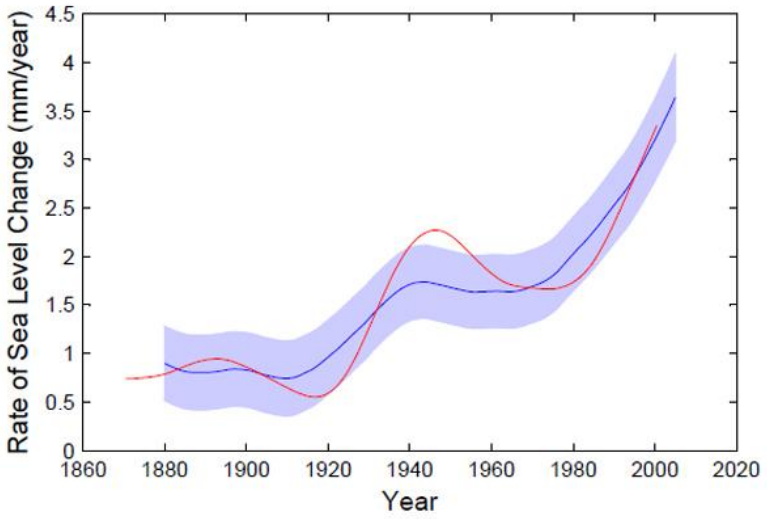


Figure 27b. Rise in global mean sea level from 1880 to 2013, relative to 1990 levels. The red line shows reconstructed values for 1880 - 2009 from coastal and island tide gauge data (Church and White, 2011; http://dx.doi.org/10.1007/s10712-011-9119-1). The area of uncertainty interval is shown in violet-blue. The blue line shows a SLR time series for 1993 - 2013from the TOPEX/Poseidon, Jason-1 and Jason-2 satellite altimetry data (Masters et al. 2012, http://dx.doi.org/10.1080/01490419.2012.717862; data supplied by Benoit Legresy, CSIRO) (Source: European Environment Agency, 2014).

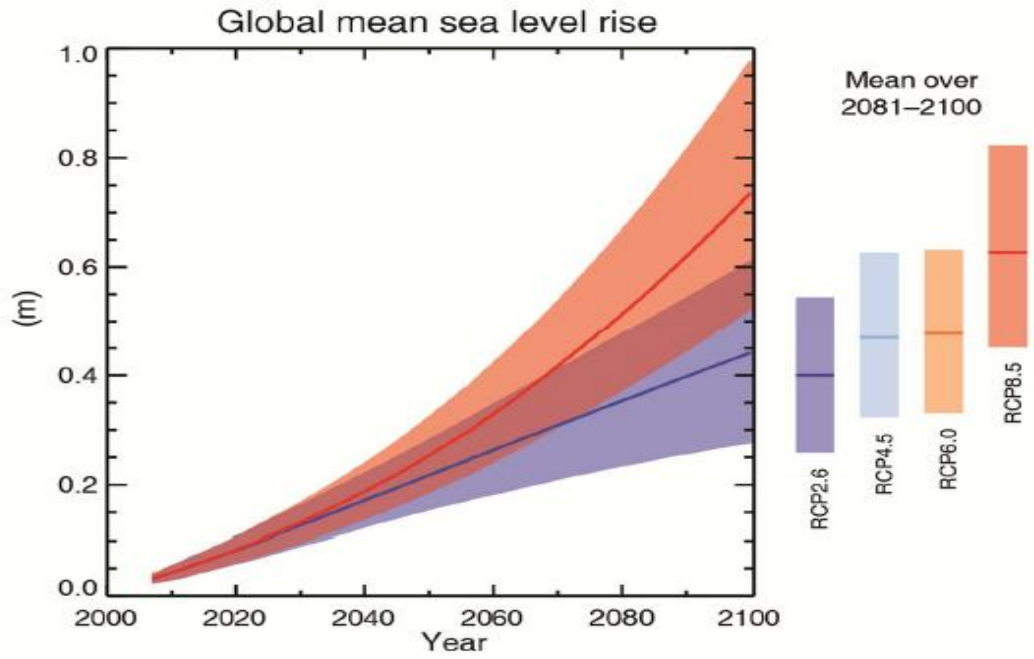


Figure 27c. Projected pattern of mean global sea-level rise (Source: IPCC, 2014a; Church et al., 2014).

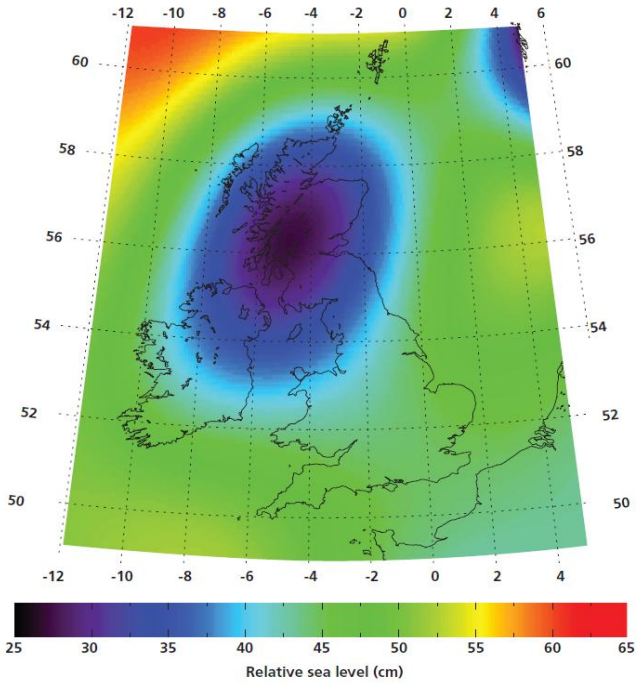


Figure 28. Projection of the likely SLR for coasts of Britain and Ireland to 2100, allowing for earth crustal movements (Source: Lowe et al., 2009).

Current projections of changes in Ireland's regional climates fit largely with the results of earlier modelling exercises[46]. Broadly, seasonal and mean annual precipitation levels (as rainfall) will increase above present levels as will mean annual temperatures. Projections from modelling show a continuance of the established decadal pattern of decrease in Atlantic storm frequencies, particularly after c.2040, but with an increased magnitude of individual storm events impacting the coasts of western Ireland[47]. Averaged annual surface wind speeds from the Atlantic show some increases on-coast, of c.0.3 m/s over the existing south to north (maximum speeds) gradient of wind speeds along Ireland's western coastal margin (Fig. 29a). Projections for changes in coastal zone significant wave heights (Hs), storm surge levels and highest tides indicate only medium - low likelihoods of any long-term major increases under the background conditions of regional atmosphere-ocean coupled warming and developing storminess patterns (Figs 29b-d)[48]. Expected increased surge levels (i.e., temporary sea surface heights above the 'background' sea level) on most western Ireland non-estuary coasts for the 20-30 year return period surge events are likely to be small, with increases of ≤9mm/year up to 2100 (c.9cm total rise)[49]. There is some evidence, however, for a significant increase in mean wave heights during Winter months for Ireland's Atlantic coasts, up to 0.3 m above present levels. Also, an increase in the frequency of extreme wave heights toward northwest Ireland is likely (Fig. 29c).

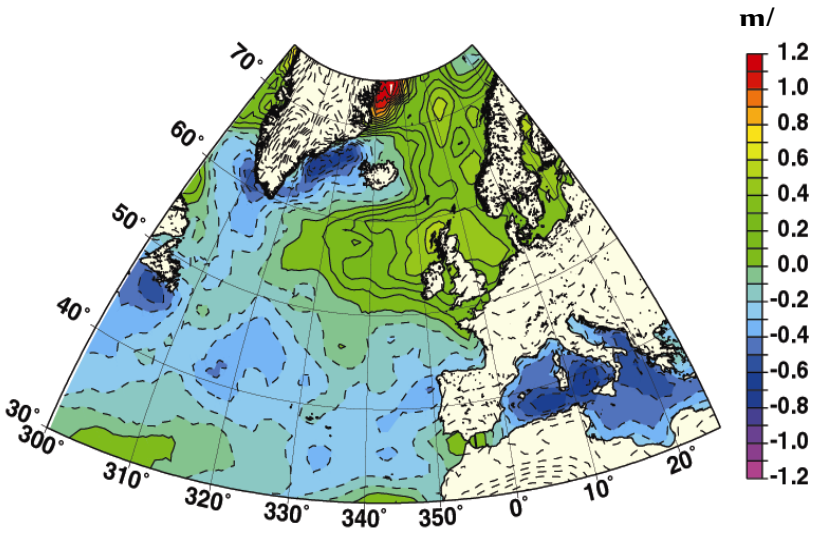


Figure 29a. Modelled averaged winter wind-wave changes by 2090 for the European Atlantic margin. For Ireland to Scotland's coasts this shows an averaged wind speed rise of 0.4- 0.6m/s by c.2090 (Source: Lozano et al., 2004).

[46] viz. IPCC, 2007, 2014; Dwyer, 2012; Gleeson et al., 2013; EPA, 2015; EPA, in prep.

[47] Lozano et al., 2004; Dunne et al., 2008.

[48] Lozano et al., 2004; Gallagher et al., 2016; O'Brien et al., 2013.

[49] Lozano et al., 2004; Dunne et al., 2008; Lowe et al., 2009; Jenkins et al., 2009.

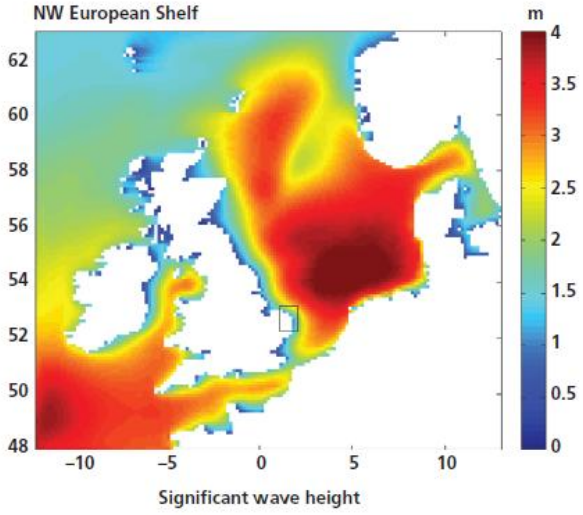


Figure 29b Projected increases in significant wave height (m) to c.2070, covering Ireland's western coasts (Source: Lowe et al., 2009).

