The Glasgow Naturalist (2009) Volume 25, Supplement. Machair Conservation: Successes and Challenges, 53-62

Dé tha cearr air a'mhachaire?
Biodiversity issues for Scottish machair: an initial appraisal

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ABSTRACT
Machair is a complex habitat and also a complex of habitats. The results of the first cycle of Scottish Natural Heritage's Site Condition Monitoring are presented and reviewed. Issues relating to the cultivated machair plain and its associated fallows in the islands of the Uists are addressed in more detail. There, socio-economic changes have led to land use changes that have resulted in variable losses of crop and fallow plant diversity. The problems of assessing this loss and the relevance of the loss are discussed, and possible causes reviewed, but it is clear that scientists require more detailed, long-term information on land use and its implications, in close consultation with land managers, if this issue is to be effectively addressed. Isolated 'snapshot' analyses may deliver misleading conclusions.

INTRODUCTION
The UK is obliged by the terms of The EC Habitats and Species Directive to report on the conservation status of Annex I habitats and Special Areas of Conservation. A range of reporting systems are used to meet this obligation, in addition to input made in respect of the Water Framework Directive (WFD). The competent authority for WFD reporting in Scotland is the Scottish Environment Protection Agency (SEPA), and attempts are being made to rationalise SNH and SEPA reporting.

There are four different mechanisms used for coastal biodiversity reporting, all largely reliant (in Scotland) on SNH's Site Condition Monitoring (SCM), so that all are based on interpretation of one field visit. SCM is fully compliant with UK Common Standards Monitoring (CSM) but is more detailed, delivering considerably more information and context. Because it is fully compliant, no further interpretation of SCM results is required to meet CSM obligations, which are met by the delivery of SCM results to the Joint Nature Conservation Committee (JNCC) by SNH. UK coastal Common Standards have been agreed by specialists from all the UK country agencies and endorsed by all their Chief Scientists.

The third variant is the formal report to Europe, which is co-ordinated by the Joint Nature Conservation Committee, who report on 'Favourable Conservation Status' (Williams 2006). FCS of habitats is concerned mainly with Special Areas of Conservation (SAC) and habitats listed on Annex I of the Habitats Directive, which includes machair. All SACs are covered by SCM, even if they are not Sites of Special Scientific Interest (SSSI). Reporting on the wider Annex I habitat should address the entire extent of that habitat, not just those areas within protected sites, but resources are not available to carry out country-wide monitoring for all listed habitats, so that in reality, the wider Favourable Conservation Status reporting is heavily reliant on SCM of the SSSI network alone.

The fourth form of reporting uses the web-based Biodiversity Action Reporting System (BARS) to update actions on the various Habitat and Species Action Plans. SCM is less suited to this process, and BARS is heavily reliant on a wide range of inputs from agencies and non government organisations, and presents a particular challenge in respect of rationalisation with other reporting.

Machair SCM covers the following mandatory attributes, in common with sand dune CSM: extent, functionality, structure, and vegetation composition. Apart from extent, where a baseline must be specified, monitoring addresses the situation purely as it pertains at the time of survey, not in respect of change since notification; monitoring is not the equivalent of surveillance. The assessment also seeks to assign a 'trend' against the feature to give an indication, based on available information, of whether the habitat is stable (no change/maintained), declining or recovering. This qualification of condition status (favourable or unfavourable) is a value judgement added by the SNH assessing officer based on whether the habitat met the targets for the attributes and wider influences on the habitat.

CSM/SCM is conducted on a six-year cycle. Results are currently available only from the first cycle, though cycle 2 is underway.

Machair as a designated feature
Almost all SSSI in Scotland were designated prior to the inception of Site Condition Monitoring in 2000, and Site Descriptions (which are legal documents) in earlier designations often used general terms to describe habitats, especially in respect of habitat suites. This was deliberate, as case law in the early 1980s

required the Nature Conservancy Council (a predecessor of SNH) to embrace as much of the interest as possible. Using the broad categorisation of the Nature Conservation Review (Ratcliffe 1977), it was possible to notify an SSSI for having 'coastal' interest without specifying the habitats involved: this exercise pre-dated the Habitats Directive and Biodiversity Action Planning, so that a retrospective examination of all SSSI Descriptions was required to identify more precisely which features were notified where. These SSSI 'citations' frequently did not distinguish between sand dune and machair where both were present, and the distribution of machair itself had not been determined. The definition of machair that had been entirely adequate since it was devised by Ritchie (1976) required greater elaboration to meet the operational requirements of SNH and Annex I of the Habitats Directive, and this was not finally achieved until 2004, with a more detailed version arriving two years later (Angus 2004, 2006). At the commencement of monitoring the designations for machair were as follows:

