IG
Irish Geography

NOVEMBER 2018
ISSN: 0075-0778 (Print) 1939-4055 (Online)

A Rapid Assessment Framework for Irish Habitats: A Case Study of Machair Habitat Quality

Thomas Gorman, Gesche Kindermann and Terry R. Morley

How to cite: Gorman, T., Kindermann, G. and Morley, T.R. (2018) 'A Rapid Assessment Framework for Irish Habitats: A Case Study of Machair Habitat Quality'. *Irish Geography*, 51(2), 205–228, DOI: 10.2014/igj.v51i2.1372

Geographical Society of Ireland
An Cumann Tíreolaíochta na hÉireann

Irish Geography
Vol. 51, No. 2 November 2018
DOI: 10.2014/igj.v51i2.1372

Geographical Society of Ireland
An Cumann Tireolaíochta na hÉireann

A Rapid Assessment Framework for Irish Habitats: A Case Study of Machair Habitat Quality

Thomas Gorman[1*], Gesche Kindermann[2] and Terry R. Morley[1]

[1] School of Archaeology and Geography and Ryan Institute, National University of Ireland, Galway, Galway, Ireland

[2] Applied Ecology Unit, School of Natural Sciences, National University of Ireland, Galway, Galway, Ireland

First received: 25 June 2018 *Accepted for publication: 20 September 2018*

Abstract: Existing habitat condition assessments in Ireland lack a standardised, quantitative methodology and are often beyond the time constraints of monitoring staff. Therefore, there is a need to develop a framework that can rapidly assess habitats and provide a benchmark against which change can be measured. We reviewed existing national and international habitat assessments to develop a new rapid habitat assessment framework specific to Ireland. This framework uses 22 variables encompassing: (i) a pre-survey that considers the site within the context of the landscape; (ii) a structured field survey to measure physical and biological variables; and (iii) a site overview that considers site management variables to generate a quantitative site score. We tested our framework using Irish machair as a case study due to it being particularly vulnerable to rapid changes from both anthropogenic and climatic sources. Our framework scores matched 70% of the current three-tiered 'traffic light' designations established in the Habitats Directive and were within expected ranges. Our approach establishes a quantitative score that creates a benchmark against which we can measure future change and the identification of specific drivers of habitat change. The framework is a practical response to the lack of a unified approach to assessing and reporting habitat condition and will help Ireland meet monitoring requirements and determine the effect(s) of management/conservation efforts.

Keywords: *machair, habitat condition, rapid assessment, ecological assessment, Ireland*

*Tom.p.gorman@gmail.com (Corresponding Author)

Introduction

Assessment of habitat quality is integral for the implementation and evaluation of national and international directives and schemes. Internationally, habitat quality assessments are primarily targeted at biodiversity offsetting, which generally aim to replace habitat losses in one area with gains in another (USFWS, 1980; DEHP, 2017), or to determine the potential impacts of development (e.g., Environmental Impact Assessment, Appropriate Assessment). In Ireland, habitat assessments are necessary as part of the EU Habitats Directive (92/43/EEC). The Habitats Directive requires both the identification of Special Areas of Conservation (SAC) and specific habitats of EU importance (Annex I habitats). The Habitats Directive further obliges member states to monitor habitats and species (Article 11) listed within these annexes. However, this is a daunting task as currently approximately 1.35M ha of land (13,500km^2) is designated as SAC in Ireland and 58 habitats and 61 species currently require monitoring (NPWS, 2013; NPWS, 2017). This includes multi-use agricultural landscapes and habitats such as machair, raised bogs and turloughs that are particularly vulnerable to both anthropogenic and climatic changes. This imparts significant staffing and financial burdens on agencies tasked with six-year cycles of reporting on habitat condition and management and increases the risk of not meeting directive targets. Indeed, the most recent assessment of Irish EU protected habitats revealed that 91% have unfavourable conservation status (NPWS, 2013). Considering the threats posed to all habitats by both anthropogenic impacts and climate change, a method of rapidly assessing these habitats is of great importance. Soft coast lines are particularly vulnerable to sea level rise and rapid change (Hansom, 2001) and, therefore, are most in need of a rapid assessment methodology.

Current Irish habitat quality assessment is either habitat specific (e.g., coastal and peatland habitats; *sensu* Ryle *et al.,* 2009; Murphy and Fernandez, 2009; Delaney *et al.,* 2013), differs across sectors, uses largely qualitative methods (Dúchas and DAF, 1999), or relies on professional judgement using highly technical surveys (Dúchas and DAF, 1999; Ryle *et al.,* 2009; Delaney *et al.,* 2013). In particular, the use of bioindicators (ecological status indicator species) often requires experts in a variety of taxonomic fields (McGeoch, 1998). While these are crucial for species inventories, they inhibit wider use and incorporation by multiple stakeholders and limit assessment to few individuals that could include conservation organisations and landowner groups. Current assessment of individual sites, and cumulatively habitats, are based on standard EU criteria that include: range, area (extent), specific structure and functions, and future prospects. These rank habitats according to only one of three 'traffic light' conditions, consisting of *favourable*, *unfavourable-inadequate* and *unfavourable-bad*. While we have a qualitative assessment of the condition of each habitat, our current system poses difficulties when attempting to compare sites, monitor sites over time, or determine a standardised conservation status designation.

Recent trials, using scoring systems for agri-environmental schemes, represent a promising improvement to habitat quality ranking systems and can be suitable for application to other habitats (Sullivan and Moran, 2017). Most notable amongst these is the Results Based Agri-environmental Payment Schemes (RBAPS), which were trialled in Spain, Ireland, Romania and the UK from 2016 to 2018. The assessments are based on criteria that reflect the '…*overall biodiversity and ecological integrity of the habitat*' (RBAPS, 2018). Similar approaches have been made in the assessment of suitable hen harrier (*Circus cyaneus*) habitat (Hen Harrier Project, 2018). The main method of assessment in the above systems is observation by a trained assessor. These frameworks represent a significant improvement on previous habitat assessment methodology (i.e., the use of participatory engagement with individual landowners). However, it still relies, in part, on subjective judgement (e.g., 'overgrazing' or 'undergrazing'). Whilst some habitat indicators and threats can be determined by observation, we can gain a quantitative understanding of them if measurements are taken to assess the threat. A metric, such as sward height, will reduce the influence of assessor bias, and allow the comparison of site data over time, regardless of the individual assessor (Suter and Cormier, 2016).

The main aim of this project was to develop a quantitative habitat assessment framework that is based on existing national and established global rapid assessment methods and specifically adapted to an Irish context. Thus, the objectives of this research were to: (i) review existing quantitative rapid habitat assessment frameworks both nationally and internationally; (ii) create a new framework that draws from established methodologies to be specifically adapted to an Irish habitat; and (iii) trial the new framework to ensure the chosen metrics are representative of the current habitat condition.