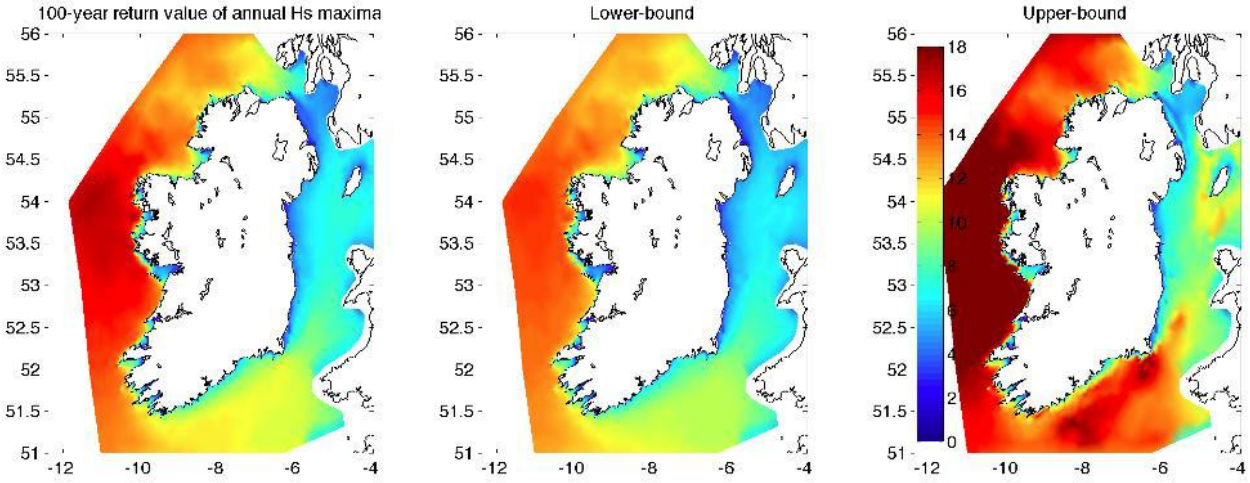
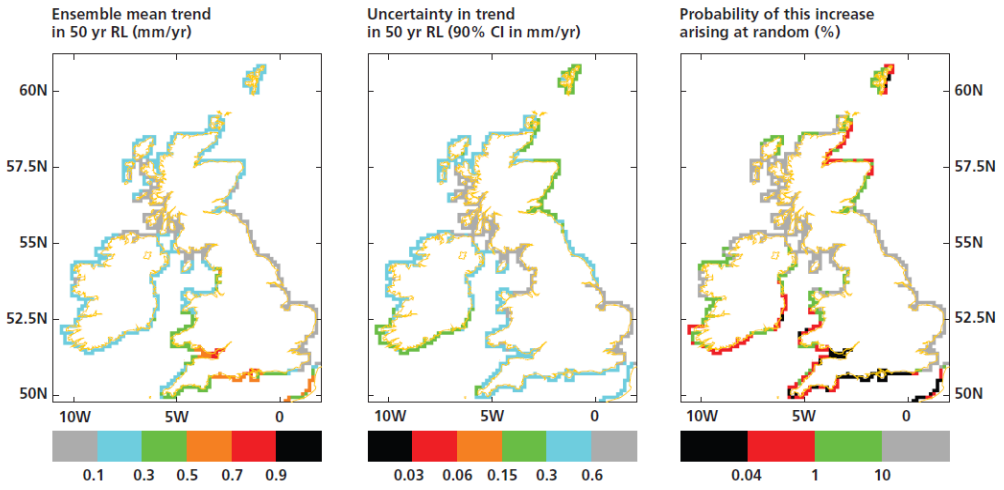


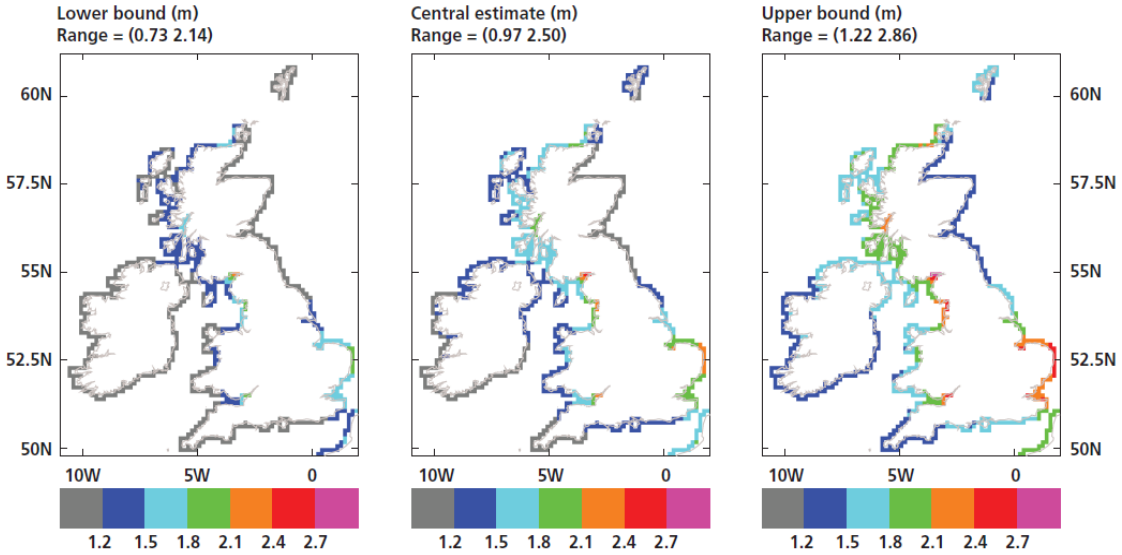
Figure 29c. Modelled occurrence of the 100-year return significant wave height Hs maxima (m), covering Ireland's western coasts (including Fanore) (Source: Gallagher et al., 2014). A longterm nearshore wave hindcast for Ireland: Atlantic and Irish Sea coasts (1979-2012). *Ocean Dynamics*, 64(8), 1163-1180.



Lowe et al., 2009

PPE ensemble mean trends in 50 yr skew surge return level from the storminess component only. Negative trends are included in the grey shading.

Figure 29d. Modelled pattern of storm surge changes for Britain and Ireland under future climate warming scenarios, showing likely small increases only for Ireland's western coasts (Source: Lowe et al., 2009).



Lowe et al., 2009

Exceedance of present-day astronomical high tides by projected future extreme water 50-yr return levels for 2095 (m). The central panel shows the estimated central value. Left and right panels show the lower and upper bounds of the 90% confidence interval. Grey shows any value < 1.2 m.

Figure 29e. Modelled pattern of likely extreme water level changes for Britain and Ireland under future climate warming scenarios (Source: Lowe et al., 2009).

Given these projections for wind, storm and tidal conditions to 2070-2100, which cover the Fanore area and central western Ireland coasts, then the acceleration in the rate and the total amount of SLR will be the primary drivers in magnifying the impacts of changes in the other hydrodynamic factors (e.g., wave heights and storminess). Sea-level rise coupled with higher magnitude storm events will cause the beach and dune systems, as at Fanore and wider, to come under increasing pressure of erosion in the decadesto 2050 and beyond. The breaching of beach-barrier systems, as at Lehinch, or their complete disintegration and the re-mobilisation of dune sand areas will result in *coastal squeeze*[50]. Incidences of dune blow-outs, potential barrier breaching and wider changes in coastal configuration for western Ireland, resulting from the re-organisation of coastal hydrodynamics, are likely to become more common and similar to the changes now being experienced at Rossbehy, Co. Kerry and Ballyheigue[51].

4.1 Likely Patterns for Change and Site Scenarios

Based on the site surveys undertaken, coupled with previous knowledge of the area, field research experience, review of the available literature and data on the environmental processes operating at the site and wider, then some likely outcomes and scenarios for the site can be defined:-

1. The beach and dune-front hydrodynamics and sedimentary processes at Fanore are controlled primarily by seasonal storm events and by the regular daily swash-aligned wave action under the predominantly southwest to westerly orientated wind regime. There is no good indication of alongshore sediments transport at the Site, or losses northwards from the Bay-Headland system. The River Caher, whilst seasonally transferring some materials (cobble to silt sizes) into the Bay, probably has a low sediments budget from this limestone region and River discharges are generally too low to move sediments far offshore. Sediments are essentially trapped within the Bay, moving back up into the beach-dune system under most wind-wave conditions and progressively onshore over time. Under conditions of future climate warming to 2050 - 2100, then this pattern of dune-front re-working of the existing sands will continue, together with increasingly the mobilization of the dune sands and the re-organisation of the dune complex eastward into a smaller area on-land.

2. Under a future sea-level rise of c.1 m by 2100[52], then the dune-front at Fanore will retreat a further c. 100 m (based on Bruun Rule type models, applicable for estimating movements of cohesionless sands)[53]. Depending on the amount of SLR and the increased frictional drag effects of the site shape and topography, this value for lateral change in the beach-dune front position will be less. The likely

[50] Devoy, 2008, 2015a; Wong et al., 2014.

[51] O'Shea & Murphy, 2012; Delaney et al., 2012; Devoy, 2015a, b; Devoy, 2015c.

[52] e.g., IPCC, 2014a, b.

[53] Carter, 1988; Carter & Woodroffe, 1994; Rosati et al., 2013.

rates of dune-front retreat are unknown, but at times dune-front shifts, are likely to be very rapid (e.g., >2-3 m / year), under the projected higher sized storms activity to c.2040. Possible increased discharges from the River Caher with a wetter climate are also likely, but will probably not radically affect this pattern of continuing sand movements onshore. Sediments on erosion, mobilisation and re-working, will be forced by SLR to move up over the present back-dune environments, particularly under storms action, creating progressively the new and condensed-dune system. This scenario of lateral sands movements fits with past records of coastal changes for such sand-rich coasts and the present day observations of the beach - dune changes. The sedimentary patterns today are conformable with the operation of 'roll over'beach-dune barrier type models[54].

3. Observations of current back-beach and dune recovery under rapid sand movements indicate that vegetation initially affected by future sand influxes into the present vegetated and stable dune areas (e.g., the White and Grey Dunes areas, Figure 14), caused by climate induced changes, is likely to show rapid re-growth[55]. Much depends though on the volumes and rates of movements of the re-mobilised sands, under the future processes operating with climate warming. However, rates of vegetation recovery could be slower with larger scale sand movements and/or variations in the extent of areas covered, as limited by the existing and developing land surface heights. The effective eastward topographic limit to the site of the Limestone escarpment means that mobilised sands will be forced to move progressively south- and northwards, covering adjacent lands not currently part of the Fanore Site. This "dunes-transfer" scenario has implications in the longer term for impacts on lands used now for farming, for farming practices and for development of wider land management policies.

4. In future, increased salinisation of the water table in the dunes will occur under local to regionally driven SLR[56]. Also, larger freshwater runoff from the Burren to the coastal areas and consequent rise in the height of freshwater table is likely to occur, though this will be modified by the shape and height relief of the developing dune-complex area. Dependent the rises in freshwater water runoff, coupled with SLR, then dune slacks (seasonal pond) type environments are likely to form in future. Such dune areas do not occur at Fanore at present, although they do elsewhere in Ireland's west coast dunes[57], potentially increasing the diversity of habitats at the Site. Plant and wider ecological diversity will also

[54] Thom & Roy, 1994; Devoy et al., 1996; Devoy, 2015; Cooper & Jackson, 2011, 2015.