39 Sites of Special Scientific Interest (SSSI)

2 Ramsar sites

Special Areas of Conservation (SAC)
The total includes two SSSIs in Dumfries and Galloway notified for machair: Back Bay to Carghidown, and Borgue Coast. It became clear on application of the revised definition that these sites are not machair, reducing the total machair SSSI to 37; SNH datasets have been amended accordingly. All machair as a valid notified feature was assessed except for 3 SSSI: Durness (North Highland), Loch an Duin (Western Isles) and Pabbay (Western Isles).

Results were thus obtained for all SAC and Ramsar machair sites and for 34 out of 37 valid machair SSSI, a reporting rate of 91.9% for SSSIs.

The methodology of coastal SCM pre-dates CSM, and the first monitoring cycle conducted by SNH on coastal habitats between 2000 and 2005 was very much an iterative process informed and altered not only by CSM but by field experience. Most machair sites were monitored towards the end of this period, so that reports are more informative and more easily applied. It is important to stress that the machair SCM is obliged to comply with UK sand dune CSM. The biodiversity element that is given considerable attention below is mandatory only in respect of uncultivated machair; as there is no equivalent of machair arable/fallow on non-Scottish UK sand dunes, SNH is free to set its own targets and thresholds. This does not mean that little attention need be paid to results for arable and fallow biodiversity, as the results are used by JNCC for reporting to Europe on the Favourable Conservation Status of the Annex I machair habitat.

There was considerable discussion within SNH about the justification for including arable land in an evaluation of favourable conservation status – by any form of reporting. This management has had a mixed perception in the history of machair conservation, and the decision to include cultivation was taken on the grounds that the arable biodiversity had been included as an important element of the scientific interest of some of the SSSI. This matter is discussed in more detail by Angus (2009).

Hurford & Guest (2006) accept a case for the monitoring of arable weeds, but their approach is not particularly applicable to machair (a habitat they do not address). Their recommendations illustrate the problems – and dangers - of applying national circumstances to the machair situation. They expect arable habitat to be "relatively homogenous, at least in terms of vegetation structure" so that "within any management unit, we should be able to monitor any part of the habitat and assume that the vegetation outside the monitoring plot will be in the same condition". This is possibly true of any cultivation patch that does not involve changes of slope or water table, but would not be true at the management unit of the township or even the croft. They go on to suggest that in a rotation, monitoring should focus on the cereal stage as "it is a waste of resources to monitor fields that are under a ley". As the fallow stages of the machair arable rotation are of undoubted conservation importance (e.g. as a source of nectar for invertebrates) this advice would not apply, and if 'ley' is meant to represent an undersown stage, then that, too, should be monitored, though its presence will contribute to unfavourable status due to very low biodiversity. Hurford & Guest further recommend that monitoring of cereal fields should concentrate on the edge, as "many arable weeds of high conservation value have a low tolerance of shading and could not survive within the main crop" and they recommend examination of the field margins. The machair monitoring guidance instructs the surveyor to avoid the area within 1m of crop margins, as the intention is to monitor the situation within the crop, to eliminate the 'edge effect'. The role of the edge effect is accommodated instead in a broad assessment of patch size – the largest and smallest patches detected in an SSSI must be monitored. Surveyors must take care to avoid damage to crops, and examination of the area within 1-2m of the edge can usually be conducted without stepping into areas of crop, or by stepping between rows of grain; a better appreciation of the arable weeds is gained by viewing the crop in the direction of ploughing.

Though the importance of the fallow stages is accommodated in the methodology, results have been treated with some caution, as it is not always possible to establish with certainty where fallows occur unless they are recent (1-2 years) and even then the stage is often uncertain.

RESULTS SUMMARY
Many machair sites have more than one designation, but the results must be reported separately for each of these designations. The relationship between the categories is not entirely straightforward, in that one SAC has no SSSI equivalent (Traigh na Berie), and one SAC (Oronsay) has an SSSI with a similar name but a very different boundary.

Ramsar sites (2)

Sleibhtean agus Cladach Thiriodh	Favourable Maintained
South Uist Machair & Lochs	Unfavourable Declining

50% Favourable, 50% Unfavourable

The factors leading to unfavourable status are reviewed in the SSSI section below.