The intent was to develop a framework to rapidly assess habitat condition (thus reducing labour costs), and one designed to provide an overall quantitative site score while identifying specific threats or resilience features to better direct and achieve long-term management and conservation objectives. Use of a standardised quantitative framework will allow for the direct comparison of similar habitats and create a benchmark figure against which we can measure the efficacy of ecological improvements and management scenarios.

Methodology and Case Study Sites

Objective 1 – Review of existing frameworks

To assess the need for and to begin developing a new framework, we carried out a literature review of existing international and national frameworks. To identify relevant frameworks, we used the search terms 'habitat-assessment', 'score', 'system', 'quantitative-assessment', 'rapid-assessment', 'biodiversity', and 'offsetting'. We evaluated existing quantitative assessment frameworks in a chronological fashion beginning with the United States Fish and Wildlife Service (1980) as a foundation for our framework. From the most relevant search results, we selected six national and six international frameworks (Table 1). This allowed us to follow the progression over time in terms of structure, metrics and the type of variables used (physical or biological).

Objective 2 – Creation of a new framework

A new framework must accurately reflect the key factors that determine the quality of a habitat while being flexible enough to be appropriate for development onto other habitats. We explored the scope of potential physical and biological variables during the literature review alongside potential score weightings. The final variables included in the framework were a combination of both general and habitat specific factors. General variables such as area, connectedness to surrounding habitats and ecological corridors could be applied to most habitats. To tailor the framework to be machair specific (Objective 3), we first determined the key characteristics that define machair habitat quality for our case study and ranked the existing threats using previous assessments to establish the thresholds for each variable (JNCC, 2004). We chose variables such as specific sward height, soil pH, and habitat indicator species and used previous sand dune assessments carried out on machair to establish the ranges and thresholds by which we could measure habitat condition (Table 1; Delaney *et al.,* 2013; Ryle *et al.,* 2009; JNCC, 2004). Our sampling methodologies were based on the methods established in the BIOMAR survey (Crawford *et al.,* 1998) and the National Vegetation Classifications (Rodwell, 2006).

Table 1: Key habitat quality scoring systems reviewed and used in the development of this framework with a focus on assessment features, metrics, purpose of the scoring system and pros (+) and cons (-) of each system.

Framework	Assessment	Metric	Purpose/objective	+/-
International				
USFWS Habitat Evaluation Procedures (USHEP). USFWS (1980)	Species - habitat based quantitative rating index.	Physical habitat structure	Impact assessment	+ Rapid, usable by non-experts, multi-habitat - Doesn't consider site conservation objectives or wider context
Wetland Rapid Assessment Procedure (WRAP). Miller and Gunsalus (1999)	Habitat based quantitative rating index	Physical habitat structure	Biodiversity offsetting	+ Rapid, usable by non-experts, habitat specific. - Doesn't consider site conservation objectives or wider context.
Queensland Environmental Offsets Policy (developed 1999) (QEOP). DEHP (2017)	Species-habitat based quantitative rating index.	Site context. Physical habitat structure. Species habitat indices.	Biodiversity offsetting	+ Considers wider site context. Uses GIS and field data. - Requires species ratings index. Difficult to use for non-experts.
South African Scoring System (SASS). Dickens and Graham (2002)	Species presence / absence.	Macro-invertebrates groups.	River habitat quality	+ Uses species presence / absence. Habitat specific. Allows comparison over time. - Only usable on rivers. Requires taxonomic expertise.

Framework	Assessment	Metric	Purpose/objective	+/-
JNCC Common Standards Monitoring (CSM). JNCC (2004)	Geological, species or habitat based quantitative rating index.	Site specific conservation objectives / threat evaluation.	Habitat quality assessment / biodiversity offsetting	+ Considers site conservation objectives and threats. - Difficult to use for non-experts.
Somerset Habitat Evaluation Procedure (SHEP). Burrows (2016)	Species-habitat based quantitative rating index.	Physical habitat structure. Species-habitat indices.	Impact assessment	+ Rapid, usable by non-experts, multi-habitat. - Doesn't consider site conservation objectives or wider context.
National				
Coastal Monitoring Project (CMP). Ryle *et al.* (2009)	Intensity/ impact model (High-Medium-Low)	130 Variables scoring between-2:2	Habitat condition assessment	+ Rapid. Covers all coastal habitats. - Difficult to use for non-experts. Requires taxonomic expertise.
Limestone Pavement Conservation Methodologies. Murphy and Fernandez (2009)	Species-habitat focused Intensity/ impact model (High-Medium-Low)	Species centric approach with negative management impacts.	Habitat condition assessment	+ Habitat specific, Uses habitat and species data. - Relies on botanical expertise. Not rapid.
Monitoring Survey of Annex 1 Sand Dune Habitats in Ireland (SDM). Delaney *et al.* (2013)	Species based quantitative rating index.	Species presence / absence. Percentage cover.	Habitat condition assessment	+ Rapid, uses physical variables and species data - Relies on botanical expertise. Doesn't consider wider site context.
Grazing Impact on Upland and Peatland Habitats. Dúchas and DAF (1999)	Agricultural impact assessment	Physical habitat structure/ Species presence / absence.	Impact assessment	+ Uses physical variables and species presence/absence. - Observational data. Broad generalist categories.
Results-Based Agri-environmental Payments Scheme (RBAPS, 2018)	Habitat based quantitative rating index	Physical habitat structure. Indicator species and site management	Habitat condition assessment	+ Rapid. Usable by non-experts. Mixture of habitat and species variables. - Doesn't consider wider site context
Hen Harrier Project (Hen Harrier Project, 2018)	Habitat based quantitative rating index	Physical habitat structure. Indicator species and site management	Habitat condition assessment	+ Rapid. Usable by non-experts. Mixture of habitat and species variables. - Doesn't consider wider site context

Objective 3 – Trial Case Study with Irish Machair

Machair is a globally rare coastal habitat that is the result of physical processes, climatic conditions, and anthropogenic influences. It consists of a relatively flat sandy plain and is only found along the north-western coasts of Ireland and Scotland (Bassett and Curtis, 1985). The combination of strong winds, high rainfall, and offshore sources of shell sand provide ideal conditions for the formation of machair in these regions. Morphologically, Scottish and Irish machair are very similar. However, a difference in traditional farming methods has led to a slight variation in vegetation. One of the defining characteristics of machair habitat is a history of human interference, which is typified by low intensity grazing (Gaynor, 2006). Due to the importance of anthropogenic influences on the establishment and survival of machair, there is a necessity to involve the local community and land owners in any conservation efforts (Gaynor, 2006). In Ireland, the main threats to machair habitat are anthropogenic in nature, through changing agricultural practices, coastal development, extraction and recreation. The impacts of these can increase erosion rates, and while erosion is necessary for the formation of machair habitat, accelerated rates represent a high threat (NPWS, 2013; JNCC, 2004).