[55] Carter et al., 1992; Devoy et al., 1996; Science Direct, 2013; Feagin et al., 2005., Doody, 2001, 2012.

[56] e.g., Science Direct, 2013; IPCC 2007b, 2014b.

[57] Carter et al., 1992; Ryle et al., 2009.

likely be increased by rising temperatures under climate warming, as well as by rises in rainfall[58].

5.0 RECOMMENDATIONS FOR PLANNING, MANAGEMENT, POLICY AND ACTIONS AT FANORE

The site requirements for action and future management, in response to the present and likely projected changes in morphology and linked environmental processes and functioning, as defined in Sections 3.0 and 4.0, are given in a series of recommendations and accompanying commentaries, as follows:-

Recommendation 1.

A series of linked process (numerical) modelling studies, covering the physical and biotic systems' functioning are needed now for Fanore. These would integrate the projected hydrodynamic, sedimentary and vegetation components, changes and scenarios for the Site, to give more precise information on the likely extent and rates of future dune movements.

Modelling of the beach - dunes and river catchment systems would help particularly in showing the future internal and external system boundary shifts of the Site over time under sand mobilisation. This type of coastal systems' modelling has become more feasible at these high resolution, site scales and would be likely to attract Environmental Protection Agency or wider EU H2020 project funding. (A current dunes - catchment modelling project which would link well with a Fanore Site study is currently being undertaken at Achill Island, under EPA funding[59].)

Recommendation 2.

There will be a need for further investment in the current Visitor facilities (e.g., toilets, showers, running water; possible construction of Visitor Centre) for daily and recreational visitors. Fanore beach-dunes Site is the only accessible beach - sands area on this stretch of the Burren coast, forming a convenient stopping point. It has natural scenic attraction, forms a good viewing point to sea and along coast and is an established location for beach leisure activities.

The current visitor usage, indicated by survey of daily, peak season to yearly numbers, seems to be moderate only (viz. Appendix 2). However, with probable increased visitor pressure in future, as response to climate warming impacts and as linked especially to the development

[58] IPCC, 2007b, 2014b; Dwyer, 2012; Climate Ireland, 2016.

[59] e.g., Environmental Protection Agency Funding, Farrell et al., 2016.

of the area as part of the Burren and Cliffs of Moher Geopark and Atlantic Way, even under future economic difficulties, then an upgrade of these facilities is desirable.

Recommendation 3.

Other needs arising from these and linked environmental changes, operating presently and in future, include:-

1. An immediate assessment study of the impacts and the treatment of water produced by the caravan site and of other lands in private ownership contiguous with the Fanore Site, including adjacent farmlands. The study should establish a long-term water management policy for the Site.

2. Given the likely changes in groundwater characteristics and water table levels within the dunes areas under climate warming, then there will be a need for increased care in the treatment and management of waste waters generation at the Site and in adjacent areas (e.g., from the fixed Caravan Park and Trailer-home area; usage of the Site by visitor - leisure activities). Need to install septic tank systems, or use of water filtration techniques. [60]

Recommendation 4.

Beach – Dune Management Requirements

In spite of the longer-term likely changes in the likely alteration by sand inundation of the extent, form and composition of the Dune vegetation complex under climate warming, then some remedial actions for the present Site protection measures already in place on the dunes would be worthwhile. This would be to, a) help maintain in the short-term the stability in the dune areas, before major sedimentary budget changes occur in future; b) to foster the development of a public awareness and involvement in good dune and wider coastal management practices. This approach is well established in people's and community use of these areas in the Netherlands[61].

An alternative view (raised in Section 3.33) is that there is no real need to protect the Site from future visitor pressure, as:-

i) The site is not unique and is only a small part of a much larger dune system. Most of this is in private ownership with limited access by the public and effectively protected from the impacts of visitors.

ii) The Site area is likely to undergo extensive 'natural' morphological and process changes under climate warming. So, why spend money on Site protection?

The view indicates adopting a policy of, 'No physical protection works for the dune areas'. This would save immediate public expenditure, at a time now of significant restrictions on

[60] Rowe, D.R. and Abdel-Magid, I.M., 1995; Virginia Coastal Resources Management Plan: Environmental Impact Statement, 1986, https://books.google.ie/books?id=r0c3AQAAMAAJ.

[61] e.g., Carter, 1988; Carter et al., 1992; Visser & Misdorp, 1998.

public funding and resources use. The approach could also be developed for publicity and other advantage for Clare County Council and the Burren - Cliffs-of-Moher Geopark; developing Fanore as, an experimental / research site, working in collaboration with relevant funding and management agencies and third level research institutions to develop appropriate dune management policy and approaches under the conditions of climate warming (Note, such a need is real and not notional and would fit with existing EPA funded international level research projects on Ireland's western coastal systems. The downside to this approach / recommendation would be, i) unacceptable levels of dune degradation/ coastal change in the immediate future (i.e. next 20 years); ii) the approach would provide apparently wrong management signals to the general public and adjacent landowners (i.e. visual and land impacts of change), unless the approach is promoted robustly, which would require public investment now.

Past experience of dune erosion, sand losses and movements at the Site, from which it appears to have recovered through, in part, current dune protection and management approaches, suggests that it is worth continuing these in the short term (next c.15-20 years). This action would help maintain the character of the Site for as long as possible, before the likely impacts of climate warming overcome the control boundary thresholds of the present beach-dune system.

Recommendations (under 4.):-

Selective renewal of the re-enforced post-and-wire fencing is now required, together with the removal of existing broken and obsolete fence sections (Fig. 30). Fence lines should be positioned (Fig. 31):-

i) at the beach - dune-foot (shoreline zone), positioned below the dune crest semi-vegetated area (Marram and Lyme Grasses) of the dune-front and

ii) from the landward side, within the fixed, Grey Dunes – dune-hills area.

The purpose of the fencing is to continue to discourage/ restrict the movements of people over these most sensitive dune areas, providing some protection from any destabilising of the dunes by people, and help maintain the integrity of the dune area to c.2030.

Issues to address:-

i) Storms have removed much of the earlier post and wire re-fencing on the Beach/ western side of the Dunes, at the dune foot, and should be replaced together the accompanying signage and its maintenance continued. This recommendation is in spite of the rapid changes occurring in the area. The fencing is relatively cheap and it helps limit the pedestrian access into the dunes from the beach-side, whilst further re-enforcing people's awareness of control of the dunes. Use of any accompanying sand fixing, through Marram grass planting and sand-fencing techniques to trap sediments will probably be unnecessary and a wasted investment. Whilst the use of such

techniques here won't 'harm' and, dependent on the pattern of storminess may even appear to be stemming erosion, this is likely to be temporary. (As defined under 3.0, nett sediment movements here are predominantly going to be onshore over time.)

ii) Within the main Dunes area, the present fencing is broken (Figs. 24 & 30) in many places and/ or has been made obsolete by erosion of the dune slopes. The fencing should be renewed/ replaced, as needed. A change in fencing type (i.e., higher, or as steel palings) is inappropriate, due to the negative visual impacts this will bring, together with people's responses to such controls, and the inheritantly temporary nature of any fencing because the ongoing storm-driven dune erosion. Problems with these 'fixed' barriers to movement though will continue, with fencing becoming lines for new walkways and foccii for wind erosion/ dune deflation inland[62]. These problems can only be tackled through establishing better behaviour in people's use of the dunes (appropriate signage, education/ interpretive actions, establishing Site supervision/ Wardens). But, pedestrian access does need to be restricted from both the seaward and landward sides, for the control of opportunistic attempts to access the beach, camping, camp fires/ BBQ sites, with increased chance of firing dune vegetation. This is particularly so with the likely increase in future tourist pressures. Renewed fencing should be re-positioned away from dune crests and a sufficient distance from the present dune-front to 'survive' the next c.10 years.

iii) Further fencing should be considered on the road margin of the Sand-sheet area, the landward margin of the Grey Dunes - dune-hills. At present there is no real restriction on people's movement over these areas of the Grey, stabilised dunes, closest to the road and Site entrance (Figs 3 & 22). The areas are also impacted by people, with well-developed trackways established at the dune-hills margin. Restriction of movement with some extension possibly of the post-wire type fencing, or a less visually intrusive barrier, would be useful here; though not of immediate importance.

[62] Browne, 2007; Keegan, 2008.

Fig. 30a.

Fig. 30b.

Fig. 30c. 

Figure 30a. - c. Current styates of fencing as broken and degraded, or 30c. obsolete.