SAC (8)

Coll Machair	Favourable Maintained
Monach Isles	Favourable Maintained
Tiree Machair	Favourable Maintained
Traigh na Berie	Favourable Maintained
Oldshoremore & Sandwood	Favourable Recovered
Oronsay	Unfavourable No change
North Uist Machair	Unfavourable Declining
South Uist Machair	Unfavourable Declining

62.5% Favourable, 37.5% Unfavourable.

The factors leading to unfavourable status are reviewed in the SSSI section below.

SSSI (34 from 37 valid features, 2 invalid features excluded) by SNH Area

Key to reasons for failure to achieve favourable condition:

AB = arable biodiversity (Uists & Berneray only),
FD = fallow biodiversity (Uists & Berneray only),
P = patchwork (Uists & Berneray only),
IG = improved grassland,
R = rabbit damage,
E = erosion,
G = heavily grazed,
B = bryophytes scarce,
F = fencing,
D = dumping,
T = transition disrupted,
S = bare ground,
C = composition of vegetation,
W = ruderals

Western Isles

Berneray	Favourable Maintained
Eoligarry	Favourable Maintained
Loch Stiapavat	Favourable Maintained
Luskentyre Banks & Saltings	Favourable Maintained
Machairs Robach & Newton	Favourable Maintained
Monach Isles	Favourable Maintained
Northton Bay	Favourable Maintained
Vallay	Favourable Maintained
Baleshare & Kirkibost	Unfavourable Declining AB, FB, P
Balranald & Loch nam Feithean	Unfavourable Declining AB, FB, P, IG
Bornish & Ormiclate	Unfavourable Declining AB, FB, P, R
Howmore Estuary, etc.	Unfavourable Declining AB, FB
Loch Bee	Unfavourable Declining FB, P
Loch Bee Machair	Unfavourable Declining AB, FB, P
Loch Druidibeg	Unfavourable Declining AB, E, R

Loch Hallan	Unfavourable Declining AB, FB, P
Argyll & Stirling	
Ceann a'Mhara to Loch a'Phuill	Favourable Maintained
Crossapol & Gunna	Favourable Maintained
Hough Bay & Balevullin	Favourable Maintained
North East Coll Lochs & Moors	Favourable Maintained
Sleibhtean agus Cladach Thiriodh	Favourable Maintained
Totamore Dunes and Loch Ballyhaugh	Favourable Maintained
North Colonsay	Unfavourable No change G
Oronsay & South Colonsay	Unfavourable No change G
Rinns of Islay	Unfavourable No change E, B, F, IG, D, T
Calgary Dunes	Unfavourable Declining E, G, T
West Highland	
Canna & Sanday	Favourable Maintained
Rum	Unfavourable Declining S, G, C
North Highland	
Strathy Coast	Favourable Maintained
Sheigra – Oldshoremore	Favourable Recovered
Northern Isles	
Northwall	Favourable Maintained
Breckon	Unfavourable No change G, F, IG
Central Sanday	Unfavourable No change E, D, G, F, T
Quendale	Unfavourable No change B, G, W, F, T

CAUSES OF FAILURE

Sixteen of the 34 SSSIs monitored are in unfavourable condition (47%). Of the sixteen SSSI supporting SACs, nine are in unfavourable condition (56%). One of the SACs, Traigh na Berie, is not supported by SSSI designation, but is in favourable condition. Of the eight SACs, three are in unfavourable condition (37.5%) but this includes two of the composite 'flagship' sites that contain the finest arable machair anywhere: North Uist and South Uist. The issues affecting the Uists are discussed in more detail below.

Seven sites were assessed as so heavily grazed in summer that plants were unable to set seed. These sites were all in Colonsay, Mull, Rum and the Northern Isles. Two of these sites – North Colonsay and Oronsay & South Colonsay are also notified for chough, and chough was regarded as having priority over machair on North Colonsay, with some compromise form of management that best meets both interests being more appropriate on the small part of Oronsay & North Colonsay SSSI that forms Oronsay SAC. However recent work suggests that the policy of permitting very heavy grazing on machair sites to favour chough may be misdirected (Bogdanova, this volume).

Four sites were suffering disruption of geomorphological processes to the extent that this had an impact on habitats: Loch Druidibeg, Rinns of Islay, Calgary and Central Sanday. This mainly took the form of serious erosion of machair surfaces, not to be confused with natural mobility of sand dunes adjacent to machair.