We chose machair as a case study habitat because it is listed as a priority habitat in Ireland under the EU Habitats Directive and there is a requirement to monitor and maintain the status of these habitats. The extent of machair in Ireland is now estimated to cover 2,752ha at 59 sites. However, approximately 62% of machair sites are classed as unfavourable-inadequate and 32% of machair sites are unfavourable-bad (Ryle *et al*., 2009). The poor overall quality is attributed largely to the changes in agricultural practices resulting in fenced areas, overgrazing, excess nutrients and poaching (Ryle *et al*., 2009). Additionally, there are no quantitative indications regarding a scale of how each site scored on this assessment. For example, of the 35 unfavourable sites, it is difficult to assess how close they are to being either favourable or bad. Thus, attributing a quantitative score to the study sites will give a clearer picture of the conservation status of Irish machair sites. Therefore, we selected ten sites that span the existing ecological habitat condition designations to trial the framework (Figure 1). Each of the ten study sites were assessed using the new framework and compared to the existing qualitative assessment by the developers and an independent assessor where possible. We selected the independent assessors from a variety of backgrounds (one environmental consultant and two non-practitioners) to test the usability of the framework by both professionals and non-professionals and ensure the repeatability of the survey and eliminate user bias (Gammon and Simon, 2000).

Data Analysis

To test the efficacy of the chosen variables, we scaled the mean scores and determined their percentage contribution to the total scores. We performed a Principal Components Analysis (PCA) to determine the major influencing variables and used a broken stick scree plot to determine the number of principal components to retain. By determining

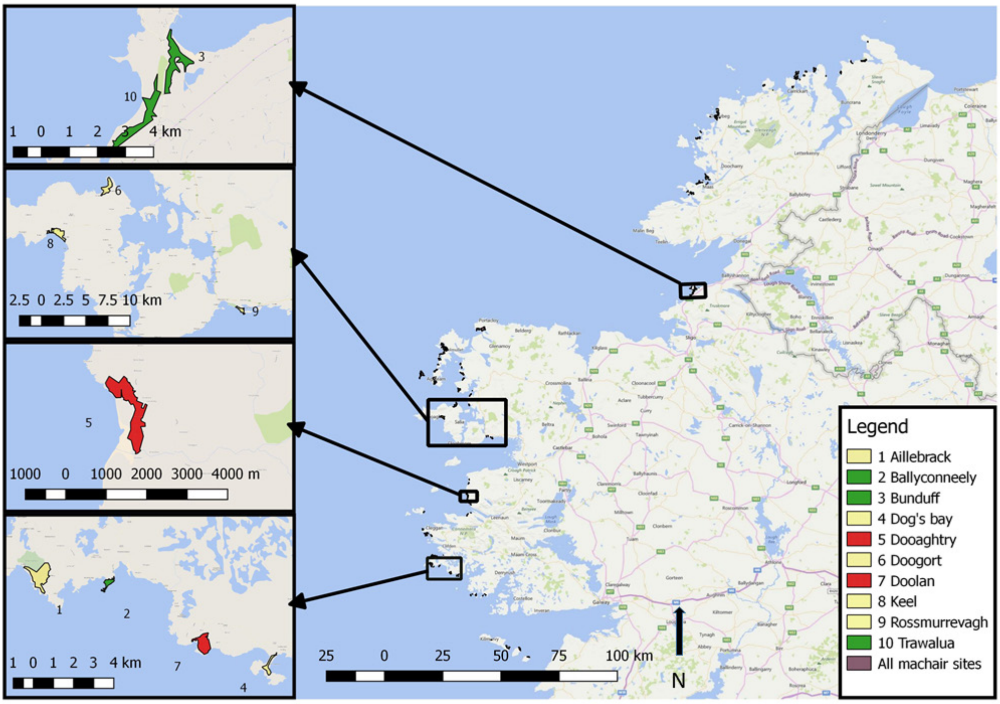

Figure 1: Distribution of machair habitat in Ireland (NPWS, 2013). Study sites are numbered and magnified.

which variables have the greatest impact on the scoring system and which offer similar metrics, the system can be refined to provide greater accuracy and reduce possible multicollinearity among site variables. We provided training to the three independent assessors in the trial methodology prior to a field visit to allow a comparison among site scoring and test the repeatability of the survey methodology. All data analysis was carried out using R-3.5.1 (R Core Team, 2017).

Results

Objective 1 – Review of existing frameworks

Our search yielded 12 suitable frameworks: six from international sources and six from Ireland (Table 1). Seven of these frameworks use species centric approaches to rating habitat condition, with the remaining five either habitat or management focused. Early efforts were primarily driven by impact assessments and biodiversity offsetting, while more recent systems focus on habitat condition assessment, although offsetting systems are still being utilised. The majority of the systems we reviewed rely primarily on a site assessment and are site specific, however, the QEOP (DEHP, 2017) considers the wider landscape context of the site via a Geographic Information Systems (GIS) based pre-survey.

Objective 2 – Creation of a new framework

The trial framework took elements from existing systems and tailored the variables to be specific to the key threats and characteristics of machair habitats. The elements brought forward are listed in Table 2.

Table 2. Existing frameworks and the features taking from them to build the trial assessment framework.

Feature	Framework
Structure & Metrics (Site Context, Site Condition)	**QEOP (DEHP, 2017)**
Area, connectedness, context, ecological corridors	
Focus (Conservation Objectives)	**CSM (JNCC, 2004)**
Sward height, soil pH, indicator species, bryophytes, organic matter, bare ground	
Threats to Irish Machair	**Article 17 Report (NPWS, 2013)**
Dumping, erosion, vehicle damage, trampling	
Thresholds for habitat variables	**CMP (Ryle *et al.*, 2009)**

The new framework combines several spatial variables to determine site quality and consists of three assessment sections: Site Context, Site Condition, and Site Overview (Appendix 1). First, Site Context is determined through a GIS-based desktop study that considers a site in the wider context of the surrounding habitat matrix. These factors include the calculation of habitat size, percentage of land uses adjacent to and within 1km of the site, and the availability and extent of ecological corridors. Site Condition is determined through a field-based study that accounts for habitat-specific positive and negative indicators (e.g., number of key species, grazing regime, erosion) and rapid soil investigations. The site visit consists of a structured 'W' walk across the machair using five quadrats, as recommended by the NVC field manual (Rodwell, 2006). Between these quadrats, four transects are undertaken to assess variables that were not suitable to be measured via a quadrat, such as vehicle damage and trampling. At each stop, a 2m × 2m quadrat is set up and a GPS point taken at the southern side following the methodology established in the BIOMAR survey (Crawford *et al.*, 1998). Upon completion of the site survey, a final section covers the site overview to assess site management variables such as sand and water extraction, recreational facilities and coastal defences to determine overall habitat quality (Table 3). Sites are scored out of a total of 20 points, with a maximum of 10 points each coming from the Site Context and Site Condition assessments.