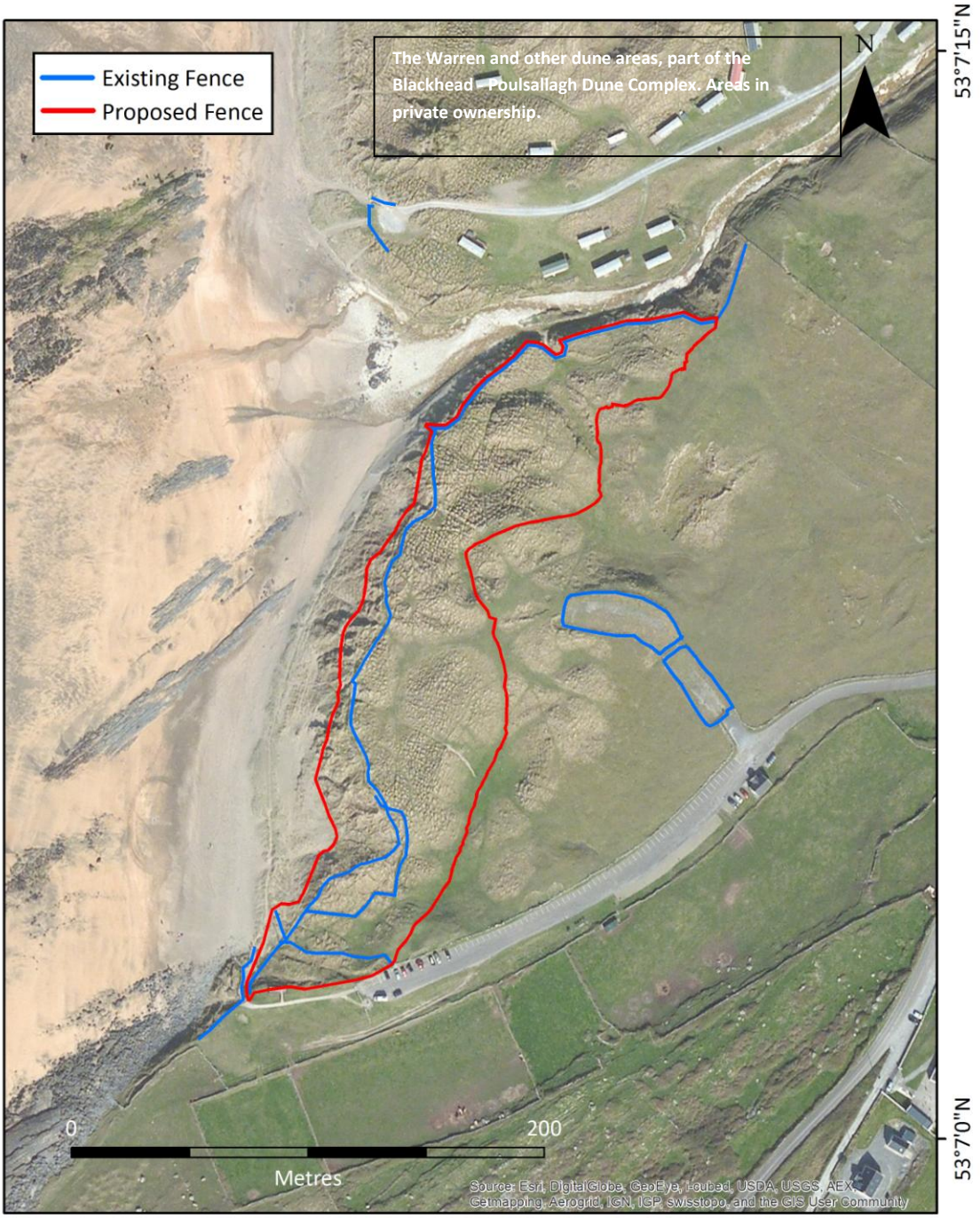


Figure 31. Aerial photograph (Source: OSI) of suggested position/ lines (in red) for the re-setting of the present post-and-wire fencing (existing fence lines shown in blue). Purpose of renewal of the fencing would be to provide short term limitation (c. next 15-20 years) pedestrian and any vehicle access into the dune-front and inland dune areas for the publically used areas at Fanore.

For the fencing lines, then the existing post-and-wire fences can be renewed, where practicable (i.e., fences not now on collapsing dune, or compomised by developed trackways), and that these fences are not on dune crest areas. Ideally all the fencing and signage should be renewed and the old removed, not left to create a 'battle-field' like appearance. Fences should be positioned on the dune

areas in all circumstances to minimise their visual impact in the landscape. The red lines indicate the approximated position for fence re-setting, showing the fence-line on the western, beach-side set back from the upper-beach - dune-foot (this marked by the present Highest Water Mark for Highest Astronomical Tides and/ or approximately the position of the "embryonic/ foredunes) by c.10 m from current positions, but below any dune crests landward. This set back is to take account of the likely erosion and recession of the dune-front over the next 5-10 years. Landward the fencing should be positioned c.300 m from the dune-front, well into the areas of fixed/ Grey Dunes, and aligned through areas of low-relief on the dunes' surface. The re-setting may change areas of dunelands curently used as commonage for grazing, but this is question to be resolved by Site management.

Note, consideration of the areas to the north of Fanore, generally in private ownership and limited public access to the rock-cliffed coast was not part of this brief. However, these areas are primary ones in the Black Head - Poulsallagh Complex SAC (Ryle et al., 2009; NPWS, 2014). Consideration should be given to the application of some of the measures outlined above (e.g., Points 10., 11.) as part of their future management.

Recommendation 5.

i) It is considered unnecessary to develop gabion/ rip-rap, or other built revetment protection of the channel sides of the Caher River, either at the beach outlet, or upstream toward the Caravan Park (CP). The present area of channel revetment walling has been developed privately.

ii) The present post-and-wire fencing within the dunes edge and along the channel margins should be replaced/ renewed, as appropriate, to help reduce people movements into the dunes and slope destabilization.

The value of this action will probably have only a short term effectiveness though (over next 10-20 years), as SLR will cause the major re-organisation of the beach and dune-front areas (releasing sands to move back over the existing dunes and re-structure them). The longer-term approach here, should be to let the river channel adjust as the process changes operating dictate, rather than 'battle' the system. The issues of intervention here will be the one of cost of maintaining this measure in future; and, when to abandon 'fencing' completely in the dunes, with removal of the fence lines.

Recommendation 6.

There is no need for investment in built, low cost type protection measures for the upper beach - dune-foot area (e.g., fabric matting, rip-rap), and as linked to a renewal of the earlier sand trap fencing at the Site.

In other coastal sand-barrier settings, on Atlantic and Mediterranean coasts, then the deployment of a wide range of low cost protection measures has commonly been the response

to the impacts of apparent increases in storm damage to coasts[63]. This is becoming the recommended practice where such areas are developed, backed by housing and high investment value urban settings[64]. Reviews of these techniques and linked larger-scale coast management protection measures given in, e.g., ECOPRO (1996), DEFRA, 2009; Cooper and Pilkey (2012), ANCORIM (2012); Devoy et al. (2015).

At Fanore, which remains undeveloped with fixed housing and where the sediment supply is essentially trapped and moving onshore, then investment in such measures would be inappropriate. Attempts to fix the shoreline/dune-front low high cost built actions, under conditions of future rapid SLRs, would compromise the 'best practice' coastal management principles, of letting the shoreface and backing dune systems adjust to future process changes.

Recommendation 7.

Need to undertake a detailed Seascapes/ Landscape Character Assessment of the Site (SAC/ LCAs), which would also include a coverage of the lands adjacent to the Fanore dunes complex. No such detailed Site survey of this type seems to have been undertaken to date.

Such work would extend the existing Clare County Council's LCA (Heritage Council, 2002a). LCA studies give a good background for future environmental data collection and monitoring surveys[65]. The SCA/ LCA techniques, though relatively sophisticated, can be acquired quickly by non-professionals and involve use of minimal field equipment, making them valuable tools where community organisations and Schools are to be included as part of continuing management work at the Site. This type of study has been widely used by Local Authorities in Ireland since c.2000, as part of approaches in land management, planning and policy development[66]. Such a study should be linked to the development of the modelling of environmental changes recommended for the Site.

Recommendation 8.

Reconstruction of the Access Stairway (Fig. 32), cut through the dune-front to the beach, is needed as a matter of urgency, much of it has collapsed from wave erosion, de-stabilising the dune-cliff slopes, and from pedestrian usage. Issues of rights of public access to the beach, safety and potential insurance claims by users are all involved here; and which require the renovation of the stairs. This work should be linked to renovation of the wooden corduroy beach access pathways, which are in a poor condition (Fig. 32), due to age and wear-and-tear.

[63] Cooper & Pilkey, 2012; Sánchez-Arcilla, 2015; Devoy, 2015; Garcia- León et al., 2015.

[64] CIIRC, 2015.

[65] DoELG, 2000; Hill et al., 2001.

[66] e.g., Heritage Council, 2002b; Kramm et al., 2010.

Fig. 32a.

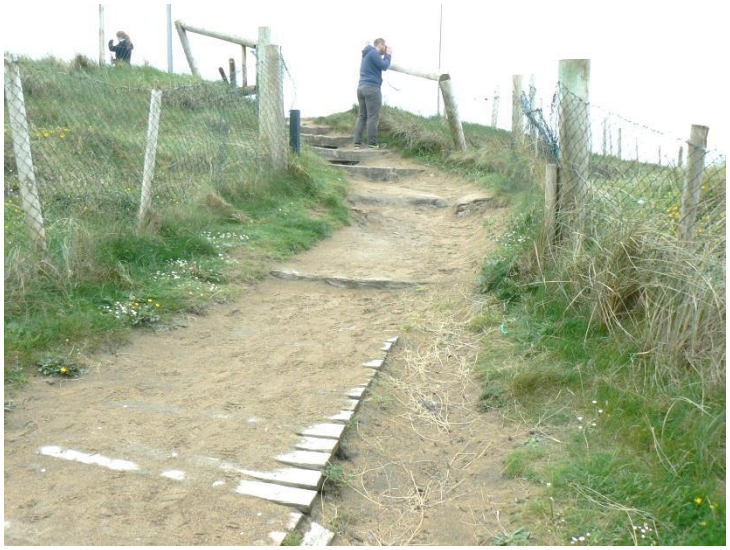


Fig. 32b.

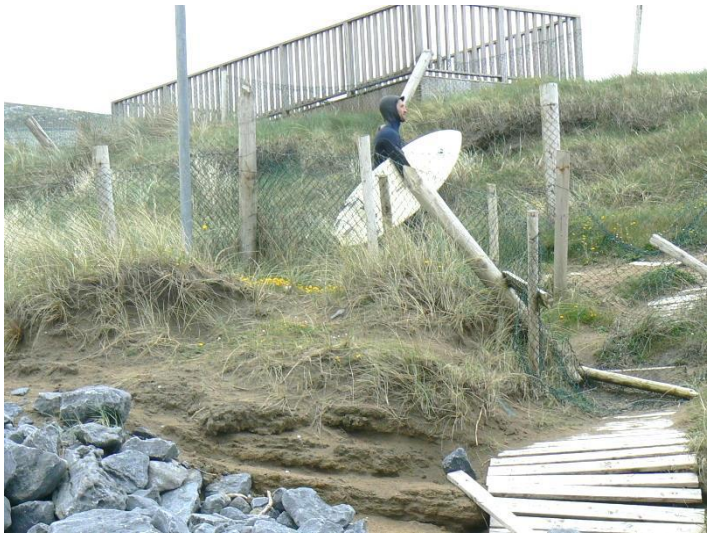


Fig. 32c.

Fig. 32d.

Fig. 32e.

Figure 32a. - e. Broken and degraded states of the Stairway to Fanore Beach and of the service corduroy wooden walkways.

Maintenance of the Stairway and the linking walkways/ paths will be an ongoing cost for the foreseeable future. Consequently, the use of more flexible materials would be valuable in its construction, if possible e.g., durable roughened plastic, grid-type box sections. These should be set into the sands for the steps, rather than the use of wood/ timber sleepers, as at present. Numbers of manuals detailing the design of infrastructure for use in beach - coastal management practice exist and should be referred to in deciding on materials use[67]. The advantages of continuing with the use of wood in re-building the Stairway is, i) Cost and ease of materials availability, ii) A natural and renewable material, so scores environmentally in 'Green'/ conservation terms. It has problems of rot and durability though, iii) Wood may also retain better grip properties over plastics for pedestrian use, an important consideration. However, it is worth experimenting with plastics. Similarly, paths at the Site currently constructed as corduroy type walkways using wooden planks, might also be made with plastics in future works. These materials would allow the easier re-positioning of the Stairway and other paths/ walkways in future when they need to be replaced, particularly in context of any rapid changes in dune-front position under continued erosion.

[67] EcoPro, 1996; New South Wales, Australia, Department of Land and Water Conservation, 2001; U.S. Army Corps of Engineers, Coastal Zone Management Manuals, 1984 - 2015.