Four sites had their transition from machair to terrestrial habitat disrupted. This is generally an issue only when the transition itself is a notified feature, but the environmental gradient associated with the landward decline of blown shell sand is often a significant aspect of machair interest.

Fencing was a serious issue on four sites, disrupting transitions and imposing artificial boundaries. The impact of fencing varies, and no site was judged unfavourable on fencing alone.

Improved grassland was an issue on three sites, and on one of the three (Balranald), the impact was restricted to a small area. This is where vegetation that would otherwise be classified as SD [Sand Dune] in the National Vegetation Classification (Rodwell 1992, 2000) contains so much planted perennial rye-grass *Lolium perenne* or crested dog's-tail *Cynosurus cristatus* that the vegetation contains significant improved grassland (NVC communities MG6 and (less frequently on machair) MG7: wholly, as intermediate, or component of mosaic).

Rabbits were believed to be a particular problem on only two sites: Loch Druidibeg and Bornish & Ormiclate, where their burrowing was having an ecological impact. Tiree, Pabbay, Rum and Berneray are presently rabbit-free, a status that must be maintained, though this might prove difficult on Berneray now that there is a causeway connecting the island to mainland North Uist. Though it has been argued that an element of rabbit burrowing and scraping enhances habitat diversity, and that rabbits may even compensate for reductions in sheep or cattle stocking levels, the rabbit is an introduced alien. In one case a Management Agreement (not associated with SCM) designed to reduce stocking levels coincided with an increase in rabbit numbers, leading to the conclusion that "The importance of rabbits is sufficient to obscure the effects of different stock management within and between sites and future vegetation trends are likely to depend more on rabbit number changes than stocking practices" (Dargie 1996). The difficulties of effective rabbit control and the erosion damage to systems from burrowing justifies the negative value attached to rabbit impact.

Dumping was perceived as a problem on two sites and low bryophyte diversity also on two sites. Species composition overall was an issue only on Rum, where extremely heavy grazing by deer and ponies has had a significant impact on diversity. Ruderals contributed to unfavourable condition only at Quendale, despite significant impact reported from several other sites, usually from ragwort *Senecio jacobaea* and thistles *Cirsium* species; it may be that reporting of ruderals requires more emphasis. Excessive bare ground (a small amount of bare ground is regarded as desirable for invertebrates) was an issue only on Rum. Though Rum might appear to emerge very unfavourably from this analysis, given its status as a key National Nature Reserve, machair is confined to one very small site – Samhnan Insir, on the island's north-west coast – and machair is being removed from the list of notified features on Rum at the time of writing.

Favourable Conservation Status may also report poor condition on sites where a habitat is present but not a notified feature, and UK obligations in respect of Habitat Action Plans may be invoked in such situations. This is a possible source of conservation conflict, and one machair site illustrates such a situation. Achnahaird SSSI in Wester Ross is a heavily eroded machair that would be in unfavourable condition if the guidance was applied. It is not, however, an SSSI for machair, and the site has been notified solely because it is the only Scottish location for petalwort *Petalophyllum ralfsii*, a liverwort that unquestionably thrives in the prevailing condition of the machair. Petalwort is listed on Appendix I of the Bern Convention and Annex II of the Habitats Directive. It is also listed as *Vulnerable* on the GB Red List and is protected under Schedule 8 of the Wildlife & Countryside Act (1981).

The reporting of Oronsay as Unfavourable merits re-examination. This SAC is managed for birds by the RSPB, very successfully. As machair here is an SAC feature, there is not the option of allowing it to remain in unfavourable condition so that birds may thrive, but the site is so atypical that its unfavourable status may

be an artefact of a generalised reporting system, and site-specific condition monitoring targets (compliant with UK CSM) may be required.

Other monitoring

The Machair of the Uists and Benbecula, Barra and Vatersay Environmentally Sensitive Area (ESA) scheme was available to new entrants until the end of 2000, but schemes operated well beyond that date. The official monitoring of the ESA, using very different methodology from Site Condition Monitoring, reported that the total area of arable and fallow habitat had decreased by 17%, but that crop biodiversity was maintained between 1996 and 2003 (Pearce *et al* 2006). These conclusions are very different from those obtained by the SNH monitoring for 2004.

2008 review of Uists

Site Condition Monitoring is resource-intensive, to the extent that Cycle 2 will cover only a sample of features, though all features will be reviewed on a rolling programme. Resources would not permit any repeat of the SCM outside this cycle, but two visits in 2008, timed to coincide with the beginning and the end of the cropping season, allowed selected aspects of arable condition to be investigated further.