		Undesirable				Moderate				Desirable	
		Guide	Score			Guide	Score			Guide	Score
Site Context (completed via GIS and aerial orthophotos)											
Area (hectares)		< 5ha	2	6-30ha	4	31-90	6	91 – 120ha	8	> 120	10
Connectedness (% natural boundary)		< 30	0			30-60	5			> 60	10
Context (% natural boundary within 1km radius)		< 30	0			30-60	5			> 60	10
Ecological Corridors (Land and Coastal Corridors)		Isolated	0			Coastal Only	5			Coastal and Land	10
Site Assessment (Five quadrats and four transects)											
Sward Height (cm; mean of five measures)	Dry	< 2 or > 10	0			> 2 – < 10	5			> 4 – < 10	10
	Wet	> 20				<10				> 10 – < 20	
pH (one representative soil pit)		< 7.0	0			7.0-7.5	3			> 7.6	5
Organic Matter Depth (cm)		> 3	0			> 1 – < 3	3			< 1	5
Percent Bareground (visual estimate)		> 10	0			5-10	3			< 5	5
Percent Bryophytes (visual estimate)		Rare	0			Occasional	3			Frequent	5
Habitat Indicator Species (count)	Dry	< 4	0			> 6	3			> 10	5
	Wet	< 3				4-5				> 5	
Transects (Four transects connecting each plot)											
Vehicle Damage		Clear tracks w/ erosion	0			Light tracks, no severe damage	3			No damage	5
Negative Indicator Species		Occasional (> 5%)	0			Rare (< 5%)	5			Absent	10
Dumping/ Material Storage		Waste or Dumping	0							Absent	5
Erosion or Coastal Squeeze		Severe	0			Moderate	3			Low to none	5
Trampling or Walked Paths		Paths of bare sand	0			Vegetated tracks	3			None	5
Site Overview (completed after site visit)											
Water Extraction		Yes	-5							No	0
Sand Extraction		Yes	-5							No	0
Coastal/Flood Defences		Sea Wall or other	-10			Minor works	-5			no impediments	10
Agricultural operations		Intensive	-10			Fenced Plots	-5				
Grazing Density		Heavily over or undergrazed	-10			Overgrazed or undergrazed	0			Appropriate	
Recreation Intensity		High	-10			Moderate	-5			Low	5
Sports Facilities		Pitch Within or adjacent	-10			Golf course, open pitch	-5			None	5

Table 3. Rapid Habitat Quality Condition variables and scoring metric for machair. Guidance values obtained from literature (see methods). Site Context variables are general whilst Site Assessment variables are machair specific. All but one variable (area) contain three ranges of condition.

Objective 3 – Testing the framework

The scores obtained by three independent assessors and the author were compared to a qualitative representation from the recent Coastal Monitoring Programme designation (Ryle *et al.,* 2009). We found that 70% of the sites matched the current designation (Table 4). The effectiveness and influence of each variable on the total score is an important metric in determining whether the score system is well balanced and representative of Irish machair. The four most influential variables on the ten assessment sites are the Site Context variables (Figure 2). In the Site Condition assessment, sward height and habitat indicator species had the greatest influence on the score.

The mean score contribution for the ten sites assessed showed that Site Context (mean = 7.1) is a more influential factor than the Site Condition (mean = 5.6). We found that ecological corridors are the most influential variable, contributing 25% of the total scores given.

Variation between trained assessors was minimal as no two scores for the same site exceeded a difference of 0.9 (mean = 0.36 ± 0.14SE). One of the key requisites of this system is its rapidity. The time spent at each assessment unit was recorded, with an average time of six and a half minutes. The time taken for each transect was not measured, as this would vary greatly with the size of each site. However, it was possible for two assessors to carry out a survey at a site within one hour.

Table 4. Site description of each study site detailing the size (hectares), current CMP 'Status' designation, new framework score (out of 20) and resulting revised CMP status, and the main threats to the site.

No.	Site	Size (ha)	CMP Status	Framework Score	Main Threats
1	Aillebrack	77.3	Unfavourable – Inadequate	11.5 Unfavourable –Inadequate	Sand extraction, recreation, and dumping
2	Ballyconneely	15	Favourable	17.75 Favourable	None
3	Bunduff	48.9	Favourable	16 Favourable	None
4	Dog's Bay	28	Unfavourable – Inadequate	10.39 Unfavourable – Inadequate	Erosion and grazing
5	Dooaghtry	137	Unfavourable – Bad	13 Unfavourable – Inadequate	Erosion and grazing
6	Doogort	58.4	Unfavourable – Inadequate	12.2 Unfavourable – Inadequate	Agricultural improvement and grazing
7	Doolan/Murvey	81	Unfavourable – Bad	13.07 Unfavourable – Inadequate	Erosion and grazing
8	Keel	92.7	Unfavourable – Inadequate	8.6 Unfavourable – Inadequate	Encroachment and grazing
9	Rossmurrevagh	79	Unfavourable – Inadequate	15.12 Favourable	Recreation, agricultural improvement and grazing
10	Trawalua	33.4	Favourable	14.25 Favourable	None

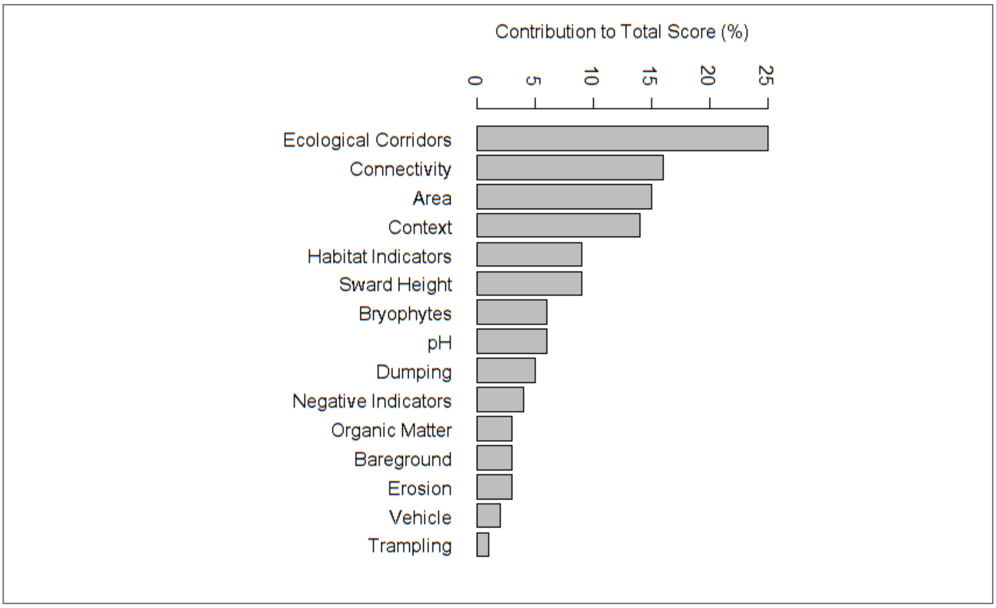

Figure 2: Percentage contribution of each variable in the new framework to the total score obtained across all study sites.