There needs to be a dedicated sourcing of the plastic Box-type sections, risers and rails: they are not off-the-shelf. Specific mouldings for toughened plastic forms (i.e., for the treads, risers and rails etc.) would need to be ordered from a plastic mouldings manufacturer. Toughened 'plastic crate/ pallet type boxes', as used in fisheries on trawlers are available though, and these might serve the purpose.

Recommendation 9.

Different signage has been used at the Site: as 'warning' type notices fixed on the fencing (Figure 26), together with interpretative information displays for the area (giving information texts, illustrations and photographs) positioned at the different public access points (e.g., in Car Park areas). Given the range of likely future environmental and visitor use changes at the Site, then it would be valuable to review now the range and content of the interpretative information provided, even though this may have been renewed in recent times. This review should be to update the signs and information displays/ interpretation to take account of the projected site changes resulting from climate warming.

Information on the different approaches needed in the use of signs and interpretative information displays, is given in, e.g., McKenna et al., 2000; Brooks and Agate, 2001; Gault et al., 2007. These works stress the need for the attractiveness and careful positioning of signage as a critical part of informing people and influencing their responses to Site restrictions and protection measures. Concerning directional and warning-type notices, as attached to fence lines, then the following is a useful guide, "signage has a range of uses including providing warnings about hazards, highlighting facilities, outlining and explaining management initiatives, and requesting compliance. A common error with signs is that they are designed to simply prohibit access and/or particular behaviours and lack a positive and explanatory emphasis that is sometimes needed. Negative signage can sometimes induce vandalism and in the end may serve to promote the very behaviour it originally intended to prohibit. Many site managers have observed that cheap, mass produced signs are more likely to be vandalised than carefully hand routed signs. The alternative is to design signage that will withstand both vandalism and the elements"[68].

Of importance for Fanore will be the development of materials that will encourage people's use of the displays and in drawing them into the changing character of the environment, the site needs and future conservation goals. This information can be linked to more sophisticated audio-visual and interactive type displays, e.g., as recently deployed in Clifden, Co. Galway[69]. Also, signage is needed specifically to encourage/ direct people to use only the established roads/ walkways at the Site.

Recommendation 10.

The Site is currently managed and supervised through staff from Clare County Council and the Burren - Cliffs-of-Moher Geopark. Given the need ideally to develop the role of the local community in the Site's management, consideration should be given to

[68] From Gault et al., 2007.

[69] Clifden, Alcock and Browne/ Marconi Centre, July 2016.

employment of a Site Warden/ Ranger (a feasibility study and costing is required). This should probably be as a part-time position, given current visitor numbers, and recruited from the local community. The job would be for daily supervision of the Site's use and for interaction with visitors in terms of environmental education, communications - interpretative information.

Recommendation 11.
Set up of regular capacity building Workshops/ field exercises and demonstration/ Site events for, 'Climate and Coastal Environmental Change' *capacity building* for visitors and the local community. This activity would be part of a Site Warden's and Geopark management's work, in community education, environmental change awareness building and conservation strategy actions.

Approaches to 'best practices' in coastal management have stressed increasingly the need for the development of *capacity building*, as part of people's responses and adaptation (in social, economic and governance organisation) to the impacts of coastal functioning, particularly under the conditions of a warming climate[70]. A useful definition and discussion of capacity building and related concepts in environmental management is given in Desmond & Shine (2012). In the Fanore Site context, and wider environmental management, capacity building is designed to help coastal communities, at both local and wider levels, to become fully involved as environmental stakeholders, enabling them to cope better with coastal changes. The tools and techniques linked now with the concept of engaging people's participation as decision makers and innovators in the areas of environmental management, policy and practice, in new jobs creation and in experimenting with new ways of dealing with the different the changes occurring in coastal areas[71].

For Local Authorities, in charge of the environmental management tasks, their role is in facilitating this approach, through the communication of key and quality environmental information, in education and in project developments at site levels. The bringing into law in Ireland of the 'Climate Bill', 2015 (Houses of the Oireachtas, 2016) will formalise the responsibilities of Local Authorities in this area. The DoECLG have already begun a process involving the running of regional workshops and training for Local Authorities to inform them of the urgent needs in this area, as part of the national response to the impacts of climate warming[72].

In Actions and practical terms for Fanore, this will mean the need to involve both the local and wider community (i.e., visitors) in the different aspects of Site management. In particular, with information gathering and the changing needs for site conservation. Possible immediate areas of involvement here would include:-

[70] Devoy, 2008; IPCC, 2007b, 2014b; Cooper & Cummins, 2009; Shine & Desmond, 2011; Gray et al., 2014; CIIRC, 2015.

[71] Cummins & Cooper, 2009; Gray et al., 2014; CoastAdapt, 2013; Climate-ADAPT, 2013.

[72] EPA, 2015.

i) The development of a programme of future Site surveys, data collection and the monitoring of the operational processes and functioning of the dunes and linked coastal areas. This would be to build on the existing series of 'professionally-based' Site surveys undertaken since 2002.

ii) Commissioning the design of a suitable Survey-Monitoring approach, structure and programme, to be operated by the community.

iii) Development of education programmes for the Site involving school students (i.e., National School to Second Level students), together with wider education programmes for Site visitors.

iv) To continue and/ or set up environmental projects on the area for Schools' work as part of regular environmental education (Site interpretation and field studies), focused on raising awareness of the dune environments and the development of a wider understanding of environmental changes under climate warming.

Recommendation 12.

To continue to develop links for the Site and wider Blackhead - Poulsallagh SACs complex with the *Atlantic Way* and the *Burren and Cliffs-of-Moher GeoPark*, in response to the likely future increases in people's recreational use of the Site and wider tourism. These links, apart from integrated management controls, would overlap in part with some of the other recommendations, as links to improvement of the signage, approaches in providing Site interpretative information; *capacity building* for change in the community.

Recommendation 13.

This is more peripheral to the practical Site actions, built works, environmental and field education as core to the Report brief (Recommendations 1 -12), but is relevant to the future management framework for the Site. There is a need for governance and policy reform for conservation practices under the longer-term effects of climate warming, affecting organisations such as Local Authorities, the National Parks and Wildlife Service (NPWS), Office of Public Works (OPW) and the DoECLG.

Future climate warming will impact all environments, not just these sensitive coastal systems, substantially[73]. Current legislation and landscape controls and their administration has been developed primarily for existing environmental conditions and less with climate change impacts in mind. Whilst the Climate Bill, 2015 will now force some revision of areas of existing Conservation legislation, it may be sometime before this is reflected in real field practices, at Site/ Project levels, i.e., the DoECLG/ NPWS to develop a more flexible approach in application of conservation measures[74].

[73] IPCC, 2007a, 2014a; Climate Ireland, 2016.

[74] viz., Kerry County Council, 2015.

6.0 REFERENCES

ANCORIM, 2012. *Atlantic Coastal Network for Coastal Risks Management: Publication Series*. BRGM & ONF, France. (Eds). Akson, Bordeaux, France.

Barratt, D., 1998. The role of vegetation in determining patterns of accretion of saltmarsh sediment. In: K.S. Black, D.M. Paterson and A. Cramp (Eds.), Sedimentary Process in the intertidal zone. *Geol. Soc. Special Publication 139*, 389-399. Geological Society of London.

Brooks, A. and Agate, E., 2001. *Sand Dunes, A Practical Handbook*. BTCV. http://handbooks.btcv.org.uk/handbooks/index/book/137

Brown, A.C. and MCLachlan, A., 2002. Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. *Environmental Conservation*, 29, 62-77.

Browne, A., 2003. *Habitat Survey of Fanore Dunes: Report*. Clare County Council, Ennis.

Browne A., 2004. *Habitat Survey of Fanore Dunes. Unpublished Report*. Clare County Council.

Browne, A., 2007. *Fanore Monitoring Programme: An Outline Response to Nature Conservation Recommendations of the Department of the Environment, Heritage and Local Government. Unpublished Report*. Clare County Council, Ennis.

Burren and The Cliffs of Moher Geopark, 2016. Co. Clare and The Burren Geology (and Caves) Reference List. http://www.burrengeopark.ie/learn-engage/research-archive/geology-reference-list/

Burrenbeotrust, 2016. Burren Landscape and Hydology. www.burrenbeo.com

Burren Connect, 2013. Burren Ecotourism Network. http://www.burrenecotourism.com

Burren National Park, 2016. www.burrennationalpark.ie

Carter, R.G.W., 1988. *Coastal Environments*. Academic Press, London.

Carter, R.W.G., 1991. Near-future sea-level impacts on coastal dune landscapes. *Landscape Ecology*, 6 (1-2), 29-39.

Carter, R.W.G., Curtis, T.G.F. & Sheehy-Skeffington, M.J., 1992. *Coastal Dunes: Ecology and Management for Conservation*. Balkema, Rotterdam.

Carter, R.W.G., Devoy, R.J.N. and Shaw, J., 1989. Holocene sea-level changes in Ireland. *J. of Quaternary Science*, 4, 7-24.

Carter, R.W.G. and Woodroffe, C.D. (Eds.), 1994. *Coastal Evolution: Late Quaternary Shoreline Morphodynamics*. Academic Press, London.

Church, J.A., Clark, P.U., et al., 2014. Sea Level Change. In: *Contribution of Working Group I to the Fifth Assessment Report on Climate Change 2014: The Physical Science Basis*, Chapter 13. Cambridge University Press, Cambridge, United Kingdom.

Clare County Council, 2010. *Clare County Development Plan 2011 – 2017, Vols 1-3*. Clare County Council, Ennis.

Clifford, L., 2002. *Storms' Meteorology, West Coasts of Ireland*. Unpublished MSc Thesis, UCC.

CIIRC(Centre Int. d'Inv. dels Recursos Costaners), 2015. *Integrated Coastal Alert System*. EU Project iCOAST, Contract No: ECHO/SUB/2013/661009. Project website: http://www.icoast.eu

Climate-ADAPT, 2013. Website information in http://climate-adapt.eea.europa.eu/

CoastAdapt, 2013. CoastAdapt Project: The Sea As Our neighbour. European Union, Northern Periphery Programme (2007-2013). http://coastadapt.org

Coastal Engineers of Ireland, 2016. Coastal erosion rates. https://www.engineersireland.ie/EngineersIreland/.../20110530

Cooper, J.A.G. and Cummins, V. (Eds.), 2009. *Coastal Management in Northwest Europe*. Elsevier, Amsterdam.

Cooper, J.A.G and Jackson, D.W.T., 2011. Geomorphology of a high energy barrier island on the rocky west coast of Ireland. *J. Coastal Res.*, SI 64, 6-9.

Cooper, J.A.G. and Muir, D. and Pétursdóttir, G., 2014. Coastal Climate Change Adaptation in The Northern Periphery Of Europe. *Ocean & Coastal Management*, 94, 1-98.

Cooper, J.A.G. and Pilkey, O., 2012. *Pitfalls of Shoreline Stabilization*. Springer, Dordrecht/ New York.