Preparatory work on a proposed bid for LIFE + funding (Walton & MacKenzie, this volume) had identified the relative roles of seaweed and artificial fertiliser as possible drivers of the biodiversity issue: the seaweeds release nutrients slowly, allowing weeds to take full advantage, whereas with NPK (typically 20:10:10) the rapid nutrient release favours the grain crop at the expense of weeds. Seaweed is now spread mechanically, using dung spreaders, and is readily apparent as dark patches on the pale April machair surface. A seaweed spreading demonstration was organised by the RSPB on their Balranald reserve, and this patch became a focus of August work.

Though a shortage of time during the second visit curtailed some investigations, many systems in South Uist were visited, as well as several in North Uist and Baile Sear, and it became clear that the 2004 (and some earlier 2001 studies) had been anomalous, or at the very least could not be regarded as demonstrating a trend of declining biodiversity. There was insufficient time to visit Berneray, but the 2004 monitoring and other past experience of this island suggest that land use patterns are slightly different from those of the other islands, and biodiversity is generally higher (Angus, unpublished).

Many townships had 'switched' their arable areas, so that some areas cropped in 2004 were fallow in 2008, which is to be expected over a four-year interval. This particularly applied on Baile Sear, where the very extensive fields noted in 2004 were no longer in cultivation, and cultivation appeared to have moved nearer the 'blackland'. Additionally, the weed component of crops was almost always present, with species numbers more variable than in 2004. Only in a few areas was a crop located with the very low species number observed in 2004: at NF7436944913, just south of the rifle range near Aird a'Mhachair at the north end of South Uist, within the MOD area, only five wild flower species were present in the crop at DAFOR scale 'o' (occasional) or above, and this included *Sinapis arvensis*. This particular crop was an unusual mix of 90% rye 10% oat, and was adjacent to a field of pure oat with only two weeds at 'o': corn marigold *Chrysanthemum segetum* and sow-thistle *Sonchus* sp. Both fields would be recorded as unfavourable in SCM had this been conducted, as would another few cultivation patches in the general area (probably in the same township).

At Balranald, with the benefit of advice from the RSPB Warden, Jamie Boyle, the situation was complex. The field where the seaweed demonstration had been conducted supported a dense crop of 50/50 rye/oat and had only six species of arable weed in total; only *Sinapis* was frequent, and only a further two achieved 'occasional' status: *Chrysanthemum segetum* and *Euphorbia helioscopa*. The same crofter had used the same seed source in a nearby patch, ploughed and planted at the same time, but using only NPK; this patch supported a total of nine weed species, all but one of them at 'o' or above; i.e. with most variables eliminated, the crop with only NPK had better biodiversity than the crop with only seaweed. Investigation of the situation by the RSPB revealed that the 'seaweed only' crop had actually had NPK applied mid-season because of very poor crop growth. A few fields in both these areas (Balranald and Aird a'Mhachair) were the only ones noted with crop biodiversity so low that they would have failed this target in SCM. Thus, at Balranald, site condition was better in 2008 than 2004, but some fields would have failed on the biodiversity criterion. The Balranald situation illustrates all too clearly the critical importance of local context in the interpretation of field results.

DISCUSSION

Arable machair is now virtually confined globally to the Uists, specifically the islands of North and South Uist, Benbecula, Baile Sear (Baleshare) and Berneray. Since the 1980s the biodiversity of the small-scale arable and rotational fallows of these islands has been regarded as a major attribute of the conservation value of these machairs. Within the period approximately 1990-2004, biodiversity had fallen dramatically in the crop, while individual crop patch area increased many-fold, occasionally to a crop area that would be comparable with a large field on a farm on the northern mainland. Monitoring suggested that this has probably had a knock-on effect on the fallows from these low biodiversity crops. Comparisons between the 2004 SCM results and earlier records are difficult because of a lack of compatible (and in some cases any) data, but the experience of the observers and access to such records as exist, give SNH confidence that the situation in 2004 represented a genuine decline in recent

biodiversity, and the verdict of 'unfavourable' was justified.

At a township or even croft level, however, particular circumstances may apply that require a more cautious approach to the issue, but this approach is reliant on knowledge of these circumstances – based on information that may not always be available.