PCA Analysis

A total of nine factors explained 100% of the variance, and 75% of the variance was attributed to three principal components with PC1 (38%), PC2 (62%) and PC3 (75%) of the total variance (Table 5).

The most influential variables for PC1 can largely be attributed to pH and organic matter. Therefore, this is generalised as 'physical characteristics'. Variables that explained the second axis (PC2) were mostly related to the vegetation characteristics of a site and included variables such as sward height and bryophyte cover and can be generalised as a 'vegetation structure' gradient. The third axis (PC3) was mostly influenced by negative indicator species and trampling and can be generalised as 'negative site condition' gradient. The first and second axis explain the majority of the variance and are displayed in Figure 3. Biplots of PC3 are included as supplemental material (Supplemental material S2).

Sites that scored within the range of *unfavourable-bad* were clustered and closely associated with the variables pH and organic matter. Sites that scored *favourable* were most closely associated with positive habitat indicator species.

Table 5: The proportions of the variation on the significant principal components as found through Principal Components Analysis (PCA).

Variables	PCA 1	PCA 2	PCA 3
Sward height	-0.689	-0.383	-0.388
pH	0.585	-0.122	-0.289
Organic matter	0.69	-0.423	0.283
Bareground	-0.907	-0.158	0.127
Bryophytes	0.117	-0.784	-0.353
Habitat indicator species	-0.160	-0.856	0.219
Vehicle damage	0.432	-0.649	-0.073
Negative indicator species	-0.528	0.148	-0.579
Dumping	-0.544	0.205	0.353
Erosion	-0.732	-0.224	-0.137
Trampling	-0.557	-0.391	0.509

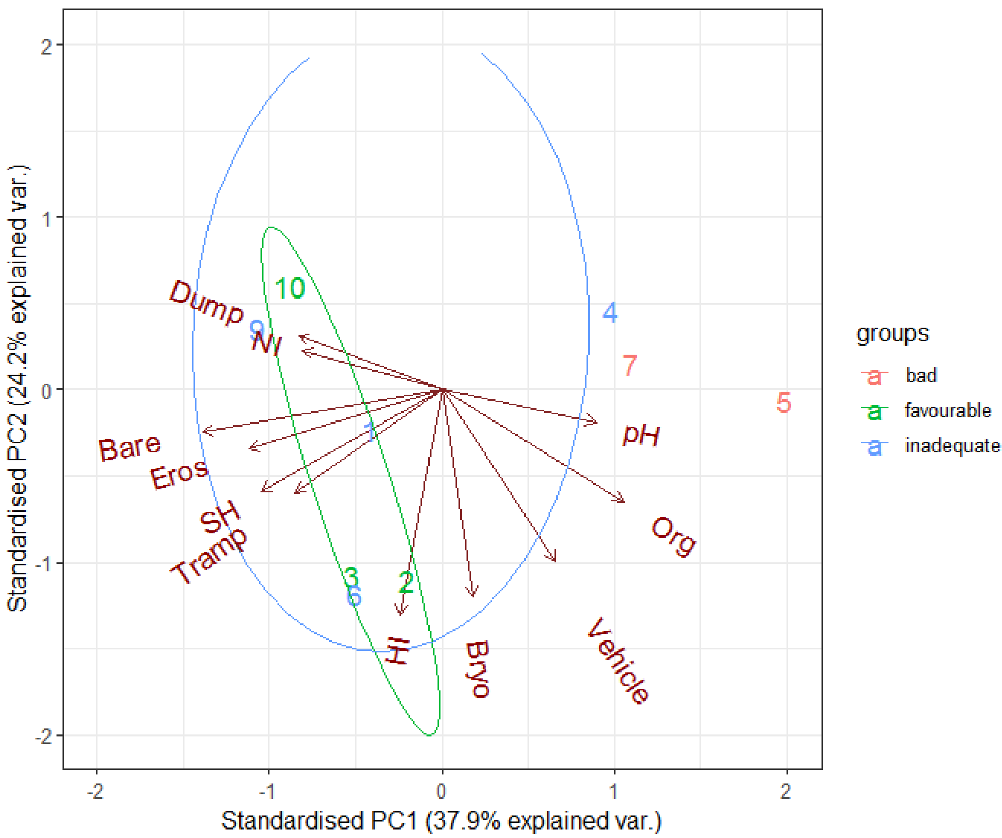

Figure 3: Principal components analysis of the variables used in the new framework Numbers refer to the site number as shown in Table 3.

Discussion

Effective habitat monitoring and establishment of baseline condition metrics from which to inform management decisions and report change remain a concern for Ireland. The framework outlined here departs from existing systems in that it provides a quantitative score that relies on habitat-specific metrics from multiple spatial scales that reflect important and practical management considerations and can be assessed by both professionals and non-professionals.

Existing qualitative assessments based on expert opinion have been shown to be prone to bias and baseline drift (Gammon and Simon, 2000). Byron *et al*. (2000) highlighted the common failures in monitoring procedures for environmental impact assessments, in that they often lack baseline data, use vague and descriptive predictions and do not attempt to quantify impacts. Further, Drayson *et al*. (2017) found that qualitative methods still dominate monitoring and that a quantitative approach would be systematic and repeatable. In their criticism of current monitoring methodologies, Legg and Nagy (2006) suggest that the poor quality of habitat monitoring is in part due to the preference to use qualitative methods and an aversion to using statistical analysis. They recommend that field assessments should select methods that are appropriate to the objectives and habitat type, ensure spatial and temporal replication and take an experimental approach to sampling design. Our framework is designed to be habitat specific and emphasise the acute threats responsible for low scores. Furthermore, multivariate techniques such as PCA allow the refinement of the score system to increase its accuracy.

Using multivariate analysis can provide a focus for what is driving habitat degradation, which has previously been unclear in the current ‘traffic light’ designations. This is shown in our data through the association of poor site scores and the pH and organic matter variables. Whilst Bassett and Curtis (1985) found no correlation between low pH and the percentage organic matter, periods of deficit in the sand supply to a machair can cause organic matter layers to form (Hansom and Angus, 2005). Factors such as the construction of infrastructural coastal defences that potentially limit the supply of windblown calcareous shell sand would exacerbate both the formation of excess organic matter and a reduction in pH. These data will be vital to future management decisions, especially in response to the threats posed by climate change.