Cowell, P.J. & Thom, B.G., 1994. Morphodynamics of coastal evolution. In, Carter, R.WG. & Woodroffe, C.D. (eds), *Coastal Evolution.* Cambridge University Press.

Davies, G.L.H. and Stephens, N., 1978. *Ireland*. Series: The Geomorphology of The British Isles. Methuen, London.

DEFRA (Department of the Environment Food and Rural Affairs), 2009. *Appraisal of Flood and Coastal Erosion Risk Management: A Defra Policy Statement*. HM Government Publications. https://www.gov.uk/government/policies/flooding-and-coastal-change

Delaney, A., Devaney, F.M, Martin, J.M. and Barron, S.J., 2013. Monitoring survey of Annex I sand dune habitats in Ireland. *Irish Wildlife Manuals*, No. 75. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Delaney, C., Devoy, R.J.N. and Jennings, S.C., 2012. Mid to late Holocene relative sea-level and sedimentary changes in southwest Ireland. In: Duffy PJ, Nolan W (Eds), *At the Anvil.* Geography Publications, Dublin, pp. 697-746.

Department of the Environment and Local Government, 2000. *Landscape and Landscape Assessment: Consultation Guidelines for Planning Authorities*. Dublin.

Desmond, M. & T. Shine, 2012. National Adaptive Capacity Assessment. Climate Change Research Programme (CCRP) 2007 – 2013, Report Series Number 17. Environmental Protection Agency, Dublin.

Desmond, M., O'Brien, P. and McGovern, F., 2015. *A Summary of the State of Knowledge on Climate Change Impacts for Ireland.* Environmental Protection Agency, Dublin.

Devoy, R.J.N., 1987. *Sea Surface Studies: A Global View*. Croom Helm-Chapman Hall, London.

Devoy, R.J.N., 1992. Questions of coastal protection and the human response to sea-level rise in Ireland and Britain. *Irish Geography*, 25, 1-22.

Devoy, R.J.N., 2008. Coastal vulnerability and the implications of sea-level rise for Ireland. *J. of Coastal Research,* 24, 325-341.

Devoy, R.J.N., 2015a. The development and management of the Dingle Bay Spit-Barriers of Southwest Ireland. In: G. Randazzo, D.W.T., Jackson and J.A.G. Cooper (Eds.), *Sand and Gravel Spits*. Springer, Dordrecht, Chp. 9, pp. 139-180.

Devoy, R.J.N., 2015b. Sea- level rise: causes, impacts and scenarios for change. In: D. Sherman & J. Ellis (Eds), *Coastal and Marine Hazards, Risks and Disasters*. Elsevier, New York, Chp. 8, pp. 197-242.

Devoy, R.J.N., 2015c. Report to Kerry County Council (KCC) on Coastal Management Issues at Ballyheigue. Kerry County Council, Tralee and the Marine Research and Energy Institute (MaREI), UCC.

Devoy, R.J.N., Delaney, C., Carter, R.W G. and Jennings, S.C., 1996. Coastal stratigraphies as indicators of environmental changes upon European Atlantic coasts in the late Holocene. *J. of Coastal Research,* 12, 564-588.

Devoy, R.J.N., Gault, J. and O'Mahony, 2015. Task D: Intervention Guidelines. Integrated Coastal Alert System (Project iCOAST), European Union, Contract No: ECHO/SUB/2013/661009. Project website: http://www.icoast.eu.

Devoy, R.J.N., Navarre, P., Vijaykumar, N. Gault, J and Cronin, K., 2004. A forty year wave hindcast atlas of Irish and neighbouring European shelf waters: Final report. In, C.G Guedes Soares (Ed.) *Hindcast of Dynamic Processes of the Ocean and Coastal Areas of Europe (HIPOCAS): Final Report*. Contract EVK2-CT1999-00038. (Commission of the European Communities, Brussels, 2004).

DoEHLG, 2009/2010. Appropriate Assessment of Plans and Projects in Ireland: Guidance for Planning Authorities. Government Publication, Dublin.

Doody, J.P., 2001. *Coastal Conservation and Management: An Ecological Perspective*. Volume 13, Conservation Biology Series, Kluwer Acad. Publ. Boston.

Doody, J.P., 2012. *Sand Dune Conservation, Management and Restoration*. Springer, Dordrecht.

Drew, D., 1990. The hydrology of The Burren. *Irish Geography*, 23(2), 69-89.

Dunne, S.S., Hanafin, J., Lynch, P., McGrath, R., Nishimura, E., Nolan, P., Venkata Ratnam, J., Semmler, T., Sweeney, C. and Wang, S., 2008. *Ireland in a Warmer World: Scientific Predictions of the Irish Climate in the 21st Century*. Met Eireann & University College Dublin, Dublin.

Dwyer, N. (ed.), 2012. *The Status of Ireland's Climate*. Environmental Protection Agency, Dublin.

ECOPRO, 1996. *Environmentally Friendly Coastal Protection: Code of Practice*. Government of Ireland, Dublin.

Edwards, R. and Craven, K., (in press). Relative sea-level change around the Irish coast. In: *The Irish Quaternary. Advances in Quaternary Science*.

Edwards, K. & Warren, W.P., 1985. *Quaternary History of Ireland.* Academic Press, London.

Ehlers, J. & Gibbard, P.L., 2004. *Quaternary Glaciations, Extent and Chronology: Part 1, Europe.* Developments in Quaternary Science, Vol. 2. Elsevier, Amsterdam.

Environmental Protection Agency (EPA, Ireland), 2015. *Second Report on the Impacts of Climate Change for Ireland*. EPA, Dublin.

Environmental Protection Agency (EPA, Ireland), 2015. Planning for Climate Change: Regional Workshop Series, October - December, 2015. DoECLG & EPA Ireland, Dublin.

European Environment Agency, 2014. Global and European sea-level rise (CLIM 012) – Assessment, published September 2014. European Environment Agency, Denmark.

E.U. Project iCoast, 2013 - 2015. Integrated Coastal Alert System (iCoast). European Commission, DG ECHO.

Feagin, R.A., Sherman, D.J. and Grant, W.E., 2005. Coastal erosion, global sea-level rise and the loss of sand dune plant habitats. *Front. Ecol. Environ*., 3(7), 359-364.

Failte Ireland, 2012/3. The Wild Atlantic Way: Project Development and Consultation. Bulletins Number 1& 2 (April, 2013). Failte Ireland, National Tourism Development Authority, Dublin.

Falaleeva, M., Gray, S., O'Mahony, C. and Gault, J., 2013. *Coastal Climate Adaptation in Ireland: Assessing Current Conditions and Enhancing the Capacity for Climate Resilience in Local Coastal Management (2008-CCRP 3.6)*. Environmental Protection Agency, Dublin.

Gallagher, S., Tiron, R. & Dias, F., 2014. A long-term nearshore wave hindcast for Ireland: Atlantic and Irish Sea coasts (1979–2012). *Ocean Dynamics*, 64(8), pp.1163–1180. DOI: 10.1007/s10236-014-0728-3

Gallagher, S., Tiron, R., Whelan, E., Gleeson, E., Dias, F. & McGrath, R. 2016. The nearshore wind and wave energy potential of Ireland: A high resolution assessment of availability and accessibility. *Renewable Energy*, 88, 494-516.

Garcia-León, M., Gracia, V., Robichaux, L., Kroger, A., Gault, J., Sánchez-Arcilla, A., 2015. Evaluation of transient defence measures against storms. *Proceedings of the Coastal Sediments Conference*, San Diego, USA.

Gault, J., Morrissey, C. & Devoy, R.J.N., 2007. *Dune Protection Plan for the Fingal Coast County Dublin*. Coastal and Marine Research Centre (CMRC), UCC, Cork.

Gleeson, E., McGrath, R. and Treanor, M., 2013. *Ireland's Climate: The Road Ahead*. Met. Éireann, Dublin.

Gracia V., Sánchez-Arcilla, A., García-León, M., Gault, J., Oller, P., Fernández, J., Sairouni, A., Cristofiori, E. and Toldrà, R., 2014. A new generation of early warning systems for coastal risk. The iCoast Project. *Proceedings of the 34th International Conference on Coastal Engineering*, Seoul, Korea.

Gray, S.R.J., Gagnon A.S., Gray S.A., O'Dwyer B., O'Mahony C., Muir D., Devoy R.J.N., Falaleeva M., 2014. Are coastal managers detecting the problem? Assessing stakeholder perception of climate vulnerability using fuzzy cognitive mapping. *Ocean & Coastal Management*, 94, 74-89.

Harley, M.D. and Ciavola, P., 2013. Managing local coastal inundation risk using real-time forecasts and artificial dune placements. *Coastal Engineering*, 77, 77-90.

Harrington, J. and Smith, G., 2013. *Guidance on the Beneficial Use of Dredge Material in Ireland*. Environmental Protection Agency, Dublin.

Heritage Council, 2002a. *Landscape Character Assessment of County Clare*. Heritage Council, Kilkenny/ Environmental Resource Management, London.

Heritage Council, 2002b. *Integrating Policies for Ireland's Landscape*. Heritage Council, Kilkenny.

Hill, M., Briggs, J., Minto, P. Bagnall, D., Foley, K. Williams, A., 2001. *Guide to Best Practice in Seascape Assessment*. The Maritime Ireland & Wales EU INTERREG Programme 1994- 1999. The Marine Institute, Dublin.

Hoctor, Z. 2016. *Management Actions Since 2002 at Fanore Beach and Dunes: A Summary*. Personal Communication, Clare County Council, Ennis.

Houses of the Oireachtas, 2016. Climate Action and Low Carbon Development Bill, 2015. Dublin. http://www.oireachtas.ie/viewdoc.asp?fn=/documents/bills28/bills/2015/215/b215d.pdf

IPCC (Intergovernmental Panel on Climate Change), 2007a. *Contribution of Working Group I to the Fifth Assessment Report on, Climate Change 2013: The Physical Science Basis*. Cambridge University Press, Cambridge, United Kingdom.

IPCC (Intergovernmental Panel on Climate Change), 2007b. *Contribution of Working Group I to the Fifth Assessment Report on, Climate Change 2013: The Physical Science Basis*. Cambridge University Press, Cambridge, United Kingdom.

IPCC (Intergovernmental Panel on Climate Change), 2014a. *Contribution of Working Group I to the Fifth Assessment Report on, Climate Change 2013: The Physical Science Basis*. Cambridge University Press, Cambridge, United Kingdom.

IPCC (Intergovernmental Panel on Climate Change), 2014b. *Contribution of Working Group II to the Fifth Assessment Report on, Climate Change 2013: Impacts, Adaptation and Vulnerability*. Cambridge University Press, Cambridge, United Kingdom.

IPCC, (Intergovernmental Panel on Climate Change), 2014c. *Climate Change 2013: Summary. Contribution from Working Group I*. Cambridge University Press, Cambridge, United Kingdom.

Irish Times, 2015. News Report, 5 January 2015. www.irishtimes.com/.../last-year-was-one-of-warmest-on-record-in-irelan.