It would be misleading to state that large cultivation areas are an entirely recent phenomenon on Uist machair; farms such as Stilligarry had large crop areas at least as long ago as 1985 but there are few farms in the Uists. Aspects of management at Balranald that might be regarded as recent developments in management are in fact long-established.

Crop plant biodiversity in 2004 was very poor compared with even a decade before. The bare patches between crop rows suggested initially that selective herbicide was being used, but local inquiries revealed that this was rarely the case, and other recent work suggests that it is used only "by a couple of growers" to control charlock *Sinapis arvensis* (Scholten *et al*, this volume). The possible role of NPK versus seaweed application has been discussed above, but the increasing use of modern 'deep' ploughs may also be a factor. Owen *et al.* (2000) found that deep ploughing "completely destroys the surface vegetation" and leads to desiccation, significantly reducing the capacity of plants to recolonise by vegetative propagation. It may also be that the seed bank becomes buried below the optimal depth for germination for many species. Incentives to encourage traditional shallow ploughing are hampered by poor local availability of equipment as old ploughs become increasingly difficult to repair.

There is then the question of how the crop biodiversity affects that of subsequent fallows. Some apparent fallows of unknown age at Balranald were more deficient in clover than is desirable, but this is difficult to confirm without confirmation of location and year of last cropping. What effect is this having on invertebrate biodiversity and on important species such as the great yellow bumblebee *Bombus distinguendus*?

Scientists hold little detailed or verifiable information about the methodology of agricultural management of machair arable, which makes interpretation of observations problematic. The most significant gap is in detailed land use history of identifiable patches of arable land. Seed is sourced from the higher-yielding crops, or sections of crops, with fewer weeds and thus weed seeds. Traditionally the 'corn' is actually a mix of rye *Secale cereale* and bristle oat (or black oat) *Avena strigosa*. Though bere (a low-yielding type of barley, *Hordeum vulgare*) is grown, it is very localised, or is a very low percentage of a crop. Though the landraces of these grains are of considerable wider conservation importance, this aspect is beyond the methodology of Site Condition Monitoring, and possibly beyond the remit of Scottish Natural Heritage, but has been studied by others (e.g. Scholten *et al*., in press).

Though there has been extensive use of artificial fertiliser in the Uists for decades, the application of seaweed fertiliser has been encouraged by a succession of funding incentives. The actual use of seaweed is unknown (but it is still widespread), but there is certainly a great deal of artificial fertiliser in use. It is not known to what extent this is instead of or in addition to seaweed. This has long-term issues for the habitat, as seaweed contains a binding agent that reduces the possibility of sandblow (Kerr 1954).

Though arable silage is preferable to an absence of cropping, it cannot compare with traditional reaping and binding in terms of conservation benefit. Obviously there is an increased risk of losing a crop if it is left for later, traditional harvest, but incentives designed to offset this risk have had little uptake (B. Bremner, pers.comm.). There is also the question of availability of reaper-binders and spares for these, though it is understood they are available in eastern Europe.

Though legislation prevents the formal amalgamation of crofts, there seems to be no barrier to them being physically merged for management to form very large crop areas. It is self-evident that a large crop area is much more easily managed than the traditional small patch, and incentives would be required to offset the 'hassle' factor of going back to these small patches.

That there is a biodiversity issue is not in doubt, but it clearly varies in extent from year to year. There is a lack of detailed information on management, to the extent that the true area of arable is unknown, and there is conflicting information on trends in arable area. The traditional forms of management – notably rotation patterns - are known to vary between areas – probably at township level – but scientists' access to this information is poor. Even without the obvious 'ownership' issues of involving local people in solving the problem, there is the very real practical issue that only local people possess the level of detailed knowledge required to restore traditional management.

The Machair Habitat Action Plan takes no account of crop and fallow biodiversity issues, having been written prior to their identification. Though the Machair HAP is unusual among coastal HAPs in including actions with a climate change context, the storm of January 2005 and subsequent studies and discussions require greater emphasis on this topic. SNH resisted submitting revised targets at the last scheduled opportunity, as to do so would have been premature, but once discussions on the above issues have identified an agreed strategy, the HAP will have to be amended accordingly, ideally with the active involvement of crofters. Though there is a subsequent approval process to be negotiated, this is not expected to present a problem.

The 2008 work was arguably as anomalous as 2004, in that in 2008 there had been very low rainfall early in the season, and several crops were observed that were probably not worth harvesting, so poor was the growth. There is clearly considerable inter-year variation, and selection of a particularly anomalous year for monitoring might give a result that is perfectly accurate for that year (as 2004) but misrepresents overall trends.