Our new framework relies on the identification and measurement of physical and managerial variables rather than bioindicators. Bioindicators, while essential for in-depth analysis of habitat condition, are unsuitable for rapid assessment as they are temporally limited and require expert knowledge to identify. This framework uses site condition assessment and habitat-specific physical features that are either already being recorded or can be easily measured by non-specialists. Some of the variables we selected are also utilised by RBAPS and the Hen Harrier Project such as positive and negative indicator plant species, site management, erosion and vegetation structure (RPABS, 2018; Hen Harrier Project, 2018). In addition to these variables, the hen harrier project scorecards also consider the site boundary. Our framework utilises similar in-field measurements but also considers the site in the wider context of the landscape via a GIS based pre-survey.

Our framework reduces potential user bias and improves the accuracy of site condition surveying by drawing elements from international score systems such as the Queensland Environmental Offsets Policy (QEOP) and applying it to modern Irish efforts.

The first trials of the new framework matched 70% of the current three-tiered designations with the remaining score discrepancies indicative of both recent habitat change and the need to refine some of the metrics. The analysis of each variable impact gave clear direction as to how this system can be refined for greater accuracy, as Site Context had a greater influence on the overall score than Site Condition. Whilst this framework is in need of refinement to correct the variable weightings to more accurately assess habitat condition, the framework is straightforward and basic training will allow non-experts to employ it easily. No specialist equipment is needed and only a basic knowledge of the key habitat indicators is required to carry out an assessment. This will allow monitoring staff to keep pace with climatic and anthropogenic impacts associated with monitored habitats.

It is perhaps no coincidence that three Irish rapid assessment score systems have been developed within the past few years that are multi-user friendly. There is a compelling case at both the local and EU level for a mechanism from which individual sites and programmes can measure and manage dynamic habitat and ecosystem change. For example, the issue of poor baseline data for measuring improvements in biodiversity is highlighted in the assessment of agri-environmental schemes in Ireland, which stated '*a lack of initial and ongoing monitoring data against which to establish a baseline and counterfactual*' (ADAS, 2016). The quantitative scores obtained from this framework can be used as a baseline against which impacts are measured either at a site level or cumulatively to describe national habitat condition trends. The successful deployment of this framework will provide a clearer understanding of the effectiveness of national efforts to improve biodiversity and assist in accounting for agri-environmental scheme expenditures.

The underfunding of conservation efforts places emphasis on resource management and the cost/time considerations of monitoring programmes (McDonald-Madden *et al*., 2010). Developing a cost-effective monitoring system will assist in determining which management methods are most appropriate. This will ensure that the maximum benefit to biodiversity is derived from programme scheme disbursements.

Future Directions

We envision a framework that is inclusive to all Irish habitats. This would take the form of a database of habitats and their major controlling variables that could be 'plugged in' to the framework. We anticipate the ability to include raw scores (e.g., average sward height) in the assessment such that should a habitat baseline shift, it is possible to easily recalculate current and historical condition scores. The scoring system will enable the comparison of similar habitats and indicate, at a much higher resolution than currently employed, the extent to which sites or habitat classifications are declining or improving.

To develop this framework further would require testing it on additional habitats and piloting its efficacy for use by various stakeholders, including non-specialists. Involving land owners in the assessment process could encourage their support for conservation measures on their land.

Conclusion

Whilst recognising that a rapid assessment methodology is not a replacement for an in-depth ecological study, this approach is a practical response to the lack of a unified method to assessing and reporting habitat condition for local, national, and EU reporting requirements. The results from the preliminary trials show that is possible to develop a rapid assessment procedure that addresses the key indicators of habitat quality. With some further refinement such as a greater sample size and additional habitat trials this framework provides an opportunity to increase dramatically the current level of monitoring across the country and help guide management to determine success and failure of efforts to improve the biodiversity value of an area.

Acknowledgements

The authors would like to thank NPWS, in particular Leonard Floyd, for their cooperation on this paper. Special thanks are due to Dr Siubhán Comer for her assistance and Ashland Pym, James Bassett and Guillermo Castro Gamba for their help in the field. This research was funded by EPA Research Programme 2014-2020 (2014-CCRP-MS.22).

References

ADAS UK Ltd., 2016. Evaluation of the GLAS. Phase 1 – Literature review. Technical Report No. CPAE002.

Bassett, J.A. and Curtis, T.G.F., 1985. The nature and occurrence of sand-dune machair in Ireland. *Proceedings of the Royal Irish Academy*. Section B: Biological, Geological, and Chemical Science, 1-20. Royal Irish Academy.

Burrows, L., 2016. Somerset Habitat Evaluation Procedure methodology. Somerset County Council, UK.

Byron, H.J., Treweek, J.R., Sheate, W.R. and Thompson, S., 2000. Road developments in the UK: an analysis of ecological assessment in environmental impact statements produced between 1993 and 1997. *Journal of Environmental Planning and Management*, 43:71-97.

Crawford, I., Bleasdale, A. and Conaghan, J., 1998. Biomar Survey of Irish Machair Sites 1996: Plant Communities. Dúchas.

DEHP, 2017. Guide to Determining Terrestrial Habitat Quality. Biodiversity Integration and Offsets, Ecosystem Outcomes, Department of Environment and Heritage Protection, State of Queensland, Australia.

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.

Dickens, C.W. and Graham, P.M., 2002. The South African Scoring System (SASS) version 5 rapid bioassessment method for rivers. *African Journal of Aquatic Science*, 27:1-10.

Drayson, K., Wood, G. and Thompson, S., 2017. An evaluation of ecological impact assessment procedural effectiveness over time. *Environmental Science and Policy*, 70:54-66.

Dúchas and DAF., 1999. A Manual for The Production of Grazing Impact Assessments in Upland and Peatland Habitats. Dúchas, The Department of Agriculture and Food, Dublin, Ireland.

Gammon, J.R. and Simon, T.P., 2000. Variation in a great river index of biotic integrity over a 20-year period. *Assessing the Ecological Integrity of Running Waters*, 291-304. Springer, Dordrecht.

Gaynor, K., 2006. The vegetation of Irish machair. *Biology and Environment: Proceedings of the Royal Irish Academy,* 311-321. Royal Irish Academy.

Habitats Directive, 92/43/EEC. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. *Official Journal of the European Union*.

Hansom, J.D., 2001. Coastal sensitivity to environmental change: a view from the beach. *Catena*, *42:*291-305.

Hansom, J.D. and Angus, S., 2005. Machair nan Eilean Siar (Machair of the Western Isles), *Scottish Geographical Journal*, 121:401-411.