Jackson, D.W.T. and Cooper, J.A.G., 2011. Coastal dunefields in Ireland: rapid regional response to climate change. *J. of Coastal Research*, SI64, 293-297.

Jelgersma, S., 1979. Sea-level changes in the North Sea Basin. In: W. Oele, R.T.E. Schuttenhelm and A.J. Wiggers (Eds.), *The Quaternary History of the North Sea*. Acta Univ. Ups. Symp. Univ. Annum Quingentesium Celebrantis, 2. Uppsala, pp. 233-248.

Jenkins, G.J., Murphy, J.M., Sexton, D.M.H., Lowe, J.A., Jones, P. and Kilsby, C.G., 2009b. *UK Climate Projections: Briefing Report*. Met Office, Hadley Centre, Exeter, UK.

Kandrot, S., Devoy, R.J.N., Cawkwell, F., Gault, J., 2014. Monitoring and modelling micro-to meso-scale dune-barrier behaviour using terrestrial laser scanning. *Poster Presentation, Irish Geomorphologists' Group* (IGGy), Nov. 2014, Trinity College Dublin. Department of Geography University College Cork.

Kandrot, S., 2016. *High Resolution Monitoring Techniques and the Modelling of Storm Impacts Upon Coastal Beach-barrier Ssystems in Southwest Ireland*. Unpublished PhD Thesis, University College Cork, Ireland.

Kandrot, S., Farrell, E. & Devoy, R.J.N., 2016 (in prep.). The Winter Storms of 2013-2014: Impacts on a Breached Barrier. *ESPL Special Issue, Geomorphology of the Irish Landscape*., Irish Geomorphologists Group, Dublin.

Keegan, E., 2008. *Fanore Dune Monitoring 2008: Report*. Clare County Council, Ennis

Kerry County Council, 2015. *Habitats Directive Assessment Screening Report: For the proposed Waste Water Discharge Licenses in respect of the Ardfert village agglomeration, which discharges to the River Tyshe upstream of Ballyheigue Bay*. Environmental Assessment Unit, Planning Department, Kerry County Council.

Knight, J., Coxon, P. and McCabe, A.M., 2004. *Pleistocene Glaciations in Ireland*. Elsevier, Amsterdam.

Kramm, N., Anderson, R., O'Rourke, E., Emmerson, M., O'Halloran, J. & Chisholm, N., 2010. *Farming the Iveragh Uplands: A Tale of Humans and Nature*. University College Cork. Cork.

Lindsay, A., 2002. *The Feasibility of Sustainable Development in the Coastal Zone?* MA Thesis, NUI Galway.

Lowe, J.A., Howard, T.P., Pardaens, A., Tinker, J., Holt, J., Wakelin, S.,Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., J., Dye, S. and Bradley, S., 2009a. *UK Climate Projections Science Report: Marine and Coastal Projections*. Met Office, Hadley Centre, Exeter, UK.

Lozano I, Devoy R.J.N, May W., Andersen U, 2004. Storminess and vulnerability along the Atlantic coastlines of Europe: analysis of storm records and of greenhouse gases induced climate scenario. *Marine Geology*, 210, 205-225.

Marine Institute, 2015. Wave buoy and wave data for Ireland. http://www.marine.ie/home

Masselink, G., Hughes, M.G. and Knight, J., 2011. *Coastal Processes and Geomorphology*. Hodder Education, London.

McCormack, T., Gill, L.W., Naughton, O., Johnston, P.M., 2014. Quantification of Submarine/Intertidal Groundwater Discharge and Nutrient Loading from a Lowland Karst Catchment, *Journal of Hydrology*, doi:http://dx.doi.org/10.1016/j.jhydrol.2014.09.086

MaNamara, M. E., 2009. *The Geology of The Burren Region, County* Clare, Ireland. Northern Environmental Education Project.

McNamara, M. and Hennessy, R., 2010. The Geology of The Burren Region. Burren Connect Project, Clare County Council. Ennistymon.

McKenna, J., MacLeod, M., Power, J., and Cooper, A., 2000. Rural Beach Management: A Good Practice Guide. Donegal County Council, Lifford, Co. Donegal.

Met Éireann, 2016. Meteorological Statistics Report for 2016.

MIDA (The Marine Irish Digital Atlas), 2016. Coast erosion rates. http://mida.ucc.ie/

Natura 2000, *Guidelines and Requirements for Natura 2000 Impact Statements*. See, http://www.npws.ie/protected-sites/guidance-appropriate-assessment-planning-authorities

NSW Department of Land and Water Conservation, 2001. *Coastal Dune Management: A Manual of Coastal Dune Management and Rehabilitation Techniques.* Coastal Unit, DLWC, Newcastle, New South Wales, Australia.

NPWS (National Parks and Wildlife Service), 2014. *Black Head - Poulsallagh Complex SAC (Site Code 20): Conservation Objectives Supporting Document – Coastal Habitats*. NPWS, Department of Arts, Heritage and the Gaeltacht, Dublin.

National Parks and Wildlife Service, 2015. *Natura 2000 Sites for Nature Conservation*. Department of Arts, Heritage and the Gaeltacht, Dublin.

Nicholls, R.J., Burkett, V., Codignotto, J., Hay, J. McLean, R., Ragoonaden, S. and Woodroffe, C.D., 2007. Coastal systems and low-lying areas. In: *Contribution of Working Group II to the Fourth Assessment Report on, Climate Change 2007: Impacts, Adaptation and Vulnerability*. Cambridge University Press, Cambridge, United Kingdom., pp.315-356.

Nordstrom, K.F., 1994. Developed coasts. In: Carter, R.W.G and Woodroffe, C.D. (Eds.), *Coastal Evolution: Late Quaternary Shoreline Morphodynamics*. Academic Press, London, pp. 477-509.

Orford, J.D., 1989. A review of tides, currents and waves in the Irish Sea. In: Sweeney, J.C. (Ed.), The Irish Sea: A Resource at Risk. *Geographical Soc. of Ireland*, Special Publication No. 3, pp.18-46.

Orford, J.D. and Carter, R.W.G., 1984. Mechanisms to account for the longshore spacing of overwash on a coarse clastic dominated barrier beach in southeast Ireland. *Marine Geology*, 56, 207-226. Tacumshin – Lady's Is.

Orford, J.D., Carter R.W.G., Forbes, D.L. and Taylor, R.B., 1988. Overwash occurrence consequent on morphodynamic changes following lagoon outlet closure on a coarse clastic barrier. *Earth Surface Processes & Landforms*, 13, 27-35.

Orford, J.D., Cooper, J.A.G. and Smith, B., 1997. LOICZ: the human factor as an influence on the Irish coast. In: Sweeney J (Ed.), *Global Change and the Environment*. Royal Irish Academy, Dublin, pp 88-107.

O'Brien, L., Dudley, J.M., & Dias, F., 2013. Extreme wave events in Ireland: 14, 680 BP-2012. *Nat. Hazards Earth Syst. Sci*., 13, 625-648.

O'Dwyer, B. and Gault, J., 2015. *Climate Information Platform for Ireland, Phase 2* (ICIP2). Coastal and Marine Research Centre, MaREI, University College Cork (Environmental Protection Agency Ireland Project, online details at http://cmrc.ucc.ie/).

O'Shea, M. and Murphy, J., 2013. Predicting and monitoring the evolution of a coastal barrier dune system post breaching. *J. of Coastal Research*, 29, 38-55.

O'Shea, M., 2015. *Monitoring and Modelling the Morphodynamic Evolution of a Breached Barrier Beach System*. Unpublished PhD thesis, University College Cork, Ireland.

O'Sullivan, A. 1995. *Reconstruction of the Palaeoenvironment of Ballyheigue Marsh, County Kerry, Southwest Ireland*. Unpublished BSc Dissertation, UCC.

Pontee, N., 2013. Defining coastal squeeze: a discussion. *Ocean and Coastal Management*, 84, 204-247.

Pye, K., Saye, S. and Blott, S., 2007. *Sand Dune Processes and Management for Flood and Coastal Defence, Part 3: The geomorphological and Management Status of Coastal Dunes in England and Wales*. R&D Technical Report FD1392/TR. DEFRA & Environment Agency, United Kingdom.

Randazzo, G., Cooper, J.A.G. & Jackson, J.A., 2015. *Sand and Gravel Spits*. Springer, Dordrecht/ New York.

Robinson, T., 1977. *The Burren: A Map of the Uplands of North-West Clare*, Éire. Galway.

Rosati, J.D.; Dean, R.G.; and Walton, T.L., 2013. The modified Bruun Rule extended for landward transport. *US Army Research*, Paper 219. http://digitalcommons.unl.edu/usarmyresearch/219.

Rowe, D.R. and Abdel-Magid, I.M., 1995. *Handbook of Wastewater Reclamation and Reuse*. CRC Press, Boca-Raton, Florida, USA.

Ryle, T., Murray, A., Connolly, K. and Swan, M., 2009. *Coastal Monitoring Project Report 2004 - 2006. National Parks and Wildlife Service*. Department of Arts, Heritage and the Gaeltacht, Dublin.

Sala, P. 2010. *Morphodynamic Evolution of a Tidal Inlet mid-Bay Barrier System*. Unpublished Master's Thesis, University College Cork, Ireland.

Sánchez-Arcilla, A., Gracia, V., García-León, M., 2015. Natural accretion mechanisms. The role in future coastal sustainability. In, *The Proceedings of the Coastal Sediments Conference, San Diego, USA, 11-14 May 2015*.

Science Direct, 2013. *Inch, Co. Kerry: Report on Proposed Golf Course Development.* (Science Direct Consultants, Blarney, Cork).

U.S Army Corps of Engineers, 1984 - 2015. *Shore Protection Manuals*. Coastal Engineering Research Centre, Washington, D.C.

Vial, T., 2008. *Monitoring the Morphological Responses of an Embayed High Energy Beach to Storms and Atlantic Waves*. Unpublished Master's Thesis, University College Cork, Ireland.

Vijaykumar, N., Devoy, R.J.N., Gault, J., Dunne, D. and O'Mahony, 2003. Validation methods and links to a coastal-GIS in the development of a high resolution limited area model (HIRLAM) for producing a 40-year wave atlas for the Irish and Celtic Seas. *The Proceedings of Coast GIS - 5th International Symposium on GIS and Computer Cartography for Coastal Zone Management*. Genoa, Italy, 16-18 October 2003.

Viles, H. and Spencer, T., 1995. *Coastal Problems: Geomorphology, Ecology and Society at the Coast*. Edward Arnold, London.

Visser, J. and Misdorp, R., 1998. Coastal Dynamic Lowlands- The Role of Water in the Development of the Netherlands: Past, Present, Future. *J. Coastal Conservation*, 4, 105-168.

Whittow, J.B., 1974. *Geology and Scenery in Ireland*. Penguin Books, London.