Though biodiversity was very much better in 2008 than 2004, and local sources suggest that the intervening years were also better than 2004, 2008 biodiversity is poorer than that of the very small patches observed in 2004 (and almost absent in 2008), and poorer than perceived biodiversity prior to that. Unfortunately older data on the composition of older fields is rare, and virtually confined to quadrat data so is incompatible with SCM methodology. At best, it would give indications of minimum historic biodiversity.

Though circumstantial evidence suggests that the application of NPK is the main cause of reduced biodiversity, there are other issues. Though it has been suggested that deep ploughing may bury the seed bank too deeply to allow full germination (Angus 2001) the case is circumstantial. Though there are reasons for promoting the use of shallow ploughs through financial incentives, there is a danger that *requiring* shallow ploughing to qualify for *any* cropping payments under the Scottish Rural Development Programme (SRDP) may discourage cropping completely, with disastrous impacts on biodiversity.

Field (or patch, as most crop areas are unfenced) size is another issue. McCracken (this volume) has established that the edge effect is important in determining biodiversity. For this reason, crop weed recording in SCM must be conducted at a minimum of 1m from the edge. Clearly the larger the crop area, the lower the length and thus area of edge, with a corresponding reduction in biodiversity, reducing still further in townships where crop and fallow patches are in separate areas of machair. There are several farms in the Uists, and these have long had large fields, but the amalgamation of crofts for management is a fairly recent phenomenon. Legislation to prevent the legal amalgamation of crofts is strictly enforced, yet there is nothing to prevent the amalgamation of two or more contiguous crofts for management. The landform of the Uist machair lends itself to this approach, and logistically there is nothing to prevent the development of 'prairie' systems with vast crop areas, and one very large area of crop was observed on Baile Sear in 2004 (an area that was fallow in 2008).

Though cropping biodiversity studies have concentrated on the crop, the 2004 SCM has also found problems with the fallows. The connection between bumblebees and the Leguminosae of the fallows is well-known, and Goulson (this volume) has pointed out that Leguminosae *require* low nitrate levels in the soil, and they become out-competed of NPK is applied. The duration of the impact of NPK application on the crop is unknown, but at least some impact on the ensuing fallows should be assumed as a precautionary measure.

Harvesting is increasingly taking the form of whole crop silage, with the traditional practice of stooking now uncommon, largely restricted to areas where incentives are offered by the RSPB to encourage corn buntings. There are also bird-based incentives for corncrake, and Long (this volume) has pointed out that bird measures are sometimes incompatible with other conservation management. In addition, the damage to crops from geese (and additional perceived damage from geese that might be attributable to other causes such as rabbits) is known to be discouraging cropping.

Though machair is the best land in the Outer Hebrides, it is poor in a Scottish context, most of it being, at best, Land Class 4 "capable of producing a narrow range of crops, with enterprises based primarily on grassland with short arable breaks (e.g. barley, oats, forage crops)." (Bibby *et al* 1982). More intensive management can increase crop yields that are obviously an advantage in providing fodder for cattle, but in national terms, yields can never match the output of land with better soils and climatic conditions.

Crofters are generally receptive to conservation incentives, but the desire to maximise yields and efficiency of management is entirely understandable. If a crofter has the option of taking his seed (for the next year's crop) from a high-yielding patch with few weeds or a low-yielding patch with many weeds, the choice is obvious. Likewise a small, narrow cultivation patch requires more 'wasted' tractor time, turning for the next run. This is a particularly important issue for seaweed or manure spreading, as in strong winds (which blow much of the time) the spreader can only be operated in one direction.

Conservationists must operate with these factors in mind: conservation can only be achieved by consent, not decree. There is little merit in attempting to enforce measures that might not only discourage fodder cropping, but also the rearing of the cattle the crops are grown to feed. Any significant reduction in cattle grazing would have a negative impact on the wider machair ecosystem, and the machairs of Lewis and Harris are testament to the considerable reduction in overall biodiversity that results from the widespread replacement of cattle by sheep. Crofters must be active participants in planning any measures designed to enhance biodiversity, but it has to be admitted that despite this attitude prevailing among all the agencies and NGOs involved, no forum exists for the exchange of such views, and there is considerable danger that incentives produced only by officials may be counter-productive to their own goals.