Hellawell, J.M., 1991. Development of a rationale for monitoring. *Monitoring for conservation and ecology,* 1-14. Springer, Dordrecht.

Hen Harrier Project, 2018. A practical results based approach to farming, flexible and locally adaptable. Hen Harrier Project. Available at http://www.henharrierproject/about.html [Accessed 25th July 2018].

JNCC, 2004. Common Standards Monitoring Guidance for Coastal, Version August 2004. Joint Nature Conservation Committee, Peterborough.

Legg, C.J. and Nagy, L., 2006. Why most conservation monitoring is, but need not be, a waste of time. *Journal of environmental management*, 78:194-199.

McDonald-Madden, E., Baxter, P.W., Fuller, R.A., Martin, T.G., Game, E.T., Montambault, J. and Possingham, H.P., 2010. Monitoring does not always count. *Trends in Ecology and Evolution*, 25:547-550.

McGeoch, M.A., 1998. The selection, testing and application of terrestrial insects as bioindicators. *Biological Reviews of the Cambridge Philosophical Society*, 73:181-201.

Miller, R.E. and Gunsalus, E.B., 1999. Wetland Rapid Assessment Procedure (WRAP). South Florida Water Management District, State of Florida, U.S.A.

Murphy, S. and Fernandez, F., 2009. The development of methodologies to assess the conservation status of limestone pavement and associated habitats in Ireland. *Irish Wildlife Manuals*, No. 43. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland.

NPWS, 2013. The Status of Protected EU Habitats and Species in Ireland. *Overview Volume 1*. Unpublished Report, National Parks and Wildlife Services. Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

NPWS, 2017. *Special Areas of Conservation*. National Parks and Wildlife Services. Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland. Available at: https://www.npws.ie/protected-sites/sac [Accessed 12 November 2017].

R Core Team, 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

RBAPS, 2018. RBAPS Project: Developing Results-Based Agri-environmental Payment Schemes in Ireland and Spain. Results-Based Agri-environmental Payment Schemes. Available at: https://rbaps.eu [Accessed 20 July 2018].

Rodwell, J.S., 2006. NVC Users' Handbook. Joint Nature Conservation Committee, Peterborough.

Ryle, T., Murray, A., Connolly, K. and Swann, M., 2009. Coastal monitoring project 2004-2006. Unpublished Report, National Parks and Wildlife Services, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Sullivan, C. and Moran, J., 2017. The development of a draft peatlands and heathlands scorecard using the Results-Based Agri-environmental Pilot Scheme scorecard Approach. Available at: https://rbaps.eu/documents/scorecards [Accessed 18 July 2018].

Suter, G.W. and Cormier, S.M., 2016. Bias in the development of health and ecological assessments and potential solutions. *Human and Ecological Risk Assessment: An International Journal*, 22:99-115.

USFWS, 1980. Habitat Evaluation Procedures (HEP). *Ecological Services Manual*, No. 101. US Fish and Wildlife Services, Washington, D.C., 214pp.

S1: Framework Data sheets

<table>
<tr><th>Site</th><th>Size(ha)</th><th>Date</th><th>Assessors</th></tr>
<tr><td>Qualifying Interests</td><td colspan="3"></td></tr>
<tr><td colspan="4">Site Diagram & Planned Route</td></tr>
</table>

<table>
<tr><th colspan="17">RAMS – Site Context Guidelines</th></tr>
<tr><td>Area</td><td>Score</td><td colspan="3">2</td><td colspan="3">4</td><td colspan="3">6</td><td colspan="3">8</td><td colspan="3">10</td></tr>
<tr><td></td><td>Guidelines</td><td colspan="3"><5ha</td><td colspan="3">6–30ha</td><td colspan="3">31–90</td><td colspan="3">91–120ha</td><td colspan="3">>120ha</td></tr>
<tr><td>Connectedness</td><td>Score</td><td colspan="5">0</td><td colspan="5">5</td><td colspan="5">10</td></tr>
<tr><td></td><td>Guidelines</td><td colspan="5"><30% Natural Boundary</td><td colspan="5">30–60% Natural Boundary</td><td colspan="5">>60% Natural Boundary</td></tr>
<tr><td>Context</td><td>Score</td><td colspan="5">0</td><td colspan="5">5</td><td colspan="5">10</td></tr>
<tr><td></td><td>Guidelines</td><td colspan="5"><30% Natural Boundary within 1km radius</td><td colspan="5">30–60% Natural Boundary within 1km radius</td><td colspan="5">>60% Natural Boundary within 1km radius</td></tr>
<tr><td>Ecological Corridors</td><td>Score</td><td colspan="5">0</td><td colspan="5">5</td><td colspan="5">10</td></tr>
<tr><td></td><td>Guidelines</td><td colspan="5">Isolated</td><td colspan="5">Coastal corridor only</td><td colspan="5">Land & coastal corridors</td></tr>
</table>

<table>
<tr><th colspan="6">Site Context Scores</th></tr>
<tr><td></td><td>Area</td><td>Connectedness</td><td>Context</td><td>Ecological Corridors</td><td>Total</td></tr>
<tr><td>Site</td><td></td><td></td><td></td><td></td><td>/40</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Site context Score (Score/ Max Score) *10</td><td>/10</td></tr>
</table>

RAMS – Site Condition Assessment				
1st Assessment Unit – Point	**GPS:**		**Wet / Dry:**	
Sward Height		0 <2cm – > 10cm	5 >2cm – <10cm	10 >4cm – <10cm
(Wet machair)		>20cm	<5cm	>10cm <20cm
pH		0 <7.0	3 7.0 – 7.5	5 >7.6
Organic Matter Depth (cm)		0 > 3cm	3 >1cm <3cm	5 <1cm
% Bareground		0 >10%	3 5–10%	5 <5%
Bryophytes Present		0 Rare	3 Occasional	5 Frequent
Habitat indicator species		0 < 4 HI species present	5 5 or more HI species	10 >10 HI species
(wet machair)		< 3 HI species present	4–5 HI species present	>5 HI species present
			Total:	/40
Transect 1		**GPS:**	**End GPS:**	
Vehicle Damage		0 Clear tracks, erosion occurring	3 Light tracks, no severe damage	5 No damage
Negative Species Indicators		0 > Occasional (>5%)	5 Rare (<5%	10 Absent
Dumping / Material Storage			0 Waste material	5 No dumping
Erosion / Coastal Squeeze		0 Severe erosion	3 Moderate erosion	5 Low to no erosion
Trampling / Walked Paths		0 Paths of bare sand	3 Clear tracks, but vegetated	5 No evidence
			Total:	/30
2nd Assessment Unit – Point	**GPS:**		**Wet / Dry:**	
Sward Height		0 <2cm – > 10cm	5 >2cm – <10cm	10 >4cm – <10cm
(Wet machair)		>20cm	<5cm	>10cm <20cm
pH		0 <7.0	3 7.0 – 7.5	5 >7.6
Organic Matter Depth (cm)		0 > 3cm	3 >1cm <3cm	5 <1cm
% Bareground		0 >10%	3 5–10%	5 <5%
Bryophytes Present		0 Rare	3 Occasional	5 Frequent
Habitat indicator species		0 < 4 HI species present	5 5 or more HI species	10 >10 HI species
(wet machair)		< 3 HI species present	4–5 HI species present	>5 HI species present
			Total:	/40