Wintle, A.G., Clarke, M.L., Musson, F.M., Orford, J.D. and Devoy, R.J.N., 1998. Luminescence dating of recent dunes on Inch Spit, Dingle Bay, southwest Ireland. *The Holocene, 8(3)*, 331-339.

Wong, P.P., Losada, I.J., et al., 2014. Coastal systems and low-lying areas. In: *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change 2014: Impacts, Adaptation and Vulnerability*. Cambridge University Press, Cambridge, United Kingdom.

Woodroffe, C.A., 2002. *Coasts: Form, Process and Evolution*. Cambridge University Press, Cambridge.

Signed: Robert J. N. Devoy Date: 30/07/16

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Appendix 1

Management Actions To Date at Fanore Beach and Dunes

By Zena Hoctor, 2016 (Burren and Cliffs of Moher Geopark).

Fanore Dunes – In 2002 a thesis (*The Feasibility of Sustainable Development in the Coastal Zone?)* undertaken as part of the M.A. in Geography at NUI Galway by Aoibheann Lindsay highlighted the requirement for 'further study of the flora and fauna of the area'.

In 2003 a baseline study was undertaken and recommendations for interventions made (Dr Amanda Browne (**2003**) '*Habitat Survey of Fanore Dunes'* Clare County Council). Survey work was carried out in July 2003, consisting of 8 quadrats (GPS and photographs) using Braun-Blanquet approach.

Findings: *Embryo dune development is absent and marram dune vegetation is patchy along the top of the dune ridge, while the seaward side of the dune consists of a sheer cliff of bare eroding sand. This topographical situation, however is not widespread throughout the surrounding dune hinterland where active dune accretion, embryo dune formation and significant marram dune development is ongoing…the natural occurring processes of erosion have been augmented by pedestrian pressure on the dunes.*

March 2003

The following recommendations were made to limit the public's access through the sensitive dune area:

- Fencing around the periphery of the dunes to prevent walking and pony trekking access. Sand fence to be erected on seaward side of dunes to trap sand. Photos to be taken and regularly monitoring and maintenance to be undertaken. Marram planting to accompany fencing. *In the future if sand fencing has not been effective in encouraging dune building,*

further coastal protection measures may be required. In order to effectively decide on the most appropriate measures to be employed a number of analyses on the physical environment of the beach need to be undertaken. Such analyses include sediment flow, wave action and beach profiling.

- Single point access to be provided for pedestrians. Fencing along access point may be necessary to prevent straying off path.
- Public awareness campaign with regard to importance of dune resource and necessity of the dune protection measures.

The recommendations of the 2003 report were implemented in 2004/2005 when periphery fencing was put around the dune; sand trap fencing was put in place along the seaward side of the dunes and a sand ladder was put in place to provide single point access to the beach by the County Council's Local Area Office.

January 2005

Sand trap fencing along gully at north end of dune 2005

Single point access to beach constructed 2005

Car park 2005

In 2006 the dunes were surveyed under the Coastal Monitoring Project commissioned by the NPWS (Tim Ryle et al. 2009 'Coastal Monitoring Project 2004-2006' Report for NPWS). This survey found the sand dune system at Fanore to *be a relatively intact dune system despite recreational pressures*. Prospects of sand dune habitat - moderate. Individual site reports in Vol II.

January 2006

In **2007**, as part of the Burren Connect Project (forerunner to the Burren & Cliffs of Moher Geopark), conservation works were planned and implemented at Fanore Beach in conjunction with the County Council's Environment Section, Local Area Office and Heritage Office and the National Parks and Wildlife Service (NPWS)

The programme included the replacement and reinforcement of the protective fencing and the installation of sand matting to encourage the re-colonisation of marram grass. A new parking area was developed to compensate for the closure of a relief car park, which was encouraging access to the beach through breaches in the protective fencing. A viewing platform was installed for those who cannot access the beach. The sand ladder, which gives pedestrian access only, to the beach, was repaired and extended. A shower unit was installed at the edge of the car park to facilitate swimmers and surfers.

May 2007

An informative signage system was developed to explain the need for the conservation project and to highlight the extensive biodiversity value of the site.

Dr Amanda Browne was commissioned to develop a monitoring programme for the dune system and the interventions which had been put in place. The resulting programme and indicator system was loosely based on the Ryle et al. Coastal Monitoring Project of 2006, using habitat mapping and fixed points (reflecting changes in morphology) plus transects (at intervals quadrat and Braun-Banquet) sampling. A reassessment of the relevés recorded in 2003 was also carried out. The recommendation was made for this survey to be completed on an annual basis during the month of July, suggesting 10 person days for survey and analysis and for additional days to be allocated to monitoring the cattle grazing regime during the winter months as well as surveying the site after major storm events.

A Schools Conservation Project was developed in partnership with Mary Immaculate Secondary School, Lisdoonvarna and Fanore National School and the Heritage office of Clare County Council. Workshops and site visits were organised for the local community to provide information on the Dunes habitat, and the conservation and monitoring programmes.

In January and February 2008 some additional areas were fenced off where damage had occurred due to fires and one area which had previously hardcore laid for parking was fenced off. In September and October new information and wildlife signs were put in place.

In December a new fence was erected between the river and the dunes in an attempt to help prevent further access with trampling that leads to erosion in this area.

First monitoring: **2008** – Elaine Keegan – 41 quadrats.

2008

2008

2013 Delaney et al, Sand Dunes Monitoring Programme (SDM)??

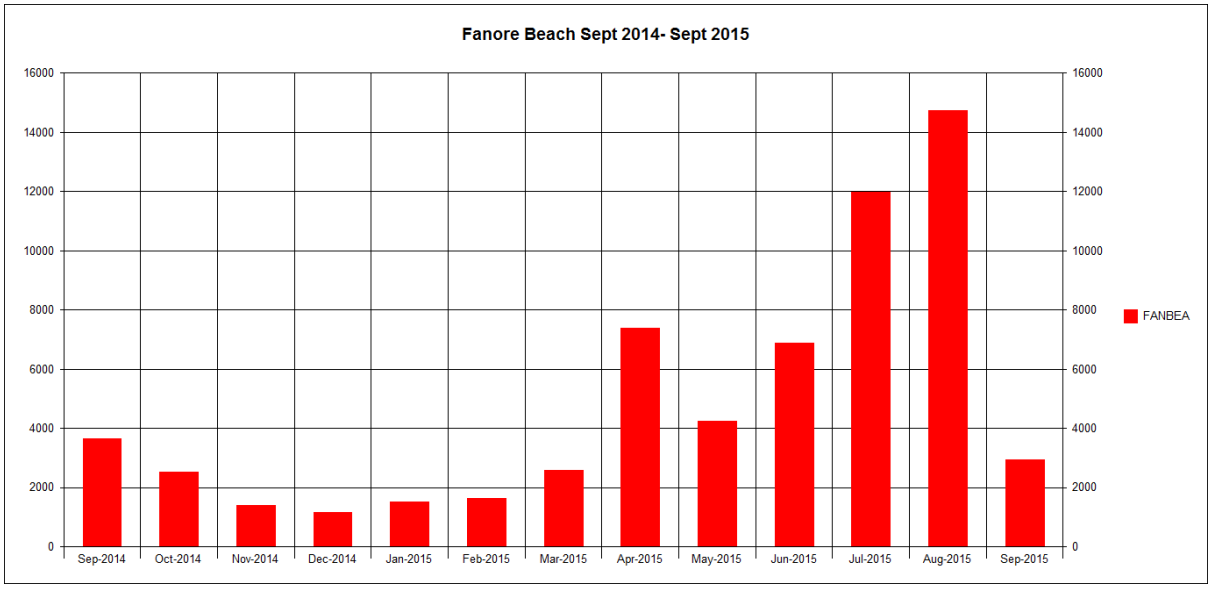
2014 – Paul Murphy and CAAS??

Management Issues at Site

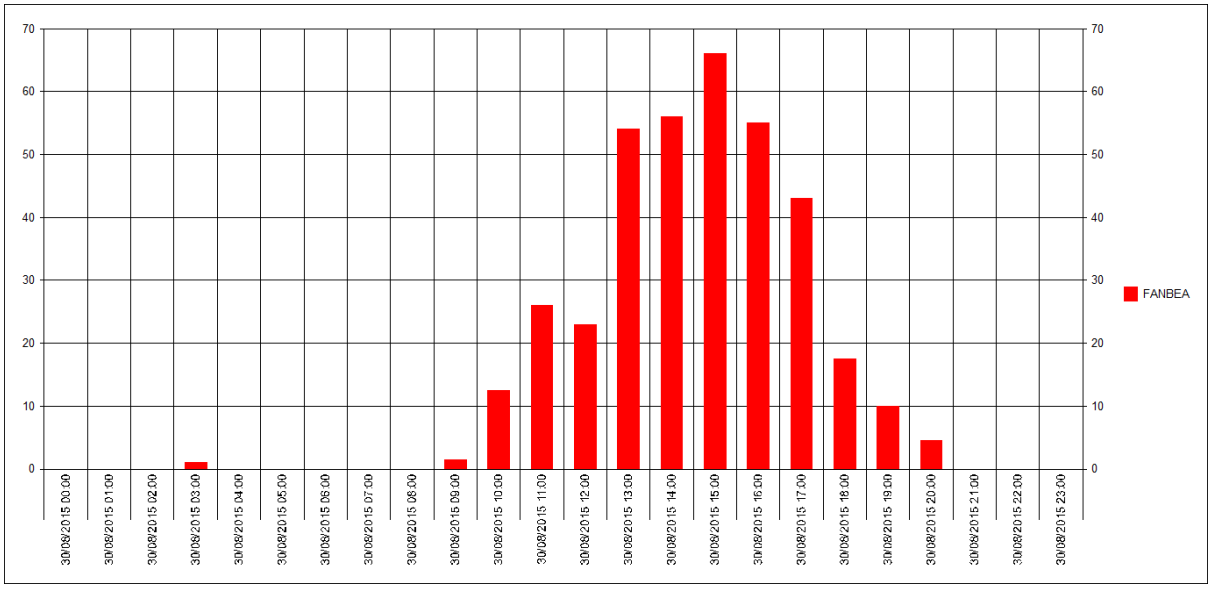
Although a monitoring programme was developed for Fanore Dunes in 2007, which recommended annual monitoring, no County Council organised monitoring work has been undertaken since 2008.

Appendix 2

Data supplied by Zena Hoctor, May 2016 (Burren and Cliffs-of-Moher Geopark).



Fanore: Total numbers for Sept 14-Sept 2015: 62,667 highest monthly total: Aug – 14,727 (23% Total). Total numbers August 2015 – March 31st 2016: 31,774



Fanore: Hourly Visitor data 31-8-15.

SITE 11 Fanore Beach

Counter Code: FANBEA
GPS Location :N53° 7' 1.8084"W9°17'18.2616"

Data from this counter has been calibrated by 0.5