In turn, however, there must be a recognition in the agricultural sector (which has its own agencies and NGOs as well as the crofters themselves) that supportive funding should be more closely linked with

conservation objectives, and the pressure for this form of support from the Europe-based funding planners and Directives is probably intensifying. In order to ensure continuation of funding, it may become increasingly important to demonstrate a connection between existing funding and *all* the desired outputs, so that a certain level of weed in the crop (with a possible corresponding reduction in yield) and an element of increased 'hassle' in management methods might help ensure future funding. Given that the officials guiding the funding packages are not necessarily authorities on the *measures* needed to ensure a high biodiversity outcome, it would be simpler to have a system of outcome-related funding, with compliance monitoring ensuring a reasonable balance between agricultural output and biodiversity, with added financial incentives for those who *demonstrably* achieve the latter.

Even this approach, which would currently be very difficult to achieve, is not infallible. There are additional socio-economic drivers of change and, unlike the land management methodology, these might not even be understood by those most affected – the crofters – or the changes may involve factors over which they have knowledge but no control.

Though conservation officers should be an integral part of any planning for land management in the machair areas, they should also be more active in their own field. It is particularly important that the functionality of biodiversity is better understood in relation to land management, when there is still time to influence this relationship. For the crofter, it may become vital to establish these links more clearly in order to protect future funding.

An additional complication in future biodiversity management is that of climate change. Much of the machair is not only low-lying, but in parts of South Uist appears to occupy an altitude below High Water Mark; though there is a detailed Digital Terrain Model available it is calibrated to Ordnance Datum, and the Vertical Offshore Reference Framework, that will allow this to be correlated with Chart Datum, is not yet available. The storm of January 2005 illustrated all too clearly how vulnerable this landscape is to marine inundation, and recent and current studies (Angus & Hansom 2004, Angus in prep.) emphasise a long-term vulnerability that will increase as sea levels rise. SNH policies on climate change related coastal change are the subject of a detailed current review, but for habitats, at least, *if* conservationists are expected to intervene to inhibit coastal change (it is unrealistic to say 'prevent') there must be biodiversity worthy of that intervention.
Ultimately climate change could result in machair being displaced by saltmarsh or even intertidal sand flats or brackish/saline water bodies. If a situation arises where machair biodiversity diminishes to the extent that such 'new' habitats are of better quality than those they displace, the conservation agencies may be prevented by their remit or legislation from making the type of contribution to the situation that local people (or the conservationists) wish. There could thus be tactical advantages for crofters in maintaining crop biodiversity at favourable levels.

The conservationists' task will be to convince agricultural interests that there is value in weeds, and any strategy or incentives designed to persuade the crofter to reduce grain yields in favour of weeds will undoubtedly meet some resistance – not so much for financial reasons – but because most crofters regard a high-yielding, 'clean' grain crop as a measure of their own success, and this contributes greatly to their job satisfaction. Persuading the crofter to give weeds more of a chance will never be just a question of offering enough money, but of the wider value of operating agriculture and conservation in a more mutually beneficial way, and ultimately, convincing the crofter that a bit less grain and a few more weeds can be part of that job satisfaction.

Current SNH or SNH-led partnership research includes 'Shorelook', a review of the impact of climate change on Scottish coasts, Cycle 2 of Site Condition Monitoring, and a detailed study of Uist machair land use. SNH is also a partner in the transnational Northern Peripheries Programme 'CoastAdapt', led by Comhairle nan Eilean Siar, examining how human communities and coastal habitats can together adjust to climate change.

Though management-related funding mechanisms are critical in the short to medium term, climate change may assume a higher profile in time. Ultimately the survival of this (even now) spectacularly successful partnership between people and environment is uncertain. What is certain is that its chances of survival will be enhanced by greater understanding of how the entire system works, and this requires dialogue between all involved as well as research.

ACKNOWLEDGEMENTS
Bridget England and Jamie Boyle (RSPB) were extremely helpful in setting up study sites in the Uists and in subsequent discussions. I am also grateful to Barbara Bremner and Brian Eardley (both SNH) for their feedback on an earlier draft of this paper, and to Maria Scholten for sharing her insight on machair land use. Richard Gulliver also provided helpful comments. Shona Sloan of SNH improved the Gaelic component of the paper's title.

As always, the Uist-based staff of SNH have been extremely supportive, and many crofters have generously shared their ideas, aspirations, time and coffee. In respect of this paper, particular thanks are due to Johanne Ferguson, Mary Harman and Andrew Stevenson (all SNH) and Alasdair Macdonald (crofter, Balranald).

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