Transect 2	GPS:		End GPS:	
Vehicle Damage		0 Clear tracks, erosion occurring	3 Light tracks, no severe damage	5 No damage
Negative Species Indicators		0 > Occasional (>5%)	5 Rare (<5%)	10 Absent
Dumping / Material Storage			0 Waste material	5 No dumping
Erosion / Coastal Squeeze		0 Severe erosion	3 Moderate erosion	5 Low to no erosion
Trampling / Walked Paths		0 Paths of bare sand	3 Clear tracks, but vegetated	5 No evidence
			Total:	/30

3rd Assessment Unit – Point	GPS:		Wet / Dry:	
Sward Height		0 <2cm – > 10cm	5 >2cm – <10cm	10 >4cm – <10cm
(Wet machair)		>20cm	<5cm	>10cm <20cm
pH		0 <7.0	3 7.0 – 7.5	5 >7.6
Organic Matter Depth (cm)		0 > 3cm	3 >1cm <3cm	5 <1cm
% Bareground		0 >10%	3 5–10%	5 <5%
Bryophytes Present		0 Rare	3 Occasional	5 Frequent
Habitat indicator species		0 < 4 HI species present	5 5 or more HI species	10 >10 HI species
(wet machair)		< 3 HI species present	4–5 HI species present	>5 HI species present
			Total:	/40

Transect 3	GPS:		End GPS:	
Vehicle Damage		0 Clear tracks, erosion occurring	3 Light tracks, no severe damage	5 No damage
Negative Species Indicators		0 > Occasional (>5%)	5 Rare (<5%)	10 Absent
Dumping / Material Storage			0 Waste material	5 No dumping
Erosion / Coastal Squeeze		0 Severe erosion	3 Moderate erosion	5 Low to no erosion
Trampling / Walked Paths		0 Paths of bare sand	3 Clear tracks, but vegetated	5 No evidence
			Total:	/30

4th Assessment Unit – Point	GPS:		Wet / Dry:	
Sward Height		0 <2cm – > 10cm	5 >2cm – <10cm	10 >4cm – <10cm
(Wet machair)		>20cm	<5cm	>10cm <20cm
pH		0 <7.0	3 7.0 – 7.5	5 >7.6
Organic Matter Depth (cm)		0 > 3cm	3 >1cm <3cm	5 <1cm
% Bareground		0 >10%	3 5–10%	5 <5%
Bryophytes Present		0 Rare	3 Occasional	5 Frequent
Habitat indicator species		0 < 4 HI species present	5 5 or more HI species	10 >10 HI species
(wet machair)		< 3 HI species present	4–5 HI species present	>5 HI species present
			Total:	/40

Transect 4	GPS:		End GPS:	
Vehicle Damage		0 Clear tracks, erosion occurring	3 Light tracks, no severe damage	5 No damage
Negative Species Indicators		0 > Occasional (>5%)	5 Rare (<5%)	10 Absent
Dumping / Material Storage			0 Waste material	5 No dumping
Erosion / Coastal Squeeze		0 Severe erosion	3 Moderate erosion	5 Low to no erosion
Trampling / Walked Paths		0 Paths of bare sand	3 Clear tracks, but vegetated	5 No evidence
			Total:	/30

5th Assessment Unit – Point	GPS:		Wet / Dry:	
Sward Height		0 <2cm – > 10cm	5 >2cm – <10cm	10 >4cm – <10cm
(Wet machair)		>20cm	<5cm	>10cm <20cm
pH		0 <7.0	3 7.0 – 7.5	5 >7.6
Organic Matter Depth (cm)		0 > 3cm	3 >1cm <3cm	5 <1cm
% Bareground		0 >10%	3 5–10%	5 <5%
Bryophytes Present		0 Rare	3 Occasional	5 Frequent
Habitat indicator species		0 < 4 HI species present	5 5 or more HI species	10 >10 HI species
(wet machair)		< 3 HI species present	4–5 HI species present	>5 HI species present
			Total:	/40
			Overall Score (A):	/320

Site Overview			
Water Extraction Occurring?	-5		0
Sand Extraction Occurring?	-10		0
Coastal / Flood Defences	-10 Sea wall or other structure running parallel to coast	-5 Minor defence works, not impeding sediment supply	5 Sediment supply unimpeded by structures
Agricultural operations	-10 Intensive	-5 Fenced Plots	5 Appropriate grazing
Grazing Density	-10 Heavily Overgrazed / Undergrazed	0	10 Appropriate grazing
Recreation	-10 High Intensity (Caravan parks etc.)	-5 Mid intensity (Tents, watersports etc.)	5 Low intensity (Little to no evidence of recreation)
Sports Facilities	-10 Bordered sports pitch with buildings	-5 Golf course, open pitch, no buildings	5 No sports
		Total (B):	
		Overall Score (A+/-B):	/350
		Site Condition Score: (Score / Max Score) * 10	/10

Final Site Assessment	
Site Context Score	/10
Site Condition Score	/10
Total Score	/20

Score	Conservation Status	Tick As Appropriate
0–6	Unfavourable – Bad	
7–13	Unfavourable – Inadequate	
14–20	Favourable	

Assessor’s Notes:

Appendices

Habitat Indicator Species			
Agrostris stolonifera		*Aira praecox*	
Bellis perennis		*Carex arenaria*	
Carex flacca		*Carex nigra*	
Cerastium fontanum		*Crepis capillaris*	
Euphrasia officinalis agg.		*Festuca rubra*	
Galium verum		*Hyrdocotyle vulgaris*	
Linum catharticum		*Lotus corniculatus*	
Orchid spp.		*Plantago lanceolata*	
Potentilla anserina		*Prunella vulgaris*	
Rhinanthus minor		*Sedum acre*	
Thymus polytrichus		*Trifolium repens*	
Viola canina		*Viola riviniana*	
Viola tricolor			

Negative Species Indicators			
Hippophae rhamnoides		*Rubus fructicosus*	
Rosa spp. (Not including R. Pimpinellifolia)		*Senecio jacobaea*	
Cirsium arvense		*Cirsium vulgare*	
Urtica dioica		*Lolium perenne*	
Arrhenatherum elatius		*Pteridium aquilinum*	

S2: Figure 3: Principal components analysis of the variables used in the new framework. Numbers refer to the site number as shown in Table 